DRAFT
Water System Master Plan

Plymouth Water Department
Town of Plymouth, MA

November 2019

Environmental Partners GROUP
A partnership for engineering solutions

DRAFT REPORT

Water System Master Plan

Plymouth Water Department

Town of Plymouth, MA

November 2019

____

Ryan J. Trahan, PE

Senior Principal

____

Adam S. Kran, PE

Project Manager

Environmental Partners Group

A partnership for engineering solutions

DRAFT

Water System Master Plan

Prepared for:

Plymouth Water Division

Town of Plymouth, MA

November 2019

Environmental Partners Group

A partnership for engineering solutions

Table of Contents

List of Tables

List of Charts

List of Figures

List of Appendices

List of Abbreviations

ADD	Average Day Demand
AL	Action Level
ASR	Annual Statistical Report
ATS	Automatic Transfer Switch
AWWA	American Water Works Association
BMP	Best Management Practice
BPS	Booster Pump Station
CI	Cast iron
ClO2	Chlorine Dioxide
CMR	Commonwealth of Massachusetts Regulations
CPVC	Chlorinated Polyvinyl Chloride
D/DBPR	Disinfection/Disinfection By-Product Rule
DBP	Disinfection By-Product
DBPR	Disinfection By-Product Rule
EP	Environmental Partners
ERP	Emergency Response Plan
FCV	Flow Control Valve
Fe	Iron
FEMA	Federal Emergency Management Agency
GAC	Granular Activated Carbon
gal	Gallons
GFCI	Ground Fault Circuit Interrupter
gpd	Gallons per Day
gpm	Gallons per Minute
GWC	Groundwater Withdrawal Category
GWR	Groundwater Rule
HAA5	Haloacetic Acids (group of 5)
HAAs	Haloacetic Acids

HGL	Hydraulic Grade Line
hp	Horsepower
ID	Identification
IDSE	Initial Distribution System Evaluation
ISO	Insurance Services Office
LCR	Lead and Copper Rule
LRAA	Locational Running Annual Average
MAPC	Metropolitan Area Planning Council
MassDEP	Massachusetts Department of Environmental Protection
MassDOT	Massachusetts Department of Transportation
MassGIS	Massachusetts Geographical Information System
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MCP	Massachusetts Contingency Plan
MDD	Maximum Day Demand
mg/L	Milligram per Liter
MG	Million Gallons
MGD	Million Gallons per Day
MGL	Massachusetts General Law
MGY	Million Gallons per Year
Mn	Manganese
MRDL	Maximum Residual Disinfection Level
NaOH	Sodium Hydroxide
NaOCl	Sodium Hypochlorite
ND	Not Detected
NGVD29	National Geodetic Vertical Datum of 1929
NHESP	National Heritage and Endangered Species Program
NFF	Needed Fire Flow
NOM	Natural Organic Matter
NT	Not Tested

O&M	Operation and Maintenance
OWR	Office of Water Resources
OSHA	Occupational Safety and Health Administration
PFAS	Per- and Polyfluoroalkyl Substances
PLC	Programmable Logic Controller
ppb	Parts per Billion
PPE	Personal Protective Equipment
PRV	Pressure Reducing Valve
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
RAA	Running Annual Average
RGPCD	Residential Gallons per Capita per Day
RTCR	Revised Total Coliform Rule
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
SMCL	Secondary Maximum Contaminant Level
SOP	Standard Operating Procedure
SWAP	Source Water Assessment and Protection
TCR	Total Coliform Rule
TEC	Tetrachloroethylene
THM	Trihalomethane
TOC	Total Organic Carbon
TTHM	Total Trihalomethanes
UAW	Unaccounted for Water
UMass	University of Massachusetts
USEPA	United States Environmental Protection Agency
USG	Utility Service Group
USGS	United States Geological Survey
UWS	Underwater Solutions, Inc.
VFD	Variable Frequency Drive

VLAC	Vinyl-Lined Asbestos Cement
VOC	Volatile Organic Compound
WMA	Water Management Act
WPS	Well Pumping Station
WRC	Water Resources Commission
WTP	Water Treatment Plant
µg/L	Micrograms per Liter
µm	Micrometers

Executive Summary

The Plymouth Water Division's (the Division's) primary goals are to assure that high quality drinking water is provided to all homes and businesses at adequate pressure without interruption and at a reasonable cost while providing fire protection throughout the Division's water system. Environmental Partners (EP) was selected by the Division to complete a Water System Master Plan. The assessment consisted of the following:

- A description of the water system;
- An evaluation of the Division's current and future water demand;
- An assessment of the water supply and pumping capacity and its ability to meet current and future demands;
- A new source site screening and desktop study;
- An assessment of distribution system storage, including its ability to meet current and future demands and fire requirements;
- An update to the water system hydraulic model and an assessment of distribution system hydraulics;
- A review of the Division's emergency procedures;
- Recommendations for water supply, storage, and distribution facilities improvements; and,
- Preparation of a Capital Improvement Program.

The planning duration for the Water System Master Plan is 2020 through 2040 with capital improvements planned through 2035. A summary of the findings, conclusions, and recommendations of the Water System Master Plan are provided below.

ES.1 EXISTING WATER SYSTEM

The Division supplies approximately 69 percent of the Town of Plymouth's population with drinking water from thirteen (13) drinking water supply wells at a total of eleven (11) groundwater supply source locations. This includes the recently permitted water supply source at the Forges Field Site, which is anticipated to be placed in service during 2020.

All of the Division's groundwater supplies are treated for pH adjustment and disinfection. The Division's two water treatment plants, the Bradford Water Treatment Plant (WTP) and the North Plymouth WTP, provide media filtration for their associated groundwater sources. Drinking water is distributed to the Division's 14,298 water system customers through more than 230 miles of pipe, ten storage tanks, four booster pump stations (BPSs), and five pressure reducing valve (PRV) vaults. The water system is controlled and monitored via a Supervisory Control and Data Acquisition (SCADA) system.

The Division's water system is divided into six pressure zones each interconnected with at least one other pressure zone to allow for distribution of water during times of peak demand or during an emergency.

The water system effectively operates as two independent systems due to a permanently closed pressure reducing valve. To the north, operators can typically move water between the Bradford, Plymouth Center, West Plymouth, and Pine Hills Pressure Zones (the Northern Pressure Zones). To the east, operators can move water between the Cedarville and Manomet Pressure Zones (the Eastern Pressure Zones).

ES.2 SOURCE WATER ASSESSMENT

The groundwater supply wells are located in two primary watersheds, the South Coastal and Buzzards Bay Watersheds as designated by Massachusetts Department of Environmental Protection (MassDEP). The Division is permitted to withdraw a daily average of 4.59 million gallons per day (MGD) from the South Coastal Watershed and a daily average of 1.59 MGD from the Buzzards Bay Watershed; however, the combined daily average withdrawal must not exceed 4.59 MGD through the year 2019; this value increases to 4.71 MGD in 2025 and 5.04 MGD in 2030. An exception is made for the Town of Plymouth's 400th Anniversary Celebration in 2020, where the Not-to-Exceed Withdrawal Volume is increased to 5.58 MGD.

The Division completed a Source Water Assessment Program (SWAP) Report in July 2003. The SWAP Report includes an assessment of the land use in Zones I and II for twelve of the Division's ground water supply wells (not including the Forges Field Well). The Zone I is the protecting area closest to the well and is typically a 400-foot radius, unless the well has an approved yield less than 0.1 MGD. The Division owns or controls the Zone I's for all water supply wells with the exception of portions of the Ship Pond Well and Wannos Pond Well Zone I's. A concerted effort should be made by the Division to gain control of Zone I's through ownership and/or conservation restrictions at the water supplies.

The Zone II is a DEP-defined well head protection area that delineates the production well's aquifer capture zone based on the predicted extent of the groundwater drawdown after a theoretical 180-day drought condition resulting from the well pumping at its approved rate. All of the Division's sources have approved Zone II delineations.

ES.3 WATER QUALITY STANDARDS

The Division is currently in compliance with the water quality requirements of 310 CMR 22.00. The source water for multiple sites within the Division's water system are known to exceed Secondary Maximum Contaminant Levels (SMCLs) for iron and manganese. These SMCLs are not enforced by the United States Environmental Protection Agency (USEPA), but are provided as guidelines for public water systems to voluntarily monitor their systems for aesthetic qualities such as taste, odor, and color. A study to evaluate alternatives for improving water quality is currently underway.

MassDEP has initiated targeted sampling to determine if Per- and Polyfluoroalkyl Substances (PFAS) are present in public water supplies (PWS). It is anticipated that MassDEP will issue a drinking water maximum contaminant level (MCL) for PFAS in the near future that may affect the Division's water quality requirements.

ES.4 WATER DEMAND

The existing average day demand is 4.29 MGD with an average-day demand of 1.35 MGD in the Eastern Pressure Zones and 2.96 MGD in the Northern Pressure Zones. The system-wide maximum day demand is 7.97 MGD with a maximum day demand of 2.50 MGD in the Eastern Pressure Zones and 5.47 MGD in the Northern Pressure Zones.

Between 2013 and 2018, the Division had an average water use of approximately 68 Residential Gallons per Capita per Day (RGPCD) and a residential percentage of metered water use of 73 percent. Annual Statistical Report (ASR) data from 2013 to 2018 shows a six-year average of 12.0 percent unaccounted-for water (UAW). Based on the Division's latest Water Management Act (WMA) Permit this percentage exceeds the allowable UAW threshold of 10 percent. The Division managed to bring UAW below 10 percent in 2018.

Future water demands were estimated based on historic water-use patterns, population growth, employment projections, and added demand from known future developments. Water demand projections forecast an average day demand of approximately 5.7 MGD by the year 2040. Based on demand projections, average day demands are estimated to meet or exceed the WMA Permit withdrawal limits in approximately 2023 until the permit limit increases to 5.04 MGD in 2026. Shortly thereafter around 2028, the demands are estimated to exceed the 5.04 MGD limit.

ES.5 WATER SUPPLY REQUIREMENTS

The current capacity of the Division's water supply to meet current and future demand was evaluated with the largest water supply source offline, also known as firm capacity. At baseline, this review was conducted before the completion of the Forges Field Well (anticipated to come online in 2020). The water system's total current firm capacity, 8.17 MGD, indicates there is sufficient supply capacity to meet the six-year average maximum-day demand of 7.97 MGD. However, the water system effectively operates as two independent systems: the Northern and Eastern Pressure Zones. By assessing the capacity of the water system in the two separate zones based on the physical and operational limitations of the system, there is insufficient capacity to meet the maximum day demands in the Northern and Eastern Pressure Zones independently. The results of this analysis are summarized in Table ES-1 below.

Table ES-1 – Current Water Supply Capacity

	Firm Capacity (MGD)	Maximum Day Demand (MGD)	Surplus Capacity (MGD)
Northern Pressure Zones	4.71[1]	5.47	-0.76
Eastern Pressure Zones	2.23	2.50	-0.27

1. Firm capacity does not include the Forges Field Well, which will increase the firm capacity of the Northern Pressure Zones to 5.76 MGD once online.

These deficits should to be addressed immediately, as a failure of one or more of the Division's water supply sources may result in a supply deficit. The Division should continue to explore options for connecting all portions of their water system to maximize operational flexibility and redundancy. An interconnection between the Northern and Eastern Pressure Zone would improve overall system flexibility and redundancy. The Division should also continue to identify and develop new water supply sources as soon as possible to provide sufficient firm capacity for current and future maximum day demands.

Limited redundant sources in all pressure zones places the Division at high risk of water supply shortages, even in the fall and winter months when demands are lower. Should a mechanical failure occur during the spring and summer months, the probability of water quality complaints, low pressures, and potential bacteriological contamination increases.

In addition to a firm capacity deficit, the Division has operational restrictions at multiple water supplies. Most notably, the Darby Pond Well production is limited by WMA Permit restrictions based on pond water levels. Since operations on neighboring properties withdraw water from Darby Pond for irrigation and cranberry bog operations, an immediate effort by the Division should be made to acquire these properties in order to alleviate pumping limitations on the Darby Pond Well. Other sources with site-specific operational restrictions include Bradford Wells No. 1 and No. 2, Federal Furnace Well, North Plymouth Well, Ship Pond Well, Ellisville Well, and Lout Pond Well.

ES.6 NEW SOURCE SITE SCREENING

A new source water supply screening desktop study for the Division identified a total of 70 parcels as potential water supply parcels and ranked the sites into favorable, potential, and unfavorable water supply sites. Seven sites are considered favorable including:

- Site #27/#28 Parting Ways
- Site #23
- Site #3 Micajah Pond
- Site #30 Entergy Site
- Site #20 Briggs Site
- Site #31
- Site #57 Indian Brook

It is recommended that the Division continue the desktop study to include non-Town owned parcels potentially available for purchase and to proceed with subsurface groundwater exploration test well drilling program.

ES.7 DISTRIBUTION STORAGE ASSESSMENT

The ability of the Division's water storage tanks to meet peak hour demand and fire protection volumes while also maintaining a minimum residual pressure of 35 psi and 20 psi to all customers during these respective demands was evaluated. The quantity of distribution storage necessary for fire protection is based in part on the fire flow requirements established by the Insurance Services Office (ISO).

Each pressure zone was reviewed individually to evaluate whether the existing storage is sufficient to meet peak hour demand and fire flow requirements specific to the pressure zone. The results of this evaluation suggest that four of the six pressure zones have inadequate peak hour storage and three of the six pressure zones have inadequate fire storage. These inadequacies are largely a result of high elevation areas within the deficient pressure zones rather than undersized tanks. It should be noted that the Division's storage tanks were constructed between the 1950s and 1990s prior to more recent development at higher elevations reducing available pressures and storage. Additionally, low pressures are typically alleviated by household plumbing fixtures which are not taken into account in this analysis.

The Plymouth Center Pressure Zone has the largest deficit of fire storage. Additionally, the majority of low pressure customers appear to be within the Plymouth Center Pressure Zone. Shifting elevated portions of the Plymouth Center Pressure Zone to the neighboring Bradford Pressure Zone, which operates at a higher hydraulic grade, may alleviate the storage deficit observed in the Plymouth Center Pressure Zone.

ES.8 WATER DISTRIBUTION HYDRAULICS

The Division's hydraulic model was updated to reflect the most current information available and used to evaluate the ability of the distribution system to provide adequate fire flow and service pressures to all areas of the distribution system. The hydraulic performance of the distribution system was assessed during average day and maximum day demand conditions utilizing present-day demand scenarios. Under current operational controls, there are many areas of high pressures (greater than 80 psi) and low pressures (less than 35 psi) within the system. Typically, high and low pressures are alleviated through the use of household mechanical devices.

Utilizing the updated hydraulic model, potential modifications to control strategies were explored in order to improve hydraulic performance, system pressures, and fire flow availability. Several Division-specific factors were considered in this analysis, including reducing reliance on sources with water quality challenges. The proposed controls strategy will stabilize the hydraulic grade in the Eastern Pressure Zones, particularly under maximum-day demand scenarios, and improve system hydraulics in the Northern Pressure Zones.

Additionaly, a fire flow analysis of the Division's water system compared modeled available fire flows to needed fire flows, as determined by the ISO. Several locations throughout the water system lack sufficient fire flow which can be addressed through targeted water main upgrades.

ES.9 EMERGENCY PROCEDURES

The Division's current emergency procedures and standards for issuing emergency orders as well as potential actions to minimize the risk of emergency events as detailed in the Division's Emergency Response Plan (ERP) are in general accordance with 310 CMR 22.04(13). The Division has several emergency sources including Great South Pond and Little South Pond with Lout Pond identified as an inactive emergency source. Additional emergency sources include interconnections with adjacent communities including two existing interconnections with the Kingston Water Department and the opportunity for a temporary interconnection with the North Sagamore Water District. No formal procedure exists for exercising interconnections.

ES.10 RECOMMENDED IMPROVEMENTS AND CAPITAL IMPROVEMENTS PLAN

A phasing plan was developed to prioritize the recommended water system improvements and to aid the Division in financing the proposed Capital Improvement Program. The improvements are categorized into three five-year implementation phases (Phases I – III) as presented in Tables ES-2 through ES-4. Opinions of probable project costs (OPPC) were established for each phase of the recommended improvements. The OPPC estimates are assumed to be Class 5 estimates, per the American Association of Cost Engineers (AACE) International Recommended Practice No. 18R-97. Police details are included within the per foot cost of the water main upgrade projects. The costs are summarized in Tables ES-2 through ES-4 in terms of 2020 dollars.

Table ES-2 – Capital Improvements Summary, Phase I (Years 2020 to 2025)

Priority No.	Recommendation	Opinion of Probable Cost
1	Operational Controls Strategy Adjustments	No Cost
2	Lift Darby Pond Well Production Restrictions	$53,000[1]
3	Water Supply and Management - New Source Exploration	$200,000
4	Manomet Pipe Upgrades and Pipe Conditions Testing	$5,100,000
5	Emergency Power Upgrades - Darby Pond WPS and Cedarville BPS	$401,000
6	Ongoing Facility Upgrades - Electrical	$750,000
7	Pine Hills Pressure Zone Interconnection	$6,400,000
8	Water Supply and Management - New Source Permitting	$300,000
9	Emergency Power Upgrades - Controlling Tank Sites	$546,000
10	Ongoing Facility Upgrades - Mechanical	$500,000
11	Ongoing Facility Upgrades - Underground Electrical Upgrades	$575,000
12	Valve and Flushing Plan	$109,000
13	Groundwater Protection District	$80,000
14	Water Supply and Management - Water Conservation Measures	$18,000
15	Water Supply and Management - New Source Design	$350,000
16	Ongoing Facility Upgrades - Instrumentation	$500,000
17	Redevelop Well Supplies	$150,000
18	Great South and Little South Pond Feasibility Study	$110,000
19	Staffing Evaluation	$33,000
20	Standard Operating Procedure for Interconnections	$9,000
21	Storage Tank Improvements	$240,000
22	Water Supply and Management - New Source Construction	$3,500,000
23	Ongoing Facility Upgrades - Treatment	$500,000
24	Water Main Upgrades - West Plymouth Pressure Zone Group I	$420,000
25	Ongoing Pipe Replacement	$500,000
26	PFAS Preparedness	$22,000
Phase I Improvements Total		**$21,229,000**

1. The cost does not include the cost to acquire the cranberry bogs located within the Zone II.

Table ES-3 – Capital Improvements Summary, Phase II (Years 2026 to 2030)

Priority No.	Recommendation	Opinion of Probable Cost
1	Bradford and Plymouth Center Pressure Zone Boundary Reconfiguration	$14,900,000
2	Ongoing Facility Upgrades - Site	$500,000
3	Ongoing Facility Upgrades - Architectural	$500,000
4	Water Main Upgrades - Plymouth Center Pressure Zone	$2,200,000
5	Lout Pond Raw Water Transmission Main to Bradford (or treatment)	$5,206,000
6	Emergency Power Upgrades - Non-Controlling Tank Sites	$364,000
7	Ongoing Pipe Replacement	$2,500,000
8	Drought Management Plan	$14,000
	Phase II Improvements Total	**$26,184,000**

Table ES-4 – Capital Improvements Summary, Phase III (Years 2031 to 2035)

Priority No.	Recommendation	Opinion of Probable Cost
1	Water Main Upgrades - Manomet Pressure Zone	$1,200,000
2	Water Main Upgrades - Cedarville Pressure Zone	$2,550,000
3	Water Main Upgrades - West Plymouth Pressure Zone Group II	$2,210,000
4	Ongoing Pipe Replacement	$2,500,000
5	SCADA Review	$58,000
6	Replace critical PRVs	$2,738,000
	Phase III Improvements Total	**$10,911,000**

EP recommends implementing the control strategy adjustments as soon as possible to improve system hydraulics. Next, the Division should move forward with lifting the Darby Pond Well production restrictions. Lifting the Darby Pond Well Production restrictions will alleviate the firm capacity deficit in the Northern Pressure Zones. Once the Darby Pond Well restrictions are lifted, well station upgrades should be made in order for the well station to be able to operate at capacity.

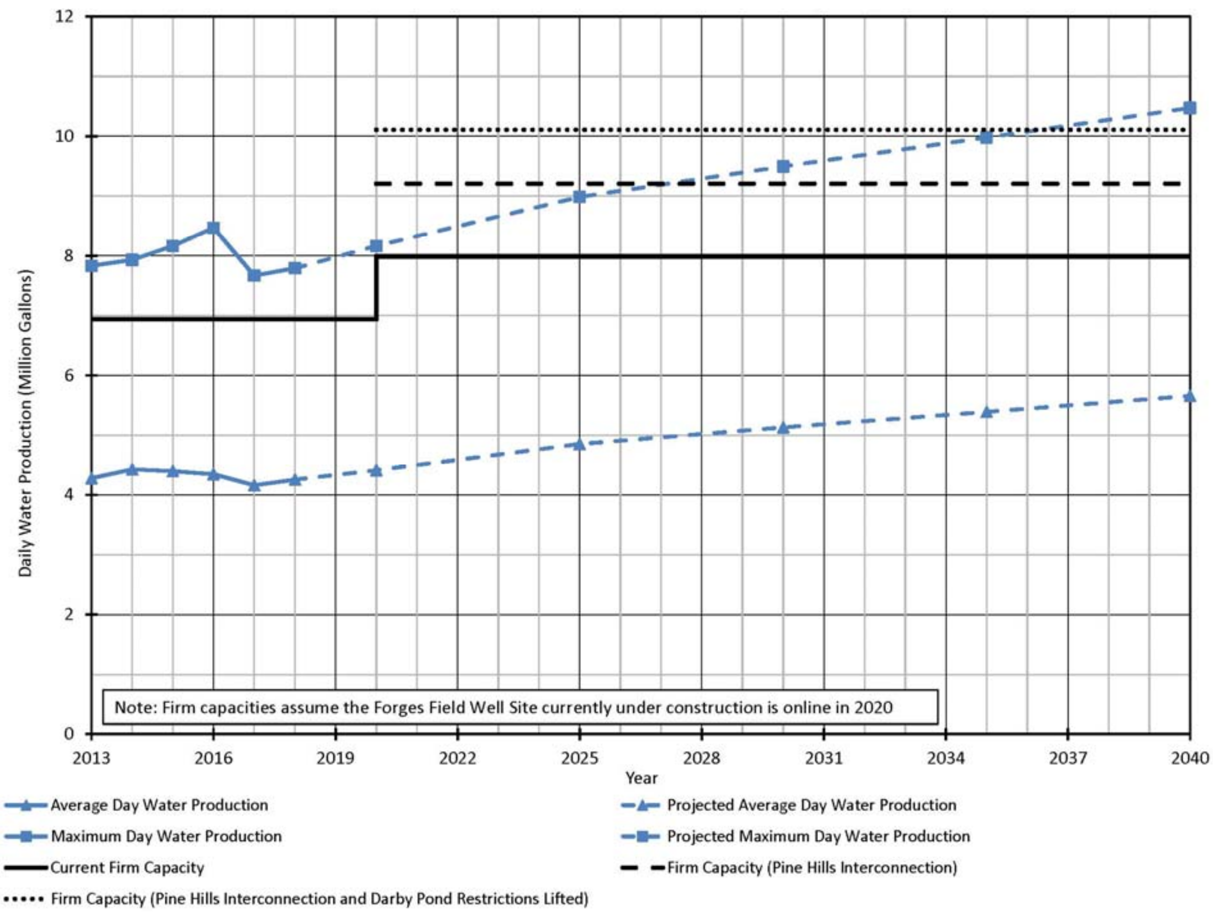
Additionally, new source exploration activities should continue in order to alleviate the Division's reliance on sources with declining water quality and to provide system redundancy and operational flexibility should a high-yield source be available. The new source process is long and onerous, so it is imperative the Division begin to investigate and develop new sources several years before they are required.

Then, the Manomet Pressure Zone Pipe Upgrade project should be prioritized to maintain adequate system pressures throughout the zone and to improve the effectiveness of the future Pine Hills Interconnection project. Following the Manomet Pressure Zone Pipe Upgrades, the Division should move forward with the Pine Hills Pressure Zone Interconnection and new source exploration to address the firm capacity deficit in the Northern Pressure Zones.

By constructing the Manomet Pipe Upgrades and the Pine Hills Pressure Zone Interconnection in conjunction with lifting the Darby Pond Well production restrictions, maximum day production is not expected exceed the system's firm capacity until around 2036 when a new source of approximately 0.4

MGD would be needed to meet 2040 demands as shown in Chart ES-1 below. Subsequent recommendations should be implemented in accordance with Table ES-2 through ES-4.

Chart ES-1 – Projected Daily Water Production vs Firm Capacity: System-Wide



Chapter 1 – Description of Water Supply System Infrastructure and Sources

1.1 SYSTEM OVERVIEW

The Division supplies approximately 69 percent of the Town of Plymouth's population with drinking water from thirteen drinking water supply wells at a total of eleven groundwater supply source locations. This includes the recently permitted water supply well and source at the Forges Field Site anticipated to be placed in service in 2020.

All of the Division's groundwater supplies are treated for pH adjustment and disinfection. The Division's two water treatment plants, the Bradford Water Treatment Plant (WTP) and the North Plymouth WTP, provide media filtration for the associated groundwater sources. Drinking water is distributed to the Division's 14,298 water system customers by means of more than 230 miles of pipe, ten storage tanks, four booster pump stations (BPSs), and five pressure reducing valves (PRV) vaults. The water system is controlled and monitored via a Supervisory Control and Data Acquisition (SCADA) system.

The Division also has several emergency sources including Great South Pond and Little South Pond; Lout Pond is identified as an inactive emergency source. Additional emergency sources include interconnections with adjacent communities including two existing interconnections with the Kingston Water Department and the opportunity for a temporary interconnection with the North Sagamore Water District (refer to Chapter 8).

The Division's water supply sources, pumping facilities, storage tanks, booster stations, and pressure zones are described below. Refer to for a full water system map.

1.1.1 Pressure zones

The Division's water system is divided into six (6) pressure zones as shown in Table 1-1 below.

Table 1-1 – Summary of Pressure Zones

Pressure Zone	Hydraulic Grade Line (NGVD29)
Bradford	250
Cedarville	272
Manomet	187
Pine Hills	300
Plymouth Center	187
West Plymouth	295

The hydraulic grade line in each pressure zone is set by the water level in the 1 to 3 storage tanks in each zone. Each pressure zone is interconnected with at least one other pressure zone to allow for distribution of water during times of peak demand or during an emergency. The four BPSs and five PRV vaults were installed to assist with interzonal water transfer. Currently, all four BPSs are in operation and none of the PRV vaults are in operation. Two of the BPSs (Nook Road and Cedarville) are outfitted with PRVs that permit flow to move from high pressure to low pressure zones.

1.1.2 Water Supply Facilities Report

In 2012, Haley and Ward prepared an *Evaluation of Plymouth Water Supplies* (2012 Facilities Evaluation). The report evaluated the Division's water supply facilities and identified potential upgrades at each site that fall under one of seven categories: architectural, mechanical, instrumentation, treatment, site, electrical, and supply. The purpose of the proposed upgrades is to improve operations, achieve regulatory compliance, extend equipment/building life, replace old equipment, and/or improve site security. The report provided potential upgrades for each facility with the exception of Wannos Pond Well Pumping Station (WPS) and Lout Pond WPS, as these facilities had been recently constructed at the time the report was prepared and was not evaluated. The Division has lacked funds and staffing in recent years to implement all of the recommendations from the 2012 Facilities Evaluation.

The proposed upgrades were reviewed through conversations with Division staff and supplementary sites visits as needed. A summary of potential upgrades is provided below for each site.

1.2 WATER SUPPLIES

The distribution of the Division's thirteen wells across its six pressure zones is presented in Table 1-2. The Pine Hills Pressure Zone is a small boosted service zone, and does not have a dedicated source.

Table 1-2 – Summary of Sources by Pressure Zone

Pressure Zone	Source	Installation Date	Depth (ft) [4]
Bradford	Bradford Well No. 1	2009	166
	Bradford Well No. 2	1995	82
	Forges Field Well	2019[1]	125
Cedarville	Savery Pond Well[2]	1990	116
Manomet	Ellisville Well	1995	136
	Ship Pond Well	1972	100
	Wannos Pond Well	1973	100
Pine Hills[3]	N/A		
Plymouth Center	South Pond Well No. 1	2011	140
	South Pond Well No. 2	1968	115
	Lout Pond Well	1980	52
West Plymouth	Federal Furnace Well	1972	80
	North Plymouth Well	2010	120
	Darby Pond Well	2002	90

1. The Forges Field Well was installed in 2019 and is anticipated to come online in 2020.
2. Also referred to as the "John Holmes Well."
3. There are no sources within the Pine Hills Pressure Zone.

4. The well depth was taken from the 2016 FG Sullivan Well Flow Testing or the 2006 Water Master Plan.

The Division is in the process of developing an additional source at the Forges Field site near Jordan Road. The future production well, with a permitted withdrawal rate of up to 1.05 million gallons per day (MGD), at the Forges Field site is currently under construction and anticipated to be placed into service during 2020. The Forges Field Well is designed to pump into the Bradford Pressure Zone and a valve control station will allow for a second point of connection between the Bradford and Plymouth Center Pressure Zones.

1.2.1 Specific Capacity of Wells

Specific capacity is defined as the quantity of yield per unit of drawdown in a well and is an indicator of well performance. As a result of plugging and clogging of the well screen, the specific capacity of water wells typically decline over time. It is recommended that a well be conditioned and redeveloped if there is a more than 15 percent reduction in specific capacity from its original capacity. Table 1-3 summarizes the specific capacity and performance of the Division's well supplies.

Table 1-3 – Specific Capacity of Well Sources

Source	Earliest Known Test Date	Earliest Known Specific Capacity (gpm/ft)[1]	Current Specific Capacity (gpm/ft)[2]	Percent Reduction
Bradford Well No. 1	1975	30.3	17.1	44%
South Pond Well No. 2	1994[3]	97.1	67.8	30%
South Pond Well No. 1	1994[3]	50.7	37.5	26%
Federal Furnace Well[4]	1973	20.0	15.0	25%
Bradford Well No. 2[5]	2005	36.6	31.5	14%
Ship Pond Well	1969	18.3	16.9	8%
Savery Pond Well	2002	50.0	48.6	3%
Darby Pond Well	1991	36.8	37.1	-1%
Wannos Pond Well	2010	35.4	35.7	-1%
Ellisville Well	1982	38.9	40.2	-3%
Lout Pond Well[6]	2009	13.5	15.7	-16%
North Plymouth Well	1975	26.0	30.8	-18%
Forges Field Well[7]	2018	12.6	--	--

1. Data for the earliest known specific capacity was obtained from the 2012 Haley and Ward Facilities Evaluation, unless otherwise noted.
2. Data for the current specific capacity was tabulated from a report by Maher Services, Inc., dated January 24, 2015.
3. The constructed specific capacity is unknown, so the largest documented historical value was used.
4. Federal Furnace was redeveloped in 2011.
5. Bradford Well #2 was redeveloped in 2014.
6. Earliest known specific capacity of the Lout Pond Well taken from March 2009 Source Final Report prepared by Horsley Witten Group.

7. Earliest known specific capacity of the Forges Field Well taken from February 2018 DEP Pumping Test Report prepared by Environmental Partners. The Forges Field Well is currently in construction and is anticipated to come online in 2020. Specific capacity testing will be completed prior to operation.

A review of the data presented in Table 1-3 indicates that the specific capacity of four water supply wells have reduced more than 15 percent from the original specific capacity: Bradford Well No. 1, South Pond Well No. 1, South Pond Well No. 2, and Federal Furnace Well. These wells should be conditioned and redeveloped to recover lost specific capacity. Additionally, the Division should perform well flow tests at each of the wells annually or biannually to monitor their performance.

1.2.2 WMA Permit

In the Commonwealth of Massachusetts, all withdrawals of water for public water consumption greater than 100,000 gallons per day (gpd) must either be registered or permitted based on the requirements of the Water Management Act (310 CMR 36.00) and Massachusetts General Law Chapter 21G (M.G.L c. 21G). The Division currently holds a Water Management Act (WMA) Permit with a withdrawal limit of 4.59 MGD (1,675.3 million gallons per year [MGY]) through the year 2019 for their groundwater supply wells. The Division does not have any registered sources.

The groundwater supply wells are located in two primary watersheds, the South Coastal and Buzzards Bay Watersheds as designated by Massachusetts Department of Environmental Protection (MassDEP). The Division is permitted to withdraw a daily average of 4.59 MGD from the South Coastal Watershed and a daily average of 1.59 MGD from the Buzzards Bay Watershed; however, the combined daily average withdrawal must not exceed 4.59 MGD through the year 2019. This value increases to 4.71 MGD in 2025 and 5.04 MGD in 2030 as outlined in Table 1-4. An exception is made for the Town of Plymouth's 400th Anniversary Celebration in 2020, where the Not-to-Exceed Withdrawal Volume is increased to 5.58 MGD.

A summary of the permitted wells is provided below in Table 1-4 – WMA Authorized Withdrawals.

Table 1-4 – WMA Authorized Withdrawals

Watershed	Wells	Maximum Daily Withdrawal (MGD)	2019 Volume Authorized	2030 Volume Authorized
South Coastal	Bradford Well No. 1	1.51	4.59 MGD (1,675.3 MGY)	5.04 MGD (1,839.6 MGY)
	Bradford No. 2			
	Ellisville Well	1.12		
	Lout Pond Well	0.72		
	North Plymouth Well	1.53		
	Savery Pond Well	1.50		
	Ship Pond Well	0.86		
	South Pond Well No. 1	1.12		
	South Pond Well No. 2	1.50		
	Wannos Pond Well	0.94		
	Forges Field Well[2]	1.05		
Buzzards Bay	Darby Pond Well	0.80	1.59 MGD (580.35 MGY)	1.59 MGD (580.35 MGY)
	Federal Furnace Well	0.79		
Not-to-Exceed Withdrawal Volume[1]			**4.59 MGD (1,675.3 MGY)**	**5.04 MGD (1,839.6 MGY)**

1. Not-to-Exceed Withdrawal Volumes are limited to 4.59 MGD in 2018 and 2019, 4.71 MGD in 2025, and 5.04 MGD in 2030. An exception is made for the 400th Anniversary Celebration in 2020, where the Not-to-Exceed Withdrawal Volume is increased to 5.58 MGD.
2. The Forges Field Well is currently in construction and is anticipated to come online in 2020.

The Division must operate within the standards of its March 1, 2019 South Coastal WMA Permit, including compliance with the residential gallons per capita day (RGPCD) water use standard of 65 gallons per day or less and the unaccounted-for water (UAW) standard of 10 percent or less. In the previous permit, these standards were 85 RGPCD and 15 percent UAW, respectively.

Under the latest WMA Permit, there are a series of water use restrictions and requirements, including water conservation, UAW performance, RGPCD performance, seasonal limits on non-essential outdoor water use, coldwater fishery resource protection, minimization, and mitigation.

1.3 TREATMENT FACILITIES

The Division's water system contains eleven treatment facilities that treat raw water from the thirteen groundwater supplies listed above. The Division is required to provide 4-log inactivation of viruses or otherwise demonstrate compliance with the Groundwater Rule. Because all of the supplies are groundwater sources, dissolved and particulate metals (iron [Fe] and manganese [Mn]) are the contaminants of concern. At three sites, the Division adds a proprietary blend of phosphates to sequester dissolved and particulate iron and manganese. All sites inject sodium hydroxide (NaOH) for pH adjustment, and sodium hypochlorite (NaOCl) for disinfection and chlorine residual. Each facility is discussed below and a summary of the facilities is provide in Table 1-5.

Table 1-5 – Summary of Treatment Facilities

Pressure Zone	Treatment Facility	Source	Treatment
West Plymouth	Federal Furnace WPS	Federal Furnace Well	Disinfection pH Adjustment Fe/Mn Sequestration
	North Plymouth WTP	North Plymouth Well	Disinfection pH Adjustment GAC Filtration
	Darby Pond WPS	Darby Pond Well	Disinfection pH Adjustment
Plymouth Center	South Pond WPS	South Pond Well No. 1 South Pond Well No. 2	Disinfection pH Adjustment
	Lout Pond WPS	Lout Pond Well	Disinfection pH Adjustment Fe/Mn Sequestration
Bradford	Bradford WTP	Bradford Well No. 1 Bradford Well No. 2	Disinfection pH Adjustment Particulate Removal
	Forges Field WPS	Forges Field Well	Disinfection pH Adjustment Fe/Mn Sequestration (future)
Manomet	Ellisville WPS	Ellisville Well	Disinfection pH Adjustment
	Ship Pond WPS	Ship Pond Well	Disinfection pH Adjustment
	Wannos Pond WPS	Wannos Pond Well	Disinfection pH Adjustment Fe/Mn Sequestration
Cedarville	Savery Pond WPS	Savery Pond Well	Disinfection pH Adjustment

1.3.1 Federal Furnace Well Pumping Station (MassDEP Plant ID: 4239000-03T)

The Federal Furnace WPS was constructed in 1973 and is located at 454 Federal Furnace Road. The WPS has a single groundwater well (MassDEP Source ID: 4239000-04G) that supplies water to the West Plymouth Pressure Zone via a 12-inch main. The Federal Furnace Well is an 80-foot deep, gravel-pack well located in the Buzzards Bay Watershed that is permitted under the provisions of the WMA to produce an annual average of 550 gpm (0.79 MGD). Currently, the station is restricted to 300 gpm (0.43 MGD) due to elevated manganese concentrations in the source water.

Raw water is pumped from the Federal Furnace Well via a vertical turbine pump through the WPS where the Division adds NaOH for pH adjustment, NaOCl for disinfection and distribution system residual, and a blended phosphate (Carus Aquamag) for sequestering. Both NaOH and NaOCl are delivered to the site by bulk truck. There is no bulk storage of NaOCl, so the driver typically fills carboys and 55-gallon drums. The blended phosphate is delivered to the site in 55-gallon drums.

The start/stop operation of the pump is primarily controlled by the water level in the Harrington Standpipe, though control via the water level in either the Samoset Street Standpipe or the North Plymouth Tank are options in SCADA. Concentrations of manganese in the raw water are typically between 0.1 and 0.3 milligrams per liter (mg/L). There is insufficient reaction time between sequesterant addition and chlorine addition, which is limiting the sequesterant effectiveness. The Division is currently evaluating the raw water quality at the Federal Furnace Well.

The WPS has an on-site emergency generator that is powered by propane gas, which is stored on-site. The WPS site does not have a perimeter fence, nor are there cameras or motion sensor lights located on the station exterior. There is a locked gate that prevents vehicle access via the access road.

A review of the Federal Emergency Management Agency (FEMA) flood zones reveals that the station is partially located within the 500 year flood zone (FEMA Zone X, 0.2% chance of flooding).

Recommended upgrades to the Federal Furnace WPS are summarized in Table 1-6.

Table 1-6 – Recommended Federal Furnace WPS Upgrades

Upgrade Category	Recommendation
Architectural	• Apply block filler to interior walls • Repaint interior walls and ceiling
Mechanical	• Install isolation butterfly valve inside station • Replace existing flow meter • Repaint process piping • Provide tankless hot water heater • Install splash plates and curtains for chemical feed systems • Install exhaust fan for chemical ventilation • Recoat and relabel chemical piping and injection sleeves • Re-pipe NaOH bulk tank overflow to containment area • Demolish existing Parco Valve
Instrumentation	• Install well level transducer and transmitter • Install pressure transmitter • Install NaOH bulk tank level sensor • Install NaOH containment flood switch • Install NaOCl and NaOH day tank level sensors • SCADA programming to indicate when chemicals are added and daily flow reset • Repair man-down alarm

Upgrade Category	Recommendation
	• Reprogram station PLC[1] and SCADA system to include new instruments
Treatment	• Install redundant chemical feed pumps • Improve chemical feed piping • Install calibration columns • Relocate bulk NaOH tank overflow to containment • Install stainless steel piping for bulk storage • Replace all PVC[2] piping with CPVC[3] • Provide 55-gallon NaOCl day tank and containment
Site	• Install perimeter fence
Electrical	• Label switches and pumps in station • Replace pump motor and starter • Install chemical feed pump local controls and alarms • Replace receptacles with GFCI[4] receptacles • Demolish obsolete equipment • Bond propane tank • Repair HVAC circuitry and temperature controls • Provide lockout tags • Install underground conduit and cable to building for antenna • Install power and control wiring and conduit for new instrumentation • Install security cameras and motion sensors • Improve station lighting • Underground conduit and wiring from the street to the pump station
Supply	None

1. PLC: Programmable Logic Controller
2. PVC: Polyvinyl Chloride
3. CPVC: Chlorinated Polyvinyl Chloride
4. GFCI: Ground Fault Circuit Interrupter

As noted in Table 1-6, it is recommended that the existing Parco valve be demolished. The station has a VFD and unless the valve is properly maintained, it can malfunction and damage the pump motor and piping.

1.3.2 North Plymouth Well Water Treatment Plant (MassDEP Plant ID: 4239000-04T)

The North Plymouth Well WTP was originally constructed in 1975 and is located at 80 Industrial Park Road. The facility has a single groundwater well (MassDEP Source ID: 4239000-05G) that supplies water to the West Plymouth Pressure Zone via a 12-inch transmission main. The North Plymouth Well is a 120-foot deep, gravel-pack well located in the South Coastal Watershed that is permitted under the provisions of the WMA to produce an annual average of 1,060 gpm (1.53 MGD).

There are three buildings located on the premises: well pumping station, treatment facility, and chemical storage building. Raw water is pumped from the well pumping station via a vertical turbine pump to the treatment facility where the Division adds NaOH for pH adjustment and NaOCl for disinfection and distribution system residual. Volatile organic compounds (VOCs) are present in the raw water, which are removed by GAC pressure filters. The GAC filters are backwashed about once per month. The backwash waste is sent to a pair of drying beds for on-site treatment. The station does not produce a large volume of residuals, so the drying beds are emptied infrequently.

The start/stop operation of the pump is primarily controlled by the water level in the Harrington Standpipe, though control via the water level in either the Samoset Street Standpipe or the North Plymouth Tank are options in SCADA.

The chemical storage building houses the NaOH bulk tank. Stainless steel transfer pipes run from the bulk tank underground to the treatment building. The NaOH day tank in the treatment facility is filled by gravity from the bulk storage tank. All NaOCl storage and chemical feed equipment is located in the treatment facility. Both NaOH and NaOCl are delivered to the site by bulk truck. There is no bulk storage of NaOCl, so the driver fills carboys and 55-gallon drums which are stored in the treatment facility.

The well pumping station has an on-site emergency generator that is powered by propane gas, which is stored on-site. There is a perimeter fence around the well pumping station, treatment facility, and the drying beds; the fences are not fitted with barbed wire. There is no perimeter fence around the NaOH building. There are no exterior motion sensing lights or cameras on the buildings, and no interior motion sensing or intrusion alarms.

A review of the FEMA flood zones reveals that the station is not located within any flood zones.

Recommended upgrades to the North Plymouth WPS are summarized in Table 1-7.

Table 1-7 – Recommended North Plymouth Well Supply Upgrades

Upgrade Category	Recommendation
Architectural	• Replace roof and eave fascia • Apply block filler to interior walls • Repaint interior walls and ceiling
Mechanical	• Replace existing flow meter • Install surge relief isolation valves • Install indoor sample tap • Repaint process piping • Provide tankless hot water heater and dehumidification system • Install splash plates and curtains for chemical feed systems • Provide PPE[1] in all chemical feed areas • Recoat and relabel chemical piping and injection sleeves • Install chemical makeup water flow meter • Demolish existing Parco valve
Instrumentation	• Repair solenoid flow controls in WTP building • Install two pressure transmitters • Install NaOH bulk tank high level alarm switch • Install NaOH containment flood switch • Install NaOCl and NaOH day tank level sensors

Upgrade Category	Recommendation
	• SCADA programming to indicate when chemicals are added and daily flow reset • Install thermostat alarm switch • Reprogram station PLC and SCADA system to include new instruments
Treatment	• Install redundant chemical feed pumps • Improve chemical feed piping • Install calibration columns • Install stainless steel piping for bulk storage • Repair NaOH chemical feed pipe leaks • Replace all PVC piping with CPVC • Provide 55-gallon NaOCl day tank and containment • Replace undersized filter manways
Site	• Remove and replace the existing line gate
Electrical	• Label switches and pumps in station • Install chemical feed pump local controls and alarms • Install exterior NaOH bulk tank level alarm light and horn • Replace receptacles with GFCI receptacles • Demolish obsolete equipment • Bond propane tank and water piping • Provide lockout tags • Install power and control wiring and conduit for new instrumentation • Install security cameras and motion sensors • Improve station lighting
Supply	None

1. PPE: Personal Protective Equipment

As noted in Table 1-7, it is recommended that the existing Parco valve is demolished. The station has a VFD and unless the valve is properly maintained, it can malfunction and damage the pump motor and piping.

1.3.3 Darby Pond Well Pumping Station (MassDEP Plant ID: 4239000-08T)

The Darby Pond WPS was constructed in 1991 and is located at 119 Graffam Road approximately 450 feet northeast of Darby Pond. The facility has a single groundwater well (MassDEP Source ID: 4239000-08G) that supplies water to the West Plymouth Pressure Zone via a 12-inch main. The Darby Pond Well is a 90-foot deep, gravel-pack well located in the Buzzards Bay Watershed that is permitted under the provisions of the WMA to produce a monthly average of 555 gpm (0.80 MGD).

Per the Division's WMA Permit, when the water level in Darby Pond drops below 121.5 feet above mean seal level (NGVD29), the WMA Permit requires the Division to limit pumping at the facility to no more than 4 hours per day. Even during high water level conditions, the Darby Pond Well cannot exceed 0.80 MGD for any 30 consecutive days during any year. The Division can run the well over 1,000 gpm for short periods, such as when the source is limited to four hours of operation per day. In 2016 and 2017, there were 161 and 227 days of restricted pumping, respectively. The lifting of the restrictions set within the WMA Permit would require negotiation with MassDEP.

The Division has taken steps to acquire cranberry bogs situated in the Zone I of the Darby Pond Well and acquired the DeGrenier property (~40 acres). A remaining property with active cranberry bog operations withdraws water from Darby Pond. The Division is currently working to acquire this property to reduce the drawdown of Darby Pond due to cranberry farming. As operations on the property withdraw water from Darby Pond for irrigation and flooding, the acquisition of these properties is expected to alleviate pumping limitations on the Darby Pond Well.

Raw water is pumped from the Darby Pond Well via a vertical turbine pump through the WPS building, where the Division adds NaOH for pH adjustment and NaOCl for disinfection and distribution system residual. Both NaOH and NaOCl are delivered to the site by bulk truck. There is no bulk storage of NaOCl, so the driver fills carboys and 55-gallon drums. All chemicals are stored inside the station. Additionally, the station has a venturi flow meter which should be updated to a magnetic flow meter to increase the accuracy of flow measurements.

The start/stop operation of the pump is primarily controlled by the water level in the Harrington Standpipe, though control via the water level in either the Samoset Street Standpipe or the North Plymouth Tank are options in SCADA.

The Darby Pond WPS is located in a heavily wooded area and frequently loses power, sometimes for days at a time according to Division operators. Power to the station is provided by overhead wires along the heavily wooded access road that is subject to obstruction. The WPS previously had a functioning propane-fired emergency generator, which is no longer functional and should be replaced as soon as possible.

A review of the FEMA flood zones reveals that the WPS is not located within any FEMA flood zones while the access road is located within the 500 year flood zone (FEMA Zone X, 0.2% chance of flooding).

Recommended upgrades to the Darby Pond WPS are summarized in Table 1-8.

Table 1-8 - Recommended Darby Pond WPS Upgrades

Upgrade Category	Recommendation
Architectural	• Install drywell and piping
Mechanical	• Replace the existing well pump • Replace existing venturi flow meter • Demolish surge control valve cabinet and compressor • Provide dehumidification system • Install splash plates and curtains for chemical feed systems • Provide PPE in all chemical feed areas • Install an additional deluge shower • Install exhaust fan for chemical ventilation • Re-pipe NaOH bulk tank overflow to containment • Recoat and relabel chemical piping and injection sleeves

Upgrade Category	Recommendation
Instrumentation	• Provide a fire extinguisher • Install pressure transmitter • Install NaOH containment flood switch • Install thermostat alarm switch • Reprogram station PLC and SCADA system to include new instruments • Install NaOCl and NaOH day tank level sensors • SCADA programming to indicate when chemicals are added and daily flow reset
Treatment	• Install redundant chemical feed pumps • Provide spare injection nozzles • Relocate NaOH injection • Replace all PVC piping with CPVC • Provide containment for 55-gallon NaOCl day tank
Site	• Repair barbed wire on perimeter fence
Electrical	• Label switches and pumps in station • Replace the existing standby power generator • Install a VFD[1] for pump motor • Replace existing security alarm panel • Replace receptacles with GFCI receptacles • Demolish obsolete equipment • Bond propane tanks • Install security cameras and motion sensors • Install power and control wiring and conduit for new instrumentation • Repair entry alarm • Improve station lighting • Install underground wiring and conduit from the street to the pump station
Supply	None

1. VFD: Variable Frequency Drive

It is recommended that the Division conduct a full electrical assessment of the site prior to generator design and electrical improvements. Additionally, the existing overhead wire service on the access road should be replaced with an underground electrical service. This will reduce the frequency of power outages due to fallen trees and could possibly reduce the length of power outages, as well. In addition to electrical service upgrades, the Division should clear trees along the access road to reduce obstruction during storm events and improve site access.

1.3.4 South Pond Well Pumping Station (MassDEP Plant ID: 4239000-09T)

Currently the "workhorse" of the Plymouth Center Pressure Zone due to its production capacity, the South Pond WPS was constructed in 1994 and is located at 166 Rocky Pond Road. The facility has two groundwater wells: South Pond Well No. 1 (MassDEP Source ID: 4239000-09G) and South Pond Well No. 2 (MassDEP Source ID: 4239000-10G). South Pond Well No. 1 and No. 2 are gravel-pack wells located in the South Coastal Watershed permitted under the provisions of the WMA to produce an annual average of 770 gpm (1.12 MGD) and 1,040 gpm (1.50 MGD), respectively. Together, the wells are permitted to withdraw an annual average of 2.62 MGD. The total operational capacity of the wells is 1,900 gpm (2.74 MGD); therefore production is limited by the permitted withdrawals.

Raw water is pumped from the South Pond Well No. 1 via a submersible pump and from South Pond Well No. 2 via a vertical turbine pump through the WPS where the Division adds NaOH for pH adjustment and NaOCl for disinfection and distribution system residual. Both NaOH and NaOCl are delivered to the site by bulk truck. There is no bulk storage of NaOCl, so the driver typically fills carboys and 55-gallon drums. All chemicals are stored inside the station.

Treated water leaves the station and enters the distribution system via a 16-inch main. The start/stop operation of the pumps are primarily controlled by the water level in the Chiltonville Tank, though control via the water level in the Lout Pond Tank is an option in SCADA. Flow through the station is currently measured using a venturi flow meter. This technology is outdated and should be updated to a magnetic flow meter to increase the accuracy of flow measurements.

The WPS has an on-site emergency generator that is powered by propane gas, which is stored on-site. However, the generator is only connected to South Pond Well No. 2 and not South Pond Well No. 1. Therefore, during an emergency, the generator cannot operate both wells and the water system effectively loses a portion of its water supply.

There is perimeter fencing around South Pond Well No. 1 and the WPS. The top of the fence around the WPS is fitted with barbed wire. There are no exterior motion sensing lights or cameras located on-site, nor are there interior motion sensors or intrusion alarms.

A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

Recommended upgrades to the South Pond WPS are summarized in Table 1-9.

Table 1-9 - Recommended South Pond WPS Upgrades

Upgrade Category	Recommendation
Architectural	• Install drywell and piping • Provide door with hardware • Touch up interior painting
Mechanical	• Replace Well #2 pump • Repaint process piping • Replace venturi flow meter • Provide indoor sample tap • Provide tankless hot water heater • Install splash plates and curtains for all chemical feed systems • Install chemical feed area exhaust fan • Install NaOH bulk tank vent to exterior • Re-pipe NaOH bulk tank overflow to containment • Recoat and relabel chemical piping and injection sleeves • Demolish existing Parco valve

Upgrade Category	Recommendation
Instrumentation	• Install level transducer and transmitter in Well #2 • Install pressure transmitters • Install NaOH containment flood switch • Reprogram station PLC and SCADA system to include new instruments • Install NaOCl and NaOH day tank level sensors • SCADA programming to indicate when chemicals are added and daily flow reset
Treatment	• Install redundant chemical feed pumps • Provide spare injection nozzles • Install stainless steel piping for bulk storage • Replace all PVC piping with CPVC • Provide 55-gallon NaOCl day tank and containment
Site	None
Electrical	• Label switches and pumps in station • Install chemical feed pump local controls and alarms • Demolish obsolete equipment • Replace receptacles with GFCI receptacles • Bond propane tank and water piping • Install security cameras and motion sensors • Provide lockout tags • Install power and control wiring and conduit for new instrumentation • Repair station alarms • Improve station lighting • Install underground wiring and conduit from the pump station to the vault • Install wiring and conduit from the generator to South Pond Well No. 1
Supply	None

As noted in Table 1-9, it is recommended that the existing Parco valves are demolished. Each pump motor is outfitted with a VFD and unless the valves are properly maintained, they can malfunction and damage the pump motor and piping.

1.3.5 Lout Pond Well Pumping Station (MassDEP Plant ID: 4239000-13T)

The Lout Pond WPS, located at 262 Billington Street, was originally constructed in 1955 and rehabilitated in 2014. The facility has a single groundwater well (MassDEP Source ID: 4239000-13G) which was replaced as part of the 2014 rehabilitation that supplies water to the Plymouth Center Pressure Zone via a 12-inch main. The Lout Pond Replacement Well is a gravel-pack well located in the South Coastal Watershed that is permitted under the provisions of the WMA to produce an annual average of 500 gpm (0.72 MGD).

High levels of iron detected in the raw water has led the Division to limit pumping at this facility to 250 gpm (0.36 MGD). The concentration of iron in the raw water is approximately 2 mg/L based on recent water quality data, which is too high to be effectively sequestered. The Division is currently evaluating the raw water quality at the Lout Pond Well and the possibility of re-routing the source to the Bradford WTP. In addition to the water quality issues, Lout Pond has been off-line since April 2018 due to VFD failure.

Raw water is pumped from the Lout Pond Replacement Well via a vertical turbine pump through the station where the Division adds NaOH for pH adjustment, NaOCl for disinfection and distribution system residual, and a blended phosphate (Carus Aquamag) for sequestering. Both NaOH and NaOCl are delivered to the site by bulk truck. There is no bulk storage of NaOCl, so the driver typically fills carboys and 55-gallon drums. The blended phosphate is delivered to the site in 55-gallon drums. All chemicals are stored inside the station.

The start/stop operation of the pump is primarily controlled by the water level in the Chiltonville Tank, though control via the water level in the Lout Pond Tank is an option in SCADA.

The pumping station has an on-site emergency generator located inside the pumping station. The generator is powered by propane, which is stored on-site. A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

It is recommended that the Division repair or replace the failed VFDs with new drive units. The long-term use of this facility is being evaluated as part of an ongoing water quality study. Additionally, the access drive and gravel walkway were reported to be overgrown during a recent site visit. It is recommended that these areas are cleared and grubbed to improve site access.

1.3.6 Bradford Water Treatment Plant (MassDEP Plant ID: 4239000-06T)

The Bradford WTP is a greensand pressure filtration plant located at 17R Natalie Way that was originally brought on-line in 1975. The treatment plant is designed to treat 1.51 MGD from two groundwater wells: Bradford Well No. 1 (MassDEP Source ID: 4239000-06G) and Bradford Well No. 2 (MassDEP Source ID: 4239000-12G). The Bradford WTP supplies water to the Bradford Pressure Zone, which provides water to the area in the vicinity of South Street, Long Pond Road, and Obery Street. The Bradford WTP is located in the South Coastal watershed. The combined operational capacity of Wells No. 1 and No. 2 is limited to 1.30 MGD due to reduced well production. The start/stop operation of the pumps is controlled by the water level in the Stafford Street Standpipe.

The construction of the original Bradford WTP was started in 1973 and the treatment plant was brought on-line in 1975 with a design capacity of 3.0 MGD. The treatment plant was constructed for the removal of iron and manganese from the groundwater supply as well as disinfection and pH adjustment. In 1993 the treatment plant's capacity was reduced to 1.51 MGD due to decreased well and filter system performance. The capacity of the treatment plant continued to decrease until Bradford Well No. 1 and the filtration system were taken off-line in 2007. The original iron and manganese removal system had become outdated and difficult to operate effectively. Bradford Well No. 2 was constructed at a shallower depth to take advantage of better groundwater quality (lower levels of iron and manganese) than observed at Bradford Well No. 1. However, the water quality at Bradford Well No. 2 steadily deteriorated to the point where chemical sequestration of the dissolved iron and manganese was no longer effective. A new operating plan for the two wells should be derived to increase the performance from Well No. 2.

The Bradford WTP was rehabilitated in 2010 in an effort to improve treated water quality and increase treatment capacity. Improvements included replacing the filtration media in the existing pressure filters with GreensandPlus™, replacing the chemical feed systems, and replacing the residuals management system.

Raw water is pumped from Bradford Wells No. 1 and No. 2 via submersible pumps into the WTP, where it is oxidized and treated with NaOH and NaOCl. The oxidized water is then pumped through three steel pressure filters for the removal of iron and manganese. After filtration, the Division adds NaOH for pH adjustment and NaOCl for disinfection and distribution system residual. Both NaOH and NaOCl are delivered to the site by bulk truck. All chemicals are stored inside the facility.

A filter backwash is triggered by either differential pressure or filter run-time, as selected by the operator. During a backwash, washwater is typically supplied by the other two on-line filters. In the event that two filters are in need of backwash at the same time, or one filter is down for maintenance, the WTP is equipped with the ability to utilize distribution system water as an emergency washwater supply. The backwash waste flows from the treatment plant to the residuals handling facility via a 12-inch ductile iron pipe. The residuals handling facility is comprised of a sub-grade tank with two access hatches: one with a crane to allow for the removal of the submersible mixer and the other for personnel access and removal of the two submersible backwash waste pumps. The backwash waste pumps discharge backwash waste from the holding tank to the drying beds on the southwestern portion of the site. In the event that the water level in the residuals handling facility is too high, there is an 8” overflow drain that allows for the residuals to flow to the onsite drainage system.

The Bradford WTP has an on-site emergency generator located just south of the treatment plant. The generator is powered by propane gas, which is stored in two tanks located just west of the generator. The power to the Bradford WTP runs overhead through woods and easements, and the facility currently experiences frequent power outages. It is recommended that the Division consider re-routing power to the facility underground and down Natalie Way to mitigate the frequency of outages due to downed trees.

There is a perimeter fence around the WTP, though it does not fully enclose the facility. There are exterior lights on the south and west walls, though there are no exterior security cameras or interior motion sensors. A review of the FEMA flood zones reveals that the station is partially located within the 500 year flood zone (FEMA Zone X, 0.2% chance of flooding).

Recommended upgrades to the Bradford WTP are summarized in Table 1-10.

Table 1-10 - Recommended Bradford WTP Upgrades

Upgrade Category	Recommendation
Architectural	None
Mechanical	• Relocate existing NaOCl deluge shower • Install splash plates and curtains for all chemical feed systems • Replace existing flow meter • Replace Well #2 pump
Instrumentation	• Install NaOCl and NaOH day tank level sensors • SCADA programming to indicate when chemicals are added and daily flow reset

Upgrade Category	Recommendation
Treatment	• Install redundant chemical feed pumps • Improve chemical feed piping • Install chemical makeup water flow meter • Replace undersized filter manways
Site	None
Electrical	• Label switches and pumps in station • Install chemical feed pump local controls and alarms • Replace existing GFCI receptacles • Provide lockout tags • Install power and control wiring and conduit for new instrumentation • Install security cameras and motion sensors • Improve station lighting • Re-route and convert overhead electric to underground electric service
Supply	• Redevelop both groundwater wells

1.3.7 Ellisville Well Pumping Station (MassDEP Plant ID: 4239000-07T)

The Ellisville WPS was constructed in 1982 and is located at 1649 State Road. The facility has a single groundwater well (MassDEP Source ID: 4239000-07G) that supplies water to the Manomet Pressure Zone via 16- and 12-inch mains. The Ellisville Well is a gravel-pack well located in the South Coastal Watershed that is permitted under the provisions of the WMA to produce an annual average of 780 gpm (1.12 MGD). Currently, the operational capacity of the station is restricted to approximately 700 gpm (1.01 MGD) due to its proximity to the Ship Pond WPS and the Cedarville Actuator Valve and the limited carrying capacity of the trunk mains in the northern portion of the Manomet Pressure Zone. When all sources are operating and the altitude valve at the Indian Hill Tank closes, the resulting high pressure surges limit the production of the Ellisville Well.

Raw water is pumped from the Ellisville Well via a vertical turbine pump through the station where the Division adds NaOH for pH adjustment, NaOCl for disinfection and distribution system residual, and a blended phosphate (Carus Aquamag) for sequestering. There is no bulk storage of NaOCl, so the driver typically fills carboys and 55-gallon drums. All chemicals are stored inside the station.

The start/stop operation of the pump is primarily controlled by the water level in the South Pine Hills Tank, though control via the water level in the Indian Hill Tank is an option in SCADA. Flow through the station is currently measured using a venturi flow meter. This technology is outdated and should be updated to a magnetic flow meter to increase the accuracy of flow measurements.

The pumping station has an on-site emergency generator that is powered by propane gas, which is stored on-site. The station does not have a perimeter fence or exterior motion sensing lights or security cameras. There are no interior motion sensors or intrusion alarms, either.

A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

Recommended upgrades to the Ellisville WPS are summarized in Table 1-11.

Table 1-11 - Recommended Ellisville WPS Upgrades

Upgrade Category	Recommendation
Architectural	• Apply block filler to interior walls • Repaint interior walls and ceiling
Mechanical	• Provide PPE for NaOCl chemical feed system • Recoat and relabel chemical piping and injection sleeves • Re-pipe NaOH bulk tank overflow to containment area • Replace venturi flow meter
Instrumentation	• Recalibrate surge relief valve • Install well level transducer and transmitter • Install pressure transmitter • Install NaOH containment flood switch • Repair man-down alarm • Install NaOH bulk tank level sensor • Install day tank high level float switches • Reprogram station PLC and SCADA system to include new instruments • Install NaOCl and NaOH day tank level sensors • SCADA programming to indicate when chemicals are added and daily flow reset
Treatment	• Install redundant chemical feed pumps • Install NaOH transfer pump bypass piping • Relocate NaOH bulk tank overflow to the chemical containment area • Replace all PVC piping with CPVC • Provide containment for NaOCl drums • Install chemical makeup water flow meter
Site	• Install perimeter fence
Electrical	• Label switches and pumps in station • Replace pump motor and starter • Replace receptacles with GFCI receptacles • Demolish obsolete equipment • Install chemical feed pump local controls and alarms • Bond propane tank • Provide lockout tags • Install power and control wiring and conduit for new instrumentation • Install security cameras and motion sensors • Improve station lighting
Supply	None

1.3.8 Ship Pond Well Pumping Station (MassDEP Plant ID: 4239000-02T)

The Ship Pond WPS was constructed in 1969 and is located at 137 Ship Pond Road. The facility has a single groundwater well (MassDEP Source ID: 4239000-03G) that supplies water to the Manomet Pressure Zone via a 12-inch main. The Ship Pond Well is a gravel-pack well located in the South Coastal Watershed that is permitted under the provisions of the WMA to produce an annual average of 600 gpm (0.86 MGD). Currently, the operational capacity of the station is restricted to 500 gpm (0.72 MGD) due to its proximity to the Ellisville WPS and Cedarville Actuator Valve, as well as limited carrying capacity in the northern portion of the Manomet Pressure Zone, as discussed above.

Raw water is pumped from the Ship Pond Well via a vertical turbine pump through the station where the Division adds NaOH for pH adjustment and NaOCl for disinfection and distribution system residual. Both NaOH and NaOCl are delivered to the site by bulk truck. There is no bulk storage of NaOCl, so the driver typically fills carboys and 55-gallon drums which are stored in the WPS building.

The start/stop operation of the pump is primarily controlled by the water level in the South Pine Hills Tank, though control via the water level in the Indian Hill Tank is an option in SCADA. The concentration of iron in the raw water routinely exceeds 0.1 mg/L. The Division is currently evaluating the raw water quality at the Ship Pond Well including the potential future addition of a sequesterant.

The pumping station has an on-site emergency generator that is powered by propane gas, which is stored on-site. The station has a perimeter fence and a single exterior door light. There are no additional motion sensing exterior lights or security cameras, nor are there interior motion sensors or intrusion alarms. A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

Recommended upgrades to the Ship Pond WPS are summarized in Table 1-12.

Table 1-12 - Recommended Ship Pond WPS Upgrades

Upgrade Category	Recommendation
Architectural	• Repair exterior coating • Install screen on intake louver • Apply block filler to interior walls • Repaint interior walls and ceiling
Mechanical	• Provide tankless hot water heater • Repair existing deluge shower • Install splash plates and curtains for all chemical feed systems • Provide PPE for all chemical feed areas • Install NaOH bulk tank vent to exterior • Re-pipe NaOH bulk tank overflow to containment • Install a makeup water flow meter
Instrumentation	• Install well level transducer and transmitter • Install pressure transmitter • Install NaOH containment flood switch • Install NaOH bulk tank high level alarm switch • Repair man-down alarm • Reprogram station PLC and SCADA system to include new instruments • Install NaOCl and NaOH day tank level sensors • SCADA programming to indicate when chemicals are added and daily flow reset

Upgrade Category	Recommendation
Treatment	• Install redundant chemical feed pumps • Provide spare injection nozzles • Relocate NaOH injector • Install stainless steel piping for bulk storage • Relocate day tank overflow to containment • Replace all PVC piping with CPVC • Provide 55-gallon NaOCl day tank and containment
Site	None
Electrical	• Label switches and pumps in station • Demolish obsolete equipment • Replace receptacles with GFCI receptacles • Bond propane tanks • Install security cameras and motion sensors • Provide lockout tags • Install power and control wiring and conduit for new instrumentation • Repair station alarms • Improve station lighting
Supply	None

1.3.9 Wannos Pond Well Pumping Station (MassDEP Plant ID: 4239000-12T)

Located at 20 Acacia Road, the Wannos Pond WPS was constructed in 2012 to replace a deteriorating well and pumping station. Historically a wellfield water supply, the current facility has a single groundwater well (MassDEP Source ID: 4239000-14G) that supplies water to the Manomet Pressure Zone via a 10-inch main. The Wannos Pond Well is a gravel-pack well located in the South Coastal Watershed that is permitted under the provisions of the WMA to produce an annual average of 650 gpm (0.94 MGD). Currently, the operational capacity of the station is hydraulically restricted to 500 gpm (0.72 MGD) because of hydraulic restrictions in the Manomet Pressure Zone.

Raw water is pumped from the Wannos Pond Well via a vertical turbine pump through the station where the Division adds NaOH for pH adjustment and NaOCl for disinfection and distribution system residual. Blended phosphate (Carus Aquamag) is available for sequestering. Both NaOH and NaOCl are delivered to the site by bulk truck. There is no bulk storage of NaOCl, so the driver typically fills 55-gallon drums. The blended phosphate is delivered to the site in 15-gallon carboys. All chemicals are stored in the station.

The start/stop operation of the pump is primarily controlled by the water level in the South Pine Hills Tank, though control via the water level in the Indian Hill Tank is an option in SCADA.

The pumping station has an on-site emergency generator that is powered by propane gas, which is stored on-site. There is a perimeter fence around the station, and a locked gate at the access drive entrance. The station is outfitted with an intrusion alarm system and exterior lighting, but no security cameras.

A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

The Division noted that the bulk NaOH storage at Wannos Pond requires more frequent deliveries than the other stations. The bulk tank vent is piped to the interior NaOH containment area, which is estimated to reduce the capacity of the bulk tank by a few hundred gallons. An additional bulk tank for NaOH should be installed to reduce the frequency of deliveries. Additionally, level sensors for the NaOCl and NaOH day tanks and a programmable chemical daily flow reset should be installed.

Additionally, the Division utilizes the Wannos Pond WPS for the storage of some spare parts for sources in the eastern pressure zones of the water system and the station is not outfitted with sufficient storage space. Additional shelving and storage units should be installed to increase capacity in order to use the Wannos WPS as a storage hub for all of the facilities in the eastern portion of the system. Additionally, the Division should provide at least one shelf spare of each required metering pump that is used at pumping stations in the eastern pressures zones.

1.3.10 Savery Pond Well Pumping Station (MassDEP Plant ID: 4239000-11T)

The Savery Pond WPS was constructed in 2002 and is located at 6R Quail Run. Also known as the John Holmes WPS, the facility has a single groundwater well (MassDEP Source ID: 4239000-11G) that is the only source of supply in the Cedarville Pressure Zone. The Savery Pond Well is a gravel-pack well located in the South Coastal Watershed that is permitted under the provisions of the WMA Permit to produce an annual average of 1,040 gpm (1.50 MGD). The operational capacity of the well and pump limit the production of the supply to approximately 845 gpm (1.22 MGD) due to frequent VFD failure.

Raw water is pumped from the Savery Pond Well via a submersible pump into the station where the Division adds NaOH for pH adjustment and NaOCl for disinfection and distribution system residual. Both NaOH and NaOCl are delivered to the site by bulk truck. There is no bulk storage of NaOCl, so the driver typically fills carboys and 55-gallon drums which are stored in the WPS building.

The start/stop operation of the pump is controlled by the water level in the Cedarville Tank. Flow through the station is currently measured using a venturi flow meter. This technology is outdated and should be updated to a magnetic flow meter to increase the accuracy of flow measurements.

The pumping station has an on-site emergency generator located inside the WPS building. The generator is powered by propane, which is stored on-site in an exterior tank. Site security consists of a perimeter fence around the station, which is outfitted with exterior lighting on two sides. The exterior lighting is not motion sensing and there are no security cameras on the building exterior. There is an existing intrusion alarm system, but the contacts have been disabled and it is not currently in use.

A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

Recommended upgrades to the Savery Pond WPS are summarized in Table 1-13

Table 1-13 - Recommended Savery Pond WPS Upgrades

Upgrade Category	Recommendation
Architectural	• Apply block filler to interior walls • Repaint interior walls and ceiling • Install building at submersible well site, move VFD into building to reduce wire length, and reduce VFD failure and damage.
Mechanical	• Provide dehumidification system • Relocate existing deluge shower • Install splash plates and curtains for all chemical feed systems • Provide PPE for all chemical feed areas • Install NaOH bulk tank vent to exterior • Re-pipe NaOH bulk tank overflow to containment • Replace venturi flow meter
Instrumentation	• Repair solenoid flow controls • Provide a fire extinguisher • Install thermostat alarm switch • Repair man-down alarm • Reprogram station PLC and SCADA system to include new instruments • Install NaOCl and NaOH day tank level sensors • SCADA programming to indicate when chemicals are added and daily flow reset
Treatment	• Install redundant chemical feed pumps • Provide calibration columns • Provide spare injection nozzles • Relocate NaOH injector • Replace all PVC feed piping with CPVC • Install a NaOH bulk tank • Install a flow meter for chemical makeup water
Site	• None
Electrical	• Label switches and pumps in station • Repair or replace existing security alarm panel • Replace receptacles with GFCI receptacles • Bond propane tanks • Install security cameras and motion sensors • Test fire alarm panel • Install power and control wiring and conduit for new instrumentation • Repair station alarms • Improve station lighting
Supply	• None

1.3.11 Forges Field Well Pumping Station

The Forges Field WPS is a groundwater supply pump station that is currently under construction and expected to be online in 2020. The pumping station is designed to operate at a maximum flow rate of 1,090 gpm for 16 hours per day (1.05 MGD), with flexibility to operate at lower flow rates. Raw water is produced from one groundwater well (MassDEP Source ID: 4239000-15G) that is located underneath the pumping station and will be fitted with a vertical turbine pump. The Forges Field Well is a gravel-pack well located in the South Coastal Watershed. The pumping station will act as a supplementary water supply for the Plymouth Center and Bradford Pressure Zones.

Raw water will be pumped from the Forges Field Well via a vertical turbine pump through the station where the Division adds NaOH for pH adjustment and NaOCl for disinfection and distribution system residual. The chemical feed systems will be located within a depressed storage area providing greater than 110 percent secondary containment. Space has been provided for a future phosphate system in the event there are changes in groundwater quality.

The pumping station has been designed with an on-site emergency generator located immediately southeast of the WPS building.

1.4 BOOSTER PUMP STATIONS

The Division's water system contains four BPSs that pump water from low pressure zones to high pressure zones. A summary of the BPSs is provided in Table 1-14 and a description of each is provided below. The Cedarville and Nook Road BPSs each contain a valve to allow for a controlled release of water from the high pressure zone to the low pressure zone.

Table 1-14 - Booster Pump Stations

Station Name	Year Constructed/ Rehabilitated	Number of Pumps	Design Flow (gpm)	Operational Capacity (gpm)	Low Pressure Zone	High Pressure Zone
Deep Water	2004	2	900 (per pump) 1,200 (both pumps)	1,760 (both pumps)	Plymouth Center	West Plymouth
Nook Road	2002	2	1,200 (per pump)	1,510 (both pumps) 500 (PRV)	Plymouth Center	Bradford
Pine Hills	1970	2	300 (per pump)	500 (both pumps)	Plymouth Center	Pine Hills
Cedarville	1983	2	350 (per pump)	820 (both pumps) 400 (PRV)	Manomet	Cedarville

1.4.1 Deep Water Booster Pump Station

The Deep Water BPS was rehabilitated in 2004 and is located at 122 Billington Street. The BPS pumps water from the Plymouth Center Pressure Zone to the West Plymouth Pressure Zone. The BPS contains two split-case centrifugal pumps in a parallel arrangement each designed for a flow rate of 900 gpm. Currently, the operational capacity of the BPS is approximately 1,760 gpm (2.54 MGD) with both pumps in operation. The station is outfitted with a surge anticipation valve that dissipates excessive pressures back to the Plymouth Center Pressure Zone to protect the West Plymouth distribution piping. Water enters the West Plymouth Pressure Zone via a 12-inch main.

The start/stop operation of the pumps are primarily controlled by the water level in the Harrington Standpipe, though control via the water level in either the Samoset Street Standpipe or the North Plymouth Tank are options in SCADA.

The BPS has an on-site emergency generator that is powered by diesel fuel, which is stored on-site. A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

Recommended upgrades to the Deep Water BPS are summarized in Table 1-15.

Table 1-15 - Recommended Deep Water BPS Upgrades

Upgrade Category	Recommendation
Architectural	None
Mechanical	None
Instrumentation	None
Site	None
Electrical	• Install intrusion alarm system • Replace receptacles with GFCI receptacles • Bond water piping • Install security cameras and motion sensors • Install power and control wiring and conduit for new instrumentation • Install man-down alarm switch • Repair station alarms • Improve station lighting

1.4.2 Nook Road Booster Pump Station

The Nook Road BPS was constructed in 2002 and is located at 45 Nook Road. The facility can pump water from the Plymouth Center Pressure Zone to the Bradford Pressure Zone. The station contains two split-case centrifugal pumps in a parallel arrangement each designed for a flow rate of 1,200 gpm. The maximum operational capacity of the BPS is approximately 1,520 gpm (2.18 MGD) with both pumps in operation. The BPS is outfitted with a control valve that allows for up to 500 gpm (0.72 MGD) of water flow from the Bradford Pressure Zone into the Plymouth Center Pressure Zone. The Division typically operates the valve, and the pumps are utilized only to supplement the Bradford WTP as needed.

The start/stop operation of the pumps are controlled by the water level in the Stafford Street Standpipe. The pumps do not operate during high demand months (June, July, and August) due to a storage/supply deficit in the Plymouth Center Pressure Zone (refer to Chapter 6).

The BPS has an on-site emergency generator located inside the pumping station. The generator is powered by propane, which is stored on-site in an exterior tank. The station has an 8-foot high perimeter fence that is topped with barbed wire. There are no exterior motion sensing lights or security cameras, nor is there an intrusion alarm system.

A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

Recommended upgrades to the Nook Road BPS are summarized in Table 1-16.

Table 1-16 - Recommended Nook Road BPS Upgrades

Upgrade Category	Recommendation
Architectural	None
Mechanical	None
Instrumentation	• Install pressure transmitter • Install station flood switch • Reprogram station PLC and SCADA system to include new instruments
Site	None
Electrical	• Demolish obsolete equipment • Replace receptacles with GFCI receptacles • Bond water piping • Install security cameras and motion sensors • Provide lockout tags • Install power and control wiring and conduit for new instrumentation

1.4.3 Pine Hills Booster Pump Station

The Pine Hills BPS was constructed in 1970 and is located at 238 Warren Avenue. The facility pumps water from the Plymouth Center Pressure Zone to the Pine Hills Pressure Zone for which it is the sole water supply. The BPS contains two split-case centrifugal pumps in a parallel arrangement each designed for a flow rate of 300 gpm. The maximum operational capacity of the station is approximately 510 gpm (0.74 MGD) with both pumps in operation; however, the station does not have a flow meter.

The start/stop operation of the pumps are controlled by the water level in the North Pine Hills Tank. If the North Pine Hills Tank water level is unavailable, the pumps can be operated based on discharge pressure. Because there are no water supplies in the Pine Hills Pressure Zone, the Pine Hills BPS is the sole source of water and a critical facility.

The BPS has an on-site emergency generator that is powered by propane gas, which is stored on-site. The station does not have a perimeter fence or exterior motion sensing lights or security cameras, nor is there a functioning intrusion alarm system. A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

Recommended upgrades to the Pine Hills BPS are summarized in Table 1-17.

Table 1-17 - Recommended Pine Hills BPS Upgrades

Upgrade Category	Recommendation
Architectural	None
Mechanical	• Replace existing booster pumps • Replace existing flow meters • Install pressure gauges • Calibrate thermostat • Install indoor sample tap • Install vent screens
Instrumentation	• Install thermostat switch • Reprogram station PLC and SCADA system to include new instruments
Site	• Install perimeter fence
Electrical	• Demolish obsolete equipment • Install GFCI receptacle • Bond water piping • Install security system • Install security cameras and motion sensors • Upgrade existing electrical service • Provide lockout tags • Install power and control wiring and conduit for new instrumentation • Improve station lighting

1.4.4 Cedarville Booster Pump Station

The Cedarville BPS was constructed in 1983 and is located at 1649 State Road. The facility pumps water from the Manomet Pressure Zone to the Cedarville Pressure Zone. The station contains two split-case centrifugal pumps in a parallel arrangement that are designed for a flow rate of 350 gpm each. The Division recently indicated that they are able to move approximately 820 gpm (1.19 MGD) through the station with both pumps in operation. The station is outfitted with a control valve that allows for up to 400 gpm (0.58 MGD) of water flow from the Cedarville Pressure Zone into the Manomet Pressure Zone. The Division primarily operates the control valve rather than the pumps because the Savery Pond WPS typically produces more water than the Cedarville Pressure Zone needs. Water enters the Cedarville Pressure Zone via a 16-inch main and the Manomet Pressure Zone via a 12-inch main.

The start/stop operation of the pumps are controlled by the water level in the Cedarville Tank. The open/close operation of the valve is also controlled by the water level in the South Pine Hills Tank. During high demand months (June, July, and August), the booster pumps do not operate due to a supply deficit in the Manomet Pressure Zone.

The pumping station does not have an on-site emergency generator, but the station is able to accept a portable generator to run the pumps. There is no perimeter fence or exterior motion sensing lights or cameras, nor is there an intrusion alarm system. A review of the FEMA flood zones reveals that the station is not located within any FEMA flood zones.

Recommended upgrades to the Cedarville BPS are summarized in Table 1-18.

Table 1-18 - Recommended Cedarville BPS Upgrades

Upgrade Category	Recommendation
Architectural	• Remove ladder cage • Remove the decommissioned pressure vessel and, if possible, install an egress at this position, eliminating the confined space designation at this station
Mechanical	• Repaint process piping • Replace flow meter
Instrumentation	• Install man-down switch • Install gas sensor • Reprogram station PLC and SCADA system to include new instruments
Site	• Install perimeter fence
Electrical	• Install receptacle and manual transfer switch for portable generator • Install VFD for each booster pump • Demolish obsolete equipment • Replace receptacles with GFCI receptacles • Bond water piping • Provide lockout tags • Install power and control wiring and conduit for new instrumentation

1.5 VALVE CONTROL STATIONS

The Division's water system contains four pressure reducing valve control stations that are capable of permitting water flow from high pressure zones to low pressure zones. A fifth valve control station is currently being constructed as discussed below. A summary of the valve control stations is provided in Table 1-19.

Table 1-19 - Valve Control Stations

Station Name	Valve Size (in)	High Pressure Zone	Low Pressure Zone
Obery Street	10	Bradford	Plymouth Center
Rocky Hill Road	8	Pine Hills	Manomet
Hall Street	8	West Plymouth	Plymouth Center
Summer Street	8	West Plymouth	Plymouth Center
Jordan Road (future)	4	Bradford	Plymouth Center

The old Newfield Street PRV, not listed above, was previously decommissioned and disconnected from the water system altogether. All four of the remaining valve control stations are currently inactive, with Hall Street and Summer Street being deemed inoperable. Each of these facilities is located underground and are all considered confined space.

The PRVs are all Cla-Val valves and are not connected to the SCADA system. Should the Division elect to bring a valve control station back online, the Division should replace the existing vault with an aboveground structure for ease of operation and maintenance.

A new, aboveground Jordan Road Flow Control Valve (FCV) is under construction and expected to be on-line in the spring of 2020. This station was designed in conjunction with the Forges Field Pump Station and Bradford Zone Water Main Expansion Project and will permit flow from the Bradford Pressure Zone to the Plymouth Center Pressure Zone.

1.6 DISTRIBUTION STORAGE FACILITIES

Water storage facilities serve several functions within a water distribution system including system pressure equalization, fire suppression volume, emergency storage, and operational flexibility. The volume of water within a storage tank is immediately available for fire protection and provides flexibility to the Division to perform routine maintenance on its treatment facilities, groundwater wells, and distribution system. The Division's water distribution system is comprised of ten water storage facilities within its six pressure zones. Combined, the storage facilities provide approximately 11 million gallons (MG) of storage. A summary of each tank is provided in Table 1-20 and further discussed below.

Table 1-20 - Distribution Storage Facilities

Pressure Zone	Storage Facility	Year Built	Year of Last Rehab	Construction Material	Diameter (ft)	Tank Heigh t (ft)	Overflow Elevation[1] (ft)	Nominal Capacity (MG)
West Plymouth	Harrington Standpipe	1973	2007	Welded Steel	50	86	295	1.25
	North Plymouth Tank	1980	Unknown	Pre-stressed concrete	70	40	295	1.15
	Samoset Street Standpipe	1964	2015	Steel	36	68.5	295	0.52
Plymouth Center	Chiltonville Standpipe	1957	2004	Welded Steel	53	61.5	187	1.00
	Lout Pond Tank	1957	1997	Welded Steel	68	37.5	187	1.00
Bradford	Stafford Street Standpipe	1972	2020	Welded Steel	50	108	250	1.50
Pine Hills	North Pine Hills Tank	1971	2013	Welded Steel	79	28	300	1.00
Manomet	South Pine Hills Tank	1975	Unknown	Pre-stressed concrete	65	40	187	1.00
	Indian Hill Tank	1964	1997	Welded Steel	65.5	40	187	1.00
Cedarville	Cedarville Tank	1995	2011	Welded Steel	66	65	272	1.65
							Total Storage	**11.07**

1. Elevations based on National Geodetic Vertical Datum of 1929 (NGVD29)

Inspections of the Division's storage facilities are completed annually, with recent inspections by Haley and Ward, Underwater Solutions, Inc (UWS), and Utility Service Group (USG). In addition, Haley and Ward completed a *Water Storage Tank Asset Management Schedule* in 2019 which includes a record of storage tank dimensions, year constructed, and date last inspected/repaired/rehabilitated. The inspection reports and asset management schedule were used as a basis for the evaluation of existing tank conditions and for the recommendations provided below.

In addition to the inspection reports, the Division operations staff noted that none of the storage facilities currently have an automatic transfer switch (ATS) or emergency power generator. An ATS and generator should be installed on-site at all storage tank sites to provide emergency power for the tank telemetry and ensure a continuity of operations during a power outage. The six controlling tank sites should be prioritized prior to the remaining tank sites.

1.6.1 Harrington Standpipe

The Harrington Standpipe is a 1.25 million gallon welded steel cylindrical standpipe with an umbrella roof constructed in 1973. The tank is located on 36 Lantern Lane and is 50 feet in diameter and 86 feet tall. It has an overflow elevation of 295 feet (NGVD29) and is connected to the West Plymouth Pressure Zone with an 8-inch diameter water main that acts as a combined entry/discharge point.

The tank is accessed via a private residence, with the 8-inch overflow pipe oriented to discharge into a drainage structure with a capacity of 250,000 gallons. Under normal operating conditions to prevent tank overflows and to avoid damage to private property, the Harrington Standpipe is the primary controlling tank in the West Plymouth Pressure Zone. Additionally, the property includes a quarter million gallon capacity overflow drainage system to protect the nearby properties

According to the 2019 Haley and Ward *Water Storage Tank Asset Management Schedule*, the Harrington Standpipe was last rehabilitated in 2007. The following observations were made in the inspection report:

- The tank has a solid exterior paint pattern, which was reported to be in good condition.
- There is potential plugging in the overflow screen, an open threaded hole in the roof, and another threaded hole with a bolt that is not completely tightened down to the roof plate.
- Other than those few small issues, which should be addressed by the Division, the tank sanitary and security conditions were reported to be satisfactory.

The 2019 Asset Management Schedule recommends the tank be rehabilitated in 2025. However, it is recommended that the Division complete a full engineering inspection to determine whether the tank should be rehabilitated in the next five years. The last full engineering inspection was conducted in 2011.

1.6.2 North Plymouth Tank

The North Plymouth Tank is a 1.15 million gallon pre-stressed concrete cylindrical reservoir constructed in 1980. The tank is located on 93 Armstrong Street and is 70 feet in diameter and 40 feet tall. It has an overflow elevation of 295 feet (NGVD29) and is connected to the West Plymouth Pressure Zone with a 12-inch diameter water main that acts as a combined entry/discharge point. Under normal operating conditions, the North Plymouth Tank is a secondary tank in the West Plymouth Pressure Zone.

The tank was last inspected by Haley and Ward in December 2018. The following observations were made in the inspection report:

- Good sanitary conditions, though the finial screen was noted to be in poor condition and in need of replacement.
- Tank security was reported to be satisfactory, despite old graffiti located on the lower portion of the wall.
- Tank exterior is protected by a shotcrete coating that was applied to the roof and walls.

- The inspection report indicated areas of the roof where the shotcrete is delaminating and exposing the concrete underneath.
- The shotcrete coating on the exterior walls is cracked in numerous locations, some of which may be caused by leakage from the interior of the tank.

- No observed rust staining of the concrete by the rebar.

The tank was last recoated in 2012 and it is not known whether it has ever been fully rehabilitated. While the tank is in mostly good condition, the Division should spot repair both the roof and wall cover. Given the age of the tank and its largely unknown history, a full engineering tank inspection should be completed. In particular, the Division should conduct maintenance inspections on the inside of this concrete tank.

The Division operations staff noted that the access road to the tank is in poor condition; this road should be rebuilt and paved to improve access to the site, particularly in the event of an emergency.

1.6.3 Samoset Street Standpipe

The Samoset Street Standpipe is a 0.52 million gallon steel cylindrical standpipe with an umbrella roof constructed in 1964. The tank is located off Samoset Street across from Pilgrim Trail and is 36 feet in diameter and 68.5 feet tall. It has an overflow elevation of 295 feet (NGVD29) and is connected to the West Plymouth Pressure Zone via an 8-inch diameter water main that acts as a combined entry/discharge point. Under normal operating conditions, the Samoset Street Standpipe is a secondary tank in the West Plymouth Pressure Zone and is outfitted with an altitude valve. The valve is set to close when the water level in the tank reaches approximately 292 feet (NGVD29).

A one-year warranty inspection of the tank was completed by the USG in 2016. The following observations were made in the inspection report:

- The tank has a solid exterior paint pattern, which appears to be in excellent condition.
- The finial vent vacuum pallet appears to be undersized and consideration should be given to replacing it. The rest of the finial vent assembly was noted to be in good condition.
- The flexible cable fall device is loosely connected and improperly positioned with only one cable guide.
- Some rust staining was observed on the bottom of the floor plate extension and rusting along the bottom of the overflow pipe bolting flange assembly.
- Some delamination of the finish coat was noted along the junction of the floor plate and the foundation.

The Division reports that the Samoset Street Standpipe was last rehabilitated in 2015. Going forward, the Division should replace the existing finial vent vacuum pallet with an appropriately-sized pallet.

1.6.4 Chiltonville Standpipe

The Chiltonville Standpipe is a 1.0 million gallon welded steel cylindrical standpipe with an umbrella roof constructed in 1957. The tank is located at 363 Sandwich Street in Plymouth and is 53 feet in diameter and 61.5 feet tall. It has an overflow elevation of 187 feet (NGVD29) and is connected to the Plymouth Center Pressure Zone with a 12-inch diameter water main that acts as a combined entry/discharge point. Under normal operating conditions, the Chiltonville Standpipe is the primary controlling tank in the Plymouth Center Pressure Zone.

The tank was last inspected by Haley and Ward in December 2018, which consisted of an exterior inspection only. The following observations were made in the inspection report:

- The finial vent assembly is in very good condition and is outfitted with a weather skirt that prevents the entry of wind-driven precipitation.
- The overflow box cover, while weather tight and locked, is in poor condition with corrosion and a hole present.
- The overflow discharge piping and screen are in good condition, but showing signs of corrosion on the flange.
- The ladder is outfitted with a security cover that is in good condition, but the ladder does not have a safety climbing system.
- The tank is surrounded by an 8-foot high chain link fence. The fence gate and access road gate are locked.

The tank was last fully rehabilitated in 2004 and a spot repair was completed in 2013.

A full engineering tank inspection should be completed, as the last full inspection was completed in 2011. As recommended in the 2018 tank inspection report, the overflow box should be replaced with a box that has a cone-shaped bottom and a safety climbing system should be installed on the tank ladder to improve safety.

The Division operations staff noted that the Chiltonville Tank does not currently have an ATS or emergency power generator. Because it is the controlling tank within the Plymouth Center Pressure Zone, an ATS and generator should be installed on-site to provide emergency power for the tank telemetry and ensure a continuity of operations during a power outage.

According to operations staff, the access road to the tank is dirt and in poor condition and should be rebuilt and paved to improve access to the site.

1.6.5 Lout Pond Tank

The Lout Pond Tank is a 1.0 million gallon welded steel cylindrical reservoir with an umbrella roof constructed in 1957. The tank is located at 262 Billington Street and is 68 feet in diameter and 37.5 feet tall. It has an overflow elevation of 187 feet (NGDV1929) and is connected to the Plymouth Center Pressure Zone with a 16-inch diameter water main that acts as a combined entry/discharge point. Under normal operating conditions, the Lout Pond Tank is a secondary tank in the Plymouth Center Pressure Zone and is outfitted with an altitude valve. The valve is set to close when the water level in the tank reaches 185.7 feet elevation.

The tank was last inspected by Haley and Ward in October 2015, which consisted of an exterior inspection only. The following observations were made in the inspection report:

- The tank finial vent assembly, hatches, rigging holes, and overflow box and outlet are in good condition.
- All of the roof hatches, ladder cover, fence gate, and access roadway gate are locked.
- The tank is surrounded by a 7-foot high chain link fence with barbed wire that is in mostly good condition, with the exception of a couple of areas where the top rail and barbed wire have been damaged.
- The exterior coating on the roof is in mostly good condition, though there are large areas where the protective coating appears to have worn thin and the steel underneath has started to corrode.
- There are smaller areas where the substrate steel is exposed and exhibits surficial corrosion, including areas on the roof adjacent to some of the rigging holes.
- The foundation was reported to be in good condition, as well.
- The tank was last fully rehabilitated in 1997 and a spot repair was completed in 2012.

It is recommended that any repairs or possible rehabilitation work on the Lout Pond Tank be coordinated with the Bradford and Plymouth Center Pressure Zone boundary adjustment project (refer to Chapter 9).

1.6.6 Stafford Street Standpipe

The Stafford Street Standpipe is a 1.5 million gallon welded steel cylindrical reservoir with an umbrella roof constructed in 1972. The tank is located in a residential area near 60 Stafford Street in Plymouth and is 50 feet in diameter and 108 feet tall. It has an overflow elevation of 250 feet (NGVD29) and is connected to the Bradford Pressure Zone with a 16-inch diameter water main that acts as a combined entry/discharge point. The Stafford Street Standpipe the sole storage tank in the Bradford Pressure Zone, and is therefore the primary controlling tank.

The tank was last inspected by Haley and Ward in December 2018, which consisted of an exterior inspection only. The following observations were made in the inspection report:

- The finial vent assembly is in mostly good condition, though the screen is in poor condition and a small opening was noted.
- The overflow pipe is fitted with a duck bill check valve that discharges to an underground pipe via an air gap. The underground pipe redirects overflow water away from the tank base.
- The shell ladder is not outfitted with a security cover and has a notched rail type safety climb system with a cage. This type of safety climbing system is no longer considered safe and is not recommended for use.

The exterior of the tank was last fully rehabilitated in 1989 (Haley and Ward, Water Storage Tank Asset Management Schedule, 2019), and it does not appear the inside of the tank has been rehabilitated. The last full engineering inspection of the tank was completed in 2015 by UWS.

This tank is scheduled to be rehabilitated during the fall of 2019 and completed in spring of 2020. The scope includes a complete restoration of the interior and exterior of the tank; installation of a mixing system; and upgrades to hatches, manways, safety rails, etc. to ensure compliance with latest Occupational Safety and Health Administration (OSHA) requirements.

1.6.7 North Pine Hills Tank

The North Pine Hills Tank is a 1.0 million gallon welded steel cylindrical reservoir with an ellipsoidal roof constructed in 1971. The tank is located at 199 State Road in Plymouth and is 79 feet in diameter and 28 feet tall. It has an overflow elevation of 300 feet (NGVD29) and is connected to the Pine Hills Pressure Zone with a 12-inch diameter water main that acts as a combined entry/discharge point. The North Pine Hills Tank is the sole storage tank in the Pine Hills Pressure Zone, and is therefore the primary controlling tank. The tank level is used to control the Pine Hills BPS, which supplies the only source of water for the pressure zone.

A one-year warranty inspection of the tank was completed by USG in 2016. The USG report did not identify any serious deficiencies with the tank.

The Division operations staff noted that the North Pine Hills Tank does not currently have an ATS or emergency power generator. Because it is the controlling tank within the Pine Hills Pressure Zone, an ATS and generator should be installed on-site to provide emergency power for the tank telemetry and ensure a continuity of operations during a power outage.

1.6.8 South Pine Hills Tank

The South Pine Hills Tank is a 1.0 million gallon pre-stressed concrete cylindrical reservoir with a flat roof constructed in 1975. The tank is located at 378 State Road in Plymouth and is 65 feet in diameter and 40 feet tall. It has an overflow elevation of 187 feet (NGVD29) and is connected to the Manomet Pressure Zone with a 12-inch diameter water main that acts as a combined entry/discharge point. Under normal operating conditions, the South Pine Hills Tank is the primary controlling tank in the Manomet Pressure Zone.

The tank was last inspected by Haley and Ward in December 2018, which consisted of an exterior inspection only. The following observations were made in the inspection report:

- The finial vent assembly was reported to be in good condition, but with a large hole in the vent screen.
  - Following the inspection, a patch was installed over the screen opening to prevent birds or insects from entering the tank.
- The overflow discharges through a headwall and is outfitted with a screen that is in good condition.
- There is no fence around the tank and the only access security measure is a locked gate on the access road.
- There is no exterior ladder on the tank.
- The roof is coated with shotcrete to protect the substrate concrete and rebar. There are a few small areas where it was reported that the shotcrete has delaminated, but sounding tests were performed over the roof area that indicated the coating was well adhered to the substrate concrete.

- There is some cracking noted on the tank walls, particularly on the portion facing State Road. Some of the cracks indicate that there may be slight leaking from the inside of the tank. The tank manway coating has failed and significant corrosion and metal loss is evident.

Given the age of the tank and the fact that it may have never been rehabilitated, the Division should contract a pre-stressed concrete tank company to conduct a full inspection of the South Pine Hills Tank. In particular, the Division should conduct maintenance inspections on the inside of this concrete tank. Once the inspection has been completed, it is recommended that the Division repair the tank to the extent necessary and potentially recoat the interior and exterior.

1.6.9 Indian Hill Tank

The Indian Hill Tank is a 1.0 million gallon welded steel cylindrical reservoir with an umbrella roof constructed in 1964. The tank is located at the northern end of Shore Drive and is 65.5 feet in diameter and 40 feet tall. It has an overflow elevation of 187 feet (NGVD29) and is connected to the Manomet Pressure Zone with a 12-inch diameter water main that acts as a combined entry/discharge point. Under normal operating conditions, the Indian Hill Tank is a secondary tank in the Manomet Pressure Zone and is outfitted with an altitude valve. The valve is set to close when the water level in the tank reaches 185.1 feet (NGVD29). The closure of this valve causes a pressure spike in the southern portion of the Manomet Pressure Zone if the Ellisville WPS, Ship Pond WPS, or the valve at the Cedarville BPS are providing water to fill the South Pine Hills Tank.

The last full engineering inspection of the tank was completed in September 2015 by UWS. The following observations were made in the inspection report:

- Ruptured coating blisters on in interior walls and floors were identified
- There are small areas of damaged coating on the exterior of the tank caused by objects impacting the tank, and mildew and graffiti accumulation on the bottom exterior of the tank.
- No sanitary, security, or safety issues were identified in the 2015 engineering inspection.
- As a part of the interior inspection, accumulated precipitate was removed from the floor (approximately 1/16” depth).

Based on the reported observations of the interior and exterior coating systems and given that the tank was last rehabilitated in 1997, the Division should rehabilitate the Indian Hill Tank.

The easement for the Indian Hill Tank is small and does not provide much room for the fence. The vegetation surrounding the tank is constantly encroaching. As a result, access to the tank is challenging and the Division should seek to routinely clear and grub the easement.

Additionally, the Division has reported difficulty accessing the Indian Hill Altitude Valve. EP Recommends the Division further investigate the nature of the existing limitation and consider retrofitting or replacing the valve vault to increase accessibility.

1.6.10 Cedarville Tank

The Cedarville Tank is a 1.65 million gallon welded steel cylindrical reservoir with an umbrella roof constructed in 1995. The tank located on 20 Buckskin Path and is 66 feet in diameter and 65 feet tall. It has an overflow elevation of 272 feet (NGVD29) and is connected to the Cedarville Pressure Zone with a 16-inch diameter water main that acts as a combined entry/discharge point. The Cedarville Tank is the sole storage tank in the Cedarville Pressure Zone, and is therefore the primary controlling tank.

The tank was last inspected by Haley and Ward in December 2018, which consisted of an exterior inspection only. The following observations were made in the inspection report:

- There are a few small areas around the exterior of the tank that are exhibiting some corrosion.
- Rust was also observed on the top of the finial collar and the welds at the handrail posts to the roof plates.

The Division should complete a coating spot repair of the areas of the tank exhibiting signs of corrosion and coating loss. This will prevent future metal loss of the substrate steel and prolong the life of the tank.

The Division operations staff noted that the Cedarville Tank does not currently have an ATS or emergency power generator. Because it is the controlling tank within the Cedarville Pressure Zone, an ATS and generator should be installed on-site to provide emergency power for the tank telemetry and ensure a continuity of operations during a power outage.

1.7 DISTRIBUTION SYSTEM PIPING

The Division's water distribution system consists of approximately 237 miles of water main ranging from 2-inch to 20-inch, as summarized in Table 1-21 below. The general extent of the water mains is shown on . The water system is generally well looped though there are multiple dead-end mains throughout the system. The Division should consider eliminating dead-end mains should the opportunity arise following hydraulic analyses to confirm the appropriate design.

Table 1-21 - Distribution System Piping by Diameter

Diameter	Length		
(in)	(ft)	(mi)	Percent
2-4	4,418	0.84	0.4%
6	96,454	18.3	7.7%
8	730,232	138	58.2%
10	93,165	17.6	7.4%
12	262,504	49.7	20.9%
16	66,696	12.6	5.3%
20	1,460	0.28	0.1%

Diameter (in)	Length		Percent
	(ft)	(mi)	
Total	1,254,929	237	100%

The primary transmission mains serving the system in the Northern Pressure Zones include a 16-inch transmission main in the Plymouth Center Pressure Zone from the South Pond Wells through the downtown area to North Plymouth. This 16-inch main is connected to a 12-inch on Sandwich Street that connects to the Chiltonville Tank, as well as a 12-inch main on Warren Avenue that connects to the Pine Hills BPS. There is a 12-inch water main that runs through the Bradford Pressure Zone from the Lout Pond Tank that was installed to help fill the Chiltonville Tank. In the Bradford Pressure Zone, there is a 16-inch main from the Bradford WTP to the Stafford Tank and the Nook Road BPS. In West Plymouth, the primary main is a 12-inch main that runs along Carver Road from the western edge of the water system to the Plymouth Center Pressure Zone. This main interconnects the Darby Pond WPS, Federal Furnace WPS, Deep Water BPS, Harrington Tank, and Samoset Street Standpipe. In the Pine Hills Pressure Zone, there is a 12-inch main that runs along State Road (Route 3A) from the Pine Hills BPS to the North Pine Hills Tank.

In the eastern region, a 16-inch main runs from the Savery Pond WPS to the Cedarville BPS and the Cedarville Tank, connecting the Cedarville and Manomet Pressure Zones. In the Manomet Pressure Zone, a 12-inch main runs south to north from the Cedarville BPS along State Road (Route 3A) to the Ellisville WPS, Ship Pond WPS, and the Indian Hill Tank. The main downsizes to 10-inch and runs to Wannos WPS and the parallel 12-inch and 6-inch mains that connect to the South Pine Hills Tank. The Division historically has difficulty moving water to the South Pine Hills Tank in north Manomet.

A summary of the distribution of water main materials is provided in Table 1-22 and a map of the distribution piping by material is provided in Figure 1-2.

Table 1-22 - Distribution System Piping by Material Type

Material	Length		Percent
	(ft)	(mi)	
Ductile Iron	458,634	86.9	36.5%
Cast Iron	325,371	61.6	25.9%
Asbestos Cement	314,094	59.5	25.0%
PVC	134,181	25.4	10.7%
Unknown	21,663	4.1	1.7%
Jacket	798	0.2	0.1%
Galvanized	188	0.04	0.01%
Total	1,254,929	237	100%

The Division has been working to replace asbestos cement and jacket piping throughout the water system. Most recently, in 2014 the Division completed a jacket water main project to eliminate the majority of the remaining jacket pipe. A majority of the asbestos cement piping is reported to be vinyl-lined. Vinyl-lined asbestos cement (VLAC) pipe is a source of tetrachloroethylene (PCE), a chemical that has been shown to be detrimental to public health when ingested or inhaled. Leaching of PCE from VLAC pipe to drinking water is therefore a public health concern and funds should continue to be set aside annually to replace these pipes. It should be noted that the Division's use of bleeders minimizes the risk of PCE leaching as the bleeders allow for water in the distribution system to keep moving in the areas where they are used.

Approximately one quarter of the distribution system piping is cast iron (CI). In many water systems, CI pipes have reduced hydraulic capacity due to tuberculation and age; however, based on reports of clean pipe coupons and hydraulic model calibration results, most CI in the Division's distribution system is believed to be in good condition. There is a total of about 12 miles of CI pipe in the water system with roughness coefficients (C-values) of less than 100. Refer to Chapter 9 for the extent of the recommended replacement of this pipe.

Ductile iron pipe represents the largest portion of the distribution system at more than 1/3 of all water mains. Upon reviewing information provided by the Division, it appears that ductile iron pipe is the current standard for all new main construction and has been since late 1970s/early 1980s.

Environmental Partners (EP) reviewed the distribution system for parallel mains and determined that they are only used when two neighboring pressure zones are present, with the exception of 2,500 feet of 12-inch ductile-iron water main installed alongside the existing 8-inch ductile-iron water main on Camelot Drive in 2019 as part of the Bradford Pressure Zone Expansion project.

The Division has an existing flushing plan and currently flushes two pressure zones each year. The Division has noted issues with finding and operating gate valves. These problems can be primarily attributed to inadequate records and a lack of a valve exercising program. In order to improve the performance of the distribution system, the following improvements are recommended:

- Test and locate all valves and hydrants with a geographic position system (GPS);
- Develop valve and hydrant exercising plans that utilize a GIS-based asset management system;
- Purchase a motorized valve exerciser to speed up valve exercising operations; and
- Update the existing flushing plan to a unidirectional flushing program utilizing the updated water system hydraulic model and increase annual flushing to include 100 percent of the water system.

1.8 SCADA SYSTEM

The Division utilizes a SCADA system to control and monitor all well supplies, storage tanks, and booster pump stations from a central computer located in the Water Division Office. The SCADA system has three main functions: data communication; data acquisition and presentation; and equipment automation and remote control as described below.

1.8.1 Data Communication

The remote sites communicate via radio to the central SCADA computer located in the Water Division Office. It should be noted that the Division's current Teledesign Systems radios are no longer supported and will need to be upgraded in the future. The Division is currently working to provide short and long-term solutions to ensure radio connectivity.

At the central SCADA computer, Division personnel are able to remotely view water system parameters at each of the sites (e.g. water level, pressure, flow, water quality, pump run status, etc.). The SCADA system includes alarming software that alerts personnel of fault conditions in the system. The Division is able to diagnose the problem remotely, determine the urgency of the fault, and direct suitably qualified staff to correct the issue. This allows the Division to more efficiently operate the water system.

1.8.2 Data Acquisition and Presentation

The Division utilizes an up-to-date central computer to store all data in a database that is accessible by Division personnel. This historical data has a number of uses:

- Troubleshoot and improve system performance and operational efficiency;
- Complete state-mandated reporting;
- Monitor equipment operations to forecast maintenance, repair, and replacement;
- Identify leaks and variations from normal system operations; and,
- Verify and update hydraulic water models.

Real-time data is presented in the SCADA system in a user-friendly manner. Personnel are able to navigate to separate screens for each of the remote sites, which display various real-time water system parameters.

The Division is also able to use the SCADA software to view historical data trendlines that allows them to overlay multiple monitored parameters through the system over a period. This function is typically used for troubleshooting. The Division is able to review trended, historical data for at least more than one year, though they have not found the limit of available data.

1.8.3 Equipment Automation and Remote Control

The SCADA system uses real-time data throughout the water system to automate equipment. In general, the well supplies and booster pump stations are turned on and off by water level in the primary tanks within each corresponding pressure zone. In the event that the operations staff need to make changes to automatic operations, they are able to adjust operational set-points from the central SCADA system as well as at the facilities themselves.

1.8.4 SCADA Recommendations

The Division continues to work diligently to improve the robustness and reliability of the SCADA system. Currently, the Division is working with to replace programmable logic controllers (PLCs) and operator interface terminals (OITs) throughout the system to ensure the system remains modern and functional.

The Division staff noted a few systemic issues throughout the SCADA system, as listed below:

- The SCADA software is not currently set up to automate daily reports. The Division is currently working to implement this functionality, which will include installing level sensors the chemical day tanks at each of the well sites and associate programming.
- Trend screens provide too much information and it is difficult to tell various trends apart. It is not clear whether the current SCADA system allows for trend lines to be toggled, but it is not simple to do.
- The time delays for various alarms need to be adjusted, but they are not easily changed and are currently inadequate.
- The Division has replaced the radio systems at a few facilities. The remaining facilities should be upgraded as needed.

The Division is currently performing an audit of the existing SCADA and communications systems. It is recommended that the Division perform another holistic audit of the SCADA system in another 10 years.

Chapter 2 – Source Water Protection Areas

2.1 SOURCE WATER ASSESSMENT AND PROTECTION PROGRAM

The Federal Safe Drinking Water Act (SDWA) Amendments of 1996 included measures to protect drinking water sources from contamination and required states to develop a Source Water Assessment and Protection (SWAP) program. As part of the Massachusetts SWAP program, which was completed in 2004, Zone I, II, and III protection areas were defined for groundwater supplies.

- Zone I is the protecting area closest to the well and is typically a 400-foot radius, unless the well has an approved yield less than 0.1 MGD. According to the SWAP program, Zone I should be owned or controlled by the water supplier and limited to water supply activities.
- Zone II is the primary recharge area for the well and is defined by hydrogeologic studies that are approved by MassDEP. The Zone II areas for the Northern and Eastern Pressure Zones are shown on Figure 2-1 and 2-2, respectively.
- Zone III is the area of contribution to the well.

The Division completed a SWAP Report in July 2003. The 2003 SWAP Report includes an assessment of the land use in Zones I and II for twelve of the Division's thirteen ground water supply wells, not including the Forges Field Well. The SWAP Report identifies sources of contamination common to all areas in the Division lands, including residential fuel oil storage; lawn car and gardening; septic systems and cesspools; aquatic wildlife; fishing and boating; and stormwater drains and retention basins. The Division's SWAP Report also provides recommendations to focus protection efforts on best management practices and drinking water protection measures in the Zone I and Zone II areas.

2.2 PLYMOUTH WATER DIVISION ZONE I AND II

This section summarizes the results and recommendations of the Division's SWAP Report and changes in land use since from the time of the report, 2003, to 2018. In order to assess changes in potential sources of contamination since 2003 in each of the protection areas, orthoimagery obtained from Massachusetts Geographic Information System (MassGIS) from 2001 and 2018 was compared and significant land use changes noted. Additionally, the National Land Cover Database, which uses aerial imagery to identify land cover and publishes a dataset comparing land cover changes from 2001 to 2016, was reviewed for each water supply protection area. The Zone II areas for the Northern and Eastern Pressure Zones are shown on Figure 2-1 and 2-2, respectively.

2.2.1 Federal Furnace Well

The Federal Furnace Well is located off Federal Furnace Road. The SWAP Report identifies the Federal Furnace Well as having moderate susceptibility to contamination. The Zone I is located on a town-owned land parcel. The Federal Furnace Well Zone II includes forest, camping and outdoor recreational areas, open water, wetlands and residential areas. Minimal land use change was observed in the Federal Furnace Well Zone II when comparing 2001 and 2018 orthoimagery.

Additionally, the Plymouth Municipal Airport is located adjacent to the Zone II area for the Federal Furnace Well and could be a potential source for per- and polyfluoroalkyl substances (PFAS). PFAS sampling and regulations are discussed in Chapter 3.

2.2.2 North Plymouth Well

The North Plymouth Well is located off Industrial Park Road and Armstrong Road near the Plymouth Water Division's border with the Town of Kingston. The 2003 SWAP Report identifies the North Plymouth Well as having a high susceptibility to contamination. The Zone I is located on a town-owned land parcel. In the Zone II, potential sources of contamination identified in the SWAP Report included medical facilities; printer and blueprint shops; sand and gravel mining and washing; asphalt, coal tar and concrete plants; and industry/industrial parks.

There has been significant change in the land use within the Zone II protection area for the North Plymouth Well since the SWAP Report in 2003 with an increase in industrial and commercial land use including the development of a Walmart, numerous commercial facilities, and associated parking. The development of Route 44 and an interchange with Commerce Way was constructed since the last assessment as well as increased development at the industrial park and residential areas.

Following this development in the North Plymouth Zone II, the Division observed increased chloride levels at the North Plymouth Well. An assessment of the water quality was completed by EP in 2014. According to the assessment, the impervious area within the Zone II increased by over 300 percent from 1997 to 2013 making the North Plymouth Well Zone II over 65 percent impervious at the time. Water quality data from 1979 to 2014 was analyzed and the topographic contours were used to understand the runoff and stormwater conveyance in the area. The water quality data showed large increases observed in concentrations of chloride, hardness, sodium and conductivity beginning in 2003 suggesting salts (sodium chloride) in and around the North Plymouth Well Zone II area having an effect on the ground water quality.

The water quality assessment recommended requesting a "Reduced Salt Area" designation of the nearby Route 44 and further investigating stormwater runoff and the allowable discharges within the Zone II area of the North Plymouth Well. The Division has not been able to receive a "Reduced Salt Area" designation for Route 44 through the Massachusetts Department of Transportation (MassDOT) but continues to meet with property owners in the North Plymouth Well Zone II area to implement stormwater best management practices.

2.2.3 Darby Pond Well

The Darby Pond Well is located off Darby Station Road. The 2003 SWAP Report identifies the Darby Pond Well as having high susceptibility to contamination. Although only water supply related activities are allowed in the Zone I, the development of some well fields for water supply occurred prior to MassDEP source water projection regulations. The 2003 SWAP Report also identified cranberry bogs located in the Zone I of the Darby Pond Well. The Division recently acquired the property located within the Zone I of the Darby Pond Well, a former cranberry bog no longer in operation.

The Darby Pond Well Zone II includes forested areas, cranberry bogs, open water, wetlands and residential areas. The potential sources of contamination include pesticide and fertilizer storage or use, electric transmission rights-of-way, industry/industrial parks and potential sources of contamination common to all Zone II areas in the Division's water system. Comparing 2001 and 2018 orthoimagery, minor changes to land use were observed in the Darby Pond Well Zone II protection area. Additional cranberry bog properties remain located within the Zone II of the Darby Pond Well. The removal of cranberry farming from the Zone II will further protect water quality. The Division should work to acquire all active cranberry bog farming properties within the Zone II of the Darby Pond Well water supply to minimize pond level drawdown.

2.2.4 South Pond Wells No. 1 and No. 2

The South Pond Wells No. 1 and No. 2 are located off Rocky Pond Road. The 2003 SWAP Report identifies the South Pond Well No. 1 and No. 2 as having a high susceptibility to contamination. The Zone I is located on town-owned land. The South Pond Well No. 1 and No. 2 Zone II is primarily forested with a small area of cranberry bogs, residential area and wetlands. The potential sources of contamination include pesticide and fertilizer storage and use, and other sources common to all the Zone II areas in the Division. Minimal land use change was observed in the South Pond Wells No. 1 and No. 2 Zone II when comparing 2001 and 2018 orthoimagery. One large residential development of approximately 54 units, Watercourse Place, was recently developed within the Zone II area and should abide by the Town of Plymouth's zoning requirements for construction in an aquifer protection district.

2.2.5 Lout Pond Well

The Lout Pond Well is located off Billington Street and is currently inactive as of April 2018 (refer to Chapter 1). The 2003 SWAP Report identifies the Lout Pond Well as having a high susceptibility to contamination. The Zone I is located on a town-owned land parcel. The Lout Pond Well Zone II is primarily forested with small areas of wetlands, residential areas, and cranberry bogs. The potential sources of contamination include pesticide and fertilizer storage and use and other sources common to all Zone II areas in the Division's water system. Comparing 2001 and 2018 orthoimagery, a mixed-use commercial/residential area, the 40B Development on Home Depot Drive, is currently under development in a portion in the Zone II protection area.

The 40B Development on Home Depot Drive consists of multiple four-story residential buildings, a clubhouse, common recreation space, leasing and management offices, a medical office building, commercial and retail space, a warehouse, and a hotel. The proposed 40B Development should meet the Town of Plymouth's zoning requirements for construction in an aquifer protection district. However, the Division should also consider imposing restrictions on the use of fertilizers, road salt, and other potential contaminants to reduce the potential for source water contamination.

2.2.6 Bradford Wells No. 1 and No. 2

The Bradford Wells No. 1 and No. 2 are located off Cooks Pond Road. The 2003 SWAP Report identifies the Bradford Well as having a high susceptibility to contamination. The Zone I is located on a town-owned land parcel. The Bradford Wells No. 1 and No. 2 Zone II includes primarily forested areas and cranberry bogs with some residential developments, electric transmission right-of-ways, and open water. There is also some commercial and industrial land use areas near, but outside of, the Zone I protection area. The potential sources of contamination include pesticide and fertilizer storage or use, bus washes, services stations/auto repair shops, sand and gravel mining/washing, electric line transmission rights-of-way and potential sources of contamination common to all Zone II areas in the Division's water system. Comparing 2001 and 2018 orthoimagery, some new residential development has occurred within the Zone II as well as additional commercial buildings near the Zone I boundary.

2.2.7 Ellisville Well

The Ellisville Well is located on a long drive off State Road. The 2003 SWAP Report identifies the Ellisville Well as having a high susceptibility to contamination. The Zone I is located on town-owned land. The Ellisville GP Well Zone II is primarily forested with small areas of cranberry bogs, wetlands and residential development. In the Zone II, the potential sources of contamination include pesticide and fertilizer storage and use and other sources common to all Zone II areas in the Division's water system. Comparing 2001 and 2018 orthoimagery, minimal land use change has occurred in the Zone II.

2.2.8 Ship Pond Well

Ship Pond Well is located of Ship Pond Road. The 2003 SWAP Report identifies the Ship Pond Well as having a high susceptibility to contamination. The Zone I is mostly located on town-owned land. However, two privately owned parcels with a single family homes are located in the Zone I. The SWAP Report identifies homes with on-site septic systems located in the Zone I. The Ship Pond Well Zone II is primarily forested with cranberry bogs, and wetlands. In the Zone II, the potential sources of contamination include pesticide and fertilizer storage and use and other sources common to all Zone II areas in the Division's water system. Comparing 2001 and 2018 orthoimagery, minimal land use change has occurred in the Zone II.

2.2.9 Wannos Pond Well

Wannos Pond Well is located off Acacia Road. The 2003 SWAP Report identifies the Wannos Pond Rd as having a high susceptibility to contamination. The Zone I is mostly located on town-owned land. However, portions of two privately owned parcels with a single family homes are located in the Zone II. The SWAP Report identifies homes with on-site septic systems located in the Zone I. The Wannos Pond Well Zone II includes forest, cranberry bogs, open water, wetlands, and residential areas. In the Zone II, the potential sources of contamination include pesticide and fertilizer storage and use and other sources common to all Zone II areas in the Division's water system. Comparing 2001 and 2018 orthoimagery, some new residential development has occurred in the Zone II.

2.2.10 Savery Pond Well

The Savery Pond Well is located off Quail Run. The 2003 SWAP Report identifies the Savery Pond Well as having a moderate susceptibility to contamination. The Zone I is located on a town-owned parcel of land. The Savery Pond Well Zone II is primarily forested with a 1.75 mile stretch of Route 3, open water and small areas wetlands and of residential development. In the Zone II, the potential sources of contamination include sources common to all Zone II areas in the Division's water system. Comparing 2001 and 2018 orthoimagery, minimal land use change has occurred in the Zone II.

2.2.11 Forges Field Well

The Forges Field Well is located off Jordan Road. The Forges Field Well is currently under construction (to come online in 2020) and was not included in the 2003 SWAP Report. The Zone I is located on a town-owned parcel of land. The Forges Field Well Zone II is primarily forested, medium density residential, golf course areas, and participation recreation areas. In the Zone II, the potential sources of contamination include sources common to all Zone II areas in the Division's water system.

2.3 SWAP RECOMMENDATIONS

The 2003 SWAP Report made the following recommendations to improve the Division's source water protection measures:

- When feasible, gain control of Zone Is through ownership or conservation restrictions at the Ship Pond Well and Wannos Pond Well water supplies. Educate residents within Zone Is on best management practices for septic systems, lawn care and hazardous material use and storage.
- Work with neighboring communities (Carver and Kingston) to include Zone IIs in their wellhead protection controls.
- Develop and implement a Wellhead Protection Plan.
- Establish a wellhead protection committee.

The Division has taken steps to acquire cranberry bogs situated in the Zone I of the Darby Pond Well. Additional cranberry bog properties remain located within the Zone II of the Darby Pond Well. The removal of cranberry farming from the Zone II will further protect water quality. The Division should work to acquire all active cranberry bog farming properties within the Zone II of the Darby Pond Well water supply to minimize pond level drawdown.

2.4 PLYMOUTH WATER DIVISION AQUIFER PROTECTION BYLAW

In accordance with 310 CMR (Commonwealth of Massachusetts Regulations) 22.21(2), water suppliers are required to adopt groundwater protection zoning controls. The Plymouth Water Division Zoning Bylaw, Article 5, §206-1 defines an Aquifer Protection District to protect groundwater resources. This district is divided into Areas 1 through 3. Area 1 is the MassDEP approved Zone I; Area 2 is the MassDEP approved Zone IIs and IIIs; and, Area 3 is the area contributing to recreation water bodies. The Town of Plymouth's Zoning Bylaw lists specific land uses that are allowed, prohibited, or requiring a special permit for each area of the Aquifer Protection District. Specifics for each allowed use are detailed in Aquifer Protection District Use Table of the bylaw.

2.5 SOURCE WATER PROTECTION RECOMMENDATIONS

Considering how susceptible the Division's sources are to contamination, it is recommended that a more stringent groundwater protection district be developed. This new district could be defined as the area of an aquifer, or capture zone, which contributes water to a public well under average pumping and recharge conditions that can be realistically anticipated. This district would be more restrictive than the current Area 2 of the Town's Aquifer Protection District to protect lands that directly recharge water to the aquifer that contributes to the well's daily pumping. Hydrogeologic modeling would be required to delineate each groundwater capture zone and then the process to rewrite the Aquifer Protection District bylaw. It is recommended that in conjunction with the development of a groundwater protection district, the existing Aquifer Protection Bylaw be reviewed and updated. An example of this approach can be seen from our work with the Seekonk Water District and Town of Seekonk. The zoning bylaws and zoning map were updated to include these new protection areas. Section 6.4 of the Seekonk Zoning Bylaws currently outline this approach, which can be found on the Zoning Board of Appeals webpage.

The Division should also continue pursuing ownership of the active cranberry bogs situated in the Zone II of the Darby Pond Well. Additionally, it is recommended that the Division further investigate stormwater runoff and the allowable discharges within the Zone II area of the North Plymouth Well and consider implementing measures to protect the Zone II areas of all the Division's water supplies from excessive development.

Chapter 3 – Water Quality Standards

3.1 WATER QUALITY STANDARDS

The Division is currently in compliance with the water quality requirements of 310 CMR 22.00. An overview of several drinking water quality regulations as they relate to the Division's water system is presented below.

3.2 SAFE DRINKING WATER ACT AND AMENDMENTS

The SDWA was passed in 1974 and subsequently amended in 1986 and 1996. The SDWA was enacted to protect public health through regulations developed by the United States Environmental Protection Agency (USEPA) to protect the nation's drinking water and its sources. The USEPA established two sets of standards: national primary drinking water standards, which are enforceable standards of maximum contaminant levels (MCLs); and national secondary drinking water standards, which are established Secondary MCLs (SMCLs). These SMCLs are not enforced by the USEPA, but are provided as guidelines for public water systems to voluntarily monitor their systems for aesthetic qualities such as taste, odor, and color. Iron and manganese are two secondary contaminants that when present in excess of their SMCLs have the potential for contributing to taste, color, and odor complaints. The source water for the following sites are known to exceed SMCLs for iron and manganese:

- Iron (SMCL 0.3 mg/L): Bradford WTP, Lout Pond WPS
- Manganese (SMCL 0.05 mg/L): Bradford WTP, Federal Furnace WPS, Lout Pond WPS

The requirements of the SDWA are applicable to the Division's water system as it meets the definition of a public water supply that provides water to at least fifteen services or serves at least twenty-five people per day for at least sixty days of the year. Therefore, the regulations set forth under the SDWA are applicable to the water system. The requirements of the SDWA and its amendments that apply to the water system are discussed further in the following sections.

3.3 GROUNDWATER TREATMENT RULE AND REVISED TOTAL COLIFORM RULE

The Ground Water Rule (GWR) was promulgated by the USEPA in October 2006 to reduce the risk of exposure to fecal contamination that may be present in public water systems that use ground water sources. The 1996 amendments to the SDWA charged the USEPA with developing regulations requiring disinfection of select ground water systems based upon the results of a risk-targeted strategy that identifies systems at high risk for fecal contamination. The rule requires periodic sanitary surveys of ground water systems, source water monitoring for the presence of E. coli, corrective actions for systems with significant deficiencies, and compliance monitoring to ensure that installed treatment technology achieves at least 99.99 percent (4-log) inactivation or removal of viruses.

While the GWR addresses source water microbiological pollutants, the 1989 Total Coliform Rule (TCR) and the 2013 Revised Total Coliform Rule (RTCR) address the protection against waterborne bacteria in drinking water distribution systems. Compliance with the TCR is based on distribution system sampling results and the detection of Total Coliforms. Coliforms are a collective group of microorganisms that typically originate from the intestines of warm-blooded animals, but which may also occur naturally in the environment. Therefore, a subset of the Total Coliform group (E. coli or fecal Coliforms) is used to identify fecal contamination. The USEPA recognized that total coliform detection does not itself necessarily signify a health threat, so in 2013, the USEPA issued the RTCR to focus on E. coli. The MCL and MCL Goal (MCLG) for total Coliforms were eliminated and replaced with an MCL and MCLG for E. coli.

Water systems must collect a minimum number of distribution system samples per month based on the population served. The Division currently collects 54 routine distribution samples, 10 tank samples, 36 raw water samples, and 33 post-treatment samples per month (not including Forges Field Well, but which will be added to the sample regime once it comes online). Compliance with the RTCR is based on the presence or absence of Total Coliforms. Each Total Coliform-positive (TC+) routine sample must then be tested for the presence of E. coli. For water systems collecting less than 40 distribution system samples per month, no more than one sample per month can be positive for E. coli. For water systems collecting more than 40 distribution system samples per month, compliance with the RTCR is achieved if no more than 5 percent of the samples are positive. Any positive sample must be re-sampled within 24 hours and two additional samples taken (upstream and downstream of the site). A system is out of compliance if the results of repeat sampling are positive for fecal coliforms or E. coli, in which case the water system must contact the MassDEP within 24-hours and perform public notification. Best available treatment techniques for compliance with the RTCR include source water protection, filtration, primary disinfection, and secondary disinfection. Detailed requirements of the RTCR for Massachusetts public water systems are provided in 310 CMR 22.05.

The Division is currently in compliance with the provisions of the RTCR. Every water supply in the system utilizes NaOCl for disinfection.

3.4 DISINFECTANTS/DISINFECTION BY-PRODUCT RULE

Chemical reactions between natural organic matter (NOM) and the disinfectant chlorine can produce regulated organo-chlorine compounds called disinfection-by-products (DBPs). A group of four DBPs (chloroform, bromoform, bromodichloromethane and dibromochloromethane) referred to as total trihalomethanes (TTHMs), are regulated under the SDWA. The MCL for TTHMs under the SDWA of 1986 is 100 µg/L, based on a running annual average (RAA) of quarterly distribution system TTHM sampling results. This MCL for TTHMs applies only to community water systems which serve a population of 10,000 or more and which use a disinfectant in any part of their drinking water treatment process. Detailed requirements of the TTHM Rule are provided in 310 CMR 22.07.

The Disinfectants/Disinfection-by-Product Rule (D/DBPR) was promulgated by the USEPA in December 1998 (Federal Register December 16, 1998) and applies to all water systems that utilize a disinfectant. Under the Stage 1 D/DBPR, the TTHM MCL was lowered to 80 µg/L, and MCLs were established for a group of five haloacetic acids (HAA5: mono-chloroacetic acid, di-chloroacetic acid, tri-chloroacetic acid, mono-acetic acid, and di-acetic acid) at 60 µg/L, bromate at 10 µg/L, and chlorite at 1 mg/L. Compliance is determined based on a RAA of samples taken quarterly or annually, where the number of samples taken depends on system size and whether the source is under influence of surface water. Chlorite monitoring is required for systems that use chlorine dioxide, and bromate monitoring is required for systems that use ozone. Systems may qualify for a reduced long-term monitoring schedule if byproduct concentrations remain low.

Maximum residual disinfectant levels (MRDLs) for chlorine, chloramines, and chlorine dioxide are also established at 4 mg/L as free chlorine, 4 mg/L as total chlorine, and 0.8 mg/L as ClO2, respectively. For water systems in the Commonwealth of Massachusetts, detailed requirements of the Stage 1 D/DBP Rule are defined in 310 CMR 22.07E.

The Stage 2 Disinfectants/Disinfection-by-Product Rule was proposed by USEPA in August 2003 (Federal Register, August 18, 2003). The rule was finalized in January 2006 (Federal Register, January 4, 2006). For water systems in the Commonwealth of Massachusetts, detailed requirements of the Stage 2 D/DBP Rule are defined in 310 CMR 22.07F.

The Stage 2 D/DBPR applies to all water systems using a disinfectant other than UV and establishes more stringent TTHM and HAA5 standards. The updated TTHM and HAA5 standards were implemented in two phases:

- Under Phase I, all systems were required to meet running annual averages (RAAs) of 80 µg/L for TTHMs and 60 µg/L for HAA5s and locational running annual averages (LRAA) of 120 µg/L for TTHMs and 100 µg/L for HAA5s. Systems had to comply with the Phase I levels within three years after the rule was promulgated in January 2006, except that an additional two-year extension was available for systems requiring capital improvements; and
- Under Phase II, all systems were required to conduct an initial distribution system evaluation (IDSE) based on system size and source water type to determine new DBP monitoring sites that represent maximum DBP formation sites, unless historic monitoring results indicated TTHM levels less than 40 µg/L and HAA5 levels less than 30 µg/L (40/30 certification). In addition the LRAA levels for TTHMs and HAA5s were lowered to 80 µg/L and 60 µg/L, respectively. All systems had to comply with the Phase II levels by October 2013, except that an additional two-year extension was available for systems requiring capital improvements.

The Division is currently qualified for a 40/30 certification.

3.5 LEAD AND COPPER RULE

The Lead and Copper Rule (LCR) was promulgated by USEPA on June 6, 1991, based on the requirements of the 1986 Amendments to the SDWA. The objective of the LCR is to reduce consumer exposure to lead and copper resulting from corrosion of drinking water piping and plumbing systems. Unlike other drinking water regulations that establish MCLs, the LCR requires various treatment techniques including: optimal corrosion control treatment; source water treatment; public education; and lead service line replacement, which are triggered by lead and copper action levels (ALs) measured at the consumer's tap. USEPA has set ALs at a 90th percentile concentration of 0.015 mg/L for lead and 1.3 mg/L for copper, respectively.

Under the 1996 amendments to the SDWA, USEPA provided several revisions to the LCR (Federal Register, January 12, 2000; Federal Register, Minor Revisions, April 11, 2000) including changes or additions in requirements for: the demonstration of optimal corrosion control, lead service line replacement, public education, monitoring, analytical methods, reporting and record keeping, and special primacy considerations. Detailed requirements of the LCR are provided in 310 CMR 22.06B. The USEPA further revised the LCR in October 2007 to enhance some facets of the implementation of the LCR and improve compliance with public education requirements.

Water systems must sample tap water distribution system sites for lead and copper and for corrosion control water quality parameters based on service population. Sampling sites are selected based on an inventory of distribution system materials (lead services) and residential house age (homes built just prior to the USEPA lead ban, between 1982 and 1986). Systems that comply with the 90th percentile ALs are eligible for reduced monitoring. Systems exceeding the lead AL must install optimal corrosion control, replace lead service lines, and complete a lead public education program annually.

USEPA is expected to update the LCR in the wake of the Flint, MI episode. Once USEPA finalizes the national regulations, Massachusetts is expected to begin a process of updating 310 CMR 22.06B.

The Division is currently required to sample for lead and copper once every three years at 30 different sampling sites. In addition, the Division is continuing to remove lead services and is currently in full compliance with the requirements of the LCR. Every water supply in the system utilizes NaOH for pH adjustment and corrosion control, and the Division typically targets a finished water pH of 8.5.

3.6 EMERGING CONTAMINANTS - PFAS

Drinking water PFAS guidelines, regulations, and requirements are rapidly evolving and vary across the country. USEPA required testing of six PFAS compounds in 2013-2015 as part of the Third Unregulated Contaminant Monitoring Rule (UCMR 3). In 2016, USEPA issued a health advisory level of 70 parts per trillion (ppt) as the sum of two PFAS compounds: perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). In 2019, USEPA confirmed that they are following the standard Safe Drinking Water Act process to determine if an MCL for PFOA and PFOS will be issued. In the interim, some states are taking a more aggressive approach, including issuing MCLs, establishing regulations for more than two PFAS compounds, and setting drinking water limits below USEPA’s 70 ppt level.

Massachusetts is among the states pursuing this more aggressive approach. In June 2018, MassDEP set an ORSG level of 70 ppt for the sum of five PFAS compounds: PFOA, PFAS, perfluorononanoic acid (PFNA), perfluorohexane sulfonic acid (PFHxS), and perfluoroheptanoic acid (PFHpA). In 2019, MassDEP released draft hazardous waste regulations, which included a 20 ppt limit for the sum of six PFAS compounds: PFOA, PFAS, PFNA, PFHxS, PFHpA, and perfluorodecanoic acid (PFDA). MassDEP has indicated that they are developing a drinking water MCL that will match the hazardous waste regulations; therefore, a Massachusetts drinking water MCL of 20 ppt as the sum of the six aforementioned compounds is widely expected in the coming months.

Meanwhile, MassDEP is encouraging public water suppliers to voluntarily sample their supplies and has initiated targeted sampling to determine if PFAS are present in public water supplies (PWS) and Non-Transient Non-Community PWS with daycares, medical facilities, or schools that are within two miles of previously identified water supplies or groundwater with detections of PFAS, or locations where PFAS were potentially used. Of particular interest, MassDEP has selected three sampling sites in the neighboring Town of Carver which is located near the Plymouth Municipal Airport, a potential source for PFAS.

Chapter 4 – Evaluation of Supply and Demand

This chapter evaluates the capacity of the Division's water supplies to meet demands through 2040. The Division currently has a limited number of available well supplies with defined withdrawal limits under the Massachusetts WMA Permit and current operational constraints. Therefore, the Division needs to understand the ability of the existing system to supply water in the face of significant residential and commercial development pressures.

As building and development progresses in the Town of Plymouth, there needs to be a coordinated balance between the available water supply and the approval of new services. With the assistance of the Division, the current water supply capacity, average and maximum day water demands, and average and maximum day water production were analyzed to determine how much water is available for impending development and population growth.

4.1 WATER DEMAND ASSESSMENT

This section summarizes the average day demands, maximum day demands, and use by zone and user type.

4.1.1 Analysis of Metered Water Use

Metered water use is reported annually in the Division's Annual Statistical Report (ASR). This represents the total amount of water used by consumers and does not include unaccounted-for water, water use during treatment, or confidently estimated municipal use. Metered water use is divided among seven user categories defined by MassDEP: Residential, Residential Institutions (colleges, prisons, etc.), Commercial/Business, Agricultural, Industrial, Municipal/Institutional/Non-Profits, and Other. Total water consumption (in million gallons per year [MGY]) by user type from 2013 to 2018 is presented in Table 4-1 below. A review of the information in Table 4-1 suggests that residential water use is typically approximately one billion gallons per year and represents approximately three-quarters of total annual water use in the water system.

Table 4-1 – Annual Water Consumption by User Type

Use Type (MGY)	2013	2014	2015	2016	2017	2018	Average	Average Percent Total Consumption
Residential	1046.0	970.8	1008.9	948.2	921.1	985.9	980.1	72%
Commercial	102.2	142.5	130.4	148.2	136.9	158.3	136.4	10%
Municipal/Institution/Non-Profit	118.9	161.6	119.3	110.5	104.2	88.4	117.2	8.6%
Industrial	74.3	64.3	72.0	73.9	62.1	82.4	71.5	5.3%
Residential Institution	39.3	60.9	46.2	43.7	35.3	69.0	49.1	3.6%
Agricultural	0.58	0.17	0.15	0.38	0.18	0.23	0.28	0.02%
Total	1,381.3	1,400.3	1,376.9	1,324.9	1,259.8	1,384.2	1,354.6	

Table 4-2 below presents the annual percent change from 2013 to 2018 for each use type. While the majority of water is used by residential customers, growth in water use is driven primarily by residential institutional and commercial customers. The overall impact on total water consumption by the former is minor, as it only accounts for approximately 3.6 percent of total consumption.

Table 4-2 – Change in Water Consumption by User Type, 2013 to 2018

Use Type (MGY)	2013	2018	Average Annual Percent Change
Residential Institution	39.3	69.0	12.5%
Commercial	102.2	158.3	9.1%
Industrial	74.3	82.4	1.8%
Residential	1046.0	985.9	-1.0%
Municipal/Institution/Non-Profit	118.9	88.4	-4.3%
Agricultural	0.58	0.23	-10.1%

4.1.2 Average Day Demand

Average-day demand (ADD) is the average volume of water pumped into the distribution system in a year, calculated by dividing total volume pumped in one year by 365 days (or 366 in 2016). This metric is used as a baseline for determining the adequacy of water supply sources. Water demand, which includes unaccounted-for water (further discussed below) and treatment losses, for the past six years (2013 through 2018) was reviewed and is summarized in Table 4-3. In the ASR, this is reported as “Average Daily Raw Water Pumpage”. Based on the information available, the Division’s average water production from 2013 to 2018 was approximately 4.31 MGD or 1,573 MGY.

Table 4-3 – Annual Water Production

Year	Total Annual Demand (MGY)	Average Day Demand (MGD)
2013	1,560.81	4.28
2014	1,615.05	4.42
2015	1,603.42	4.39
2016	1,589.49	4.34
2017	1,517.77	4.16
2018	1,552.41	4.25
6-Year Average	**1,573.16**	**4.31**

The Division’s water distribution system consists of six pressure zones, namely: Bradford, Cedarville, Manomet, Pine Hills, Plymouth Center, and West Plymouth. The water system effectively operates as two independent systems as depicted in Figure 1-1. To the north, operators can typically move water between the Bradford, Plymouth Center, West Plymouth, and Pine Hills Pressure Zones. To the east, operators can move water between the Cedarville and Manomet Pressure Zones. The two regions are separated by a permanently closed pressure reducing valve (Rocky Hill PRV). Therefore, it is important to evaluate ADD regionally within the water system. Water demand data for the past six years (2013 through 2018) was reviewed and is summarized by Eastern and Northern Pressure Zones in Table 4-4 below.

Table 4-4– Average Day Water Demand by Region

Year	Eastern Pressure Zones Average Daily Demand (MGD)	Northern Pressure Zones Average Daily Demand (MGD)
2013	1.32	2.96
2014	1.37	3.06
2015	1.38	3.01
2016	1.36	2.99
2017	1.32	2.84
2018	1.37	2.89
6-Year Average	**1.35**	**2.96**

4.1.3 Maximum Day Demand

Maximum-day demand (MDD) is the largest 24-hour demand during the course of a calendar year and is an essential component used in the evaluation of pumping facilities. Comparing periods of maximum demand to the capabilities of supply sources is critical to ensure that storage tank levels remain adequate and system pressures stay within acceptable ranges.

MDD is typically expressed as a ratio of the ADD. This ratio varies based on the characteristics of the individual community. Water systems with low density, residential communities have relatively large fluctuations; conversely, highly industrialized, densely populated communities are generally not subject to significant seasonal fluctuations and have a smaller maximum day demand ratio. The Division serves a mix of residential, commercial, and industrial customers.

A summary of MDD relative to ADD between the years of 2013 to 2018 is presented in Table 4-5. A review of the data shown in Table 4-5 indicates that the raw-water average MDD is 7.97 MGD and the average ratio of MDD to ADD is 1.85. Based on past experiences with water system planning, this average ratio is similar to other southeastern Massachusetts systems with mixed residential, commercial, and industrial customers.

Table 4-5 – Maximum Day Water Demand

Year	Average Daily Demand (MGD)	Maximum Day Demand (MGD)	MDD/ADD Ratio
2013	4.28	7.83	1.83
2014	4.42	7.93	1.79
2015	4.39	8.16	1.86
2016	4.34	8.47	1.95
2017	4.16	7.67	1.84
2018	4.25	7.79	1.83
6-Year Average	**4.31**	**7.97**	**1.85**

Similarly, a summary of MDD and its regional variations relative to the Eastern and Northern Pressure Zones between the years of 2013 to 2018 is presented in Table 4-6. A review of the data shown in Table 4-6 indicates that the total average MDD is approximately 7.97 MGD with an average MDD of 2.50 MGD in the eastern pressure zones and 5.47 MGD in the Northern Pressure Zones.

Table 4-6 – Maximum Day Water Demand by Region

Year	Eastern Pressure Zones Maximum Daily Demand (MGD)	Northern Pressure Zones Maximum Daily Demand (MGD)
2013	2.42	5.42
2014	2.45	5.48
2015	2.56	5.58
2016	2.65	5.82
2017	2.42	5.24
2018	2.50	5.30
6-Year Average	**2.50**	**5.47**

4.1.4 Peak Hour Demand

Peak hour demands are the highest hourly demands that occur during a 24-hour period and generally occur in conjunction with the MDD. Because peak hour demands typically vary from 1.5 to 6.0 times the MDD and are short-term demands, they can and should be met from distribution system storage rather than from supply facilities. Peak hour demand storage is discussed in Chapter 6.

4.1.5 Residential Per-Capita Water Use

Between 2013 and 2018, the Division had an average water use of approximately 68 RGPCD and a residential percentage of metered water use of 73 percent, which are tabulated in Table 4-7, based on recent ASR data. Based on the Division's latest WMA Permit the 6-year average exceeds the allowable

RGPCD of 65; however, usage from 2016 through 2018 is within the acceptable limit of the new permit with a downward trend from 2013 to 2018.

Table 4-7 – Residential Per-Capita Water Use

Year	Residential Per-Capita Water Use (RGPCD)
2013	74
2014	70
2015	71
2016	64
2017	62
2018	65
6-year Average	**68**

4.1.6 Seasonal Demands

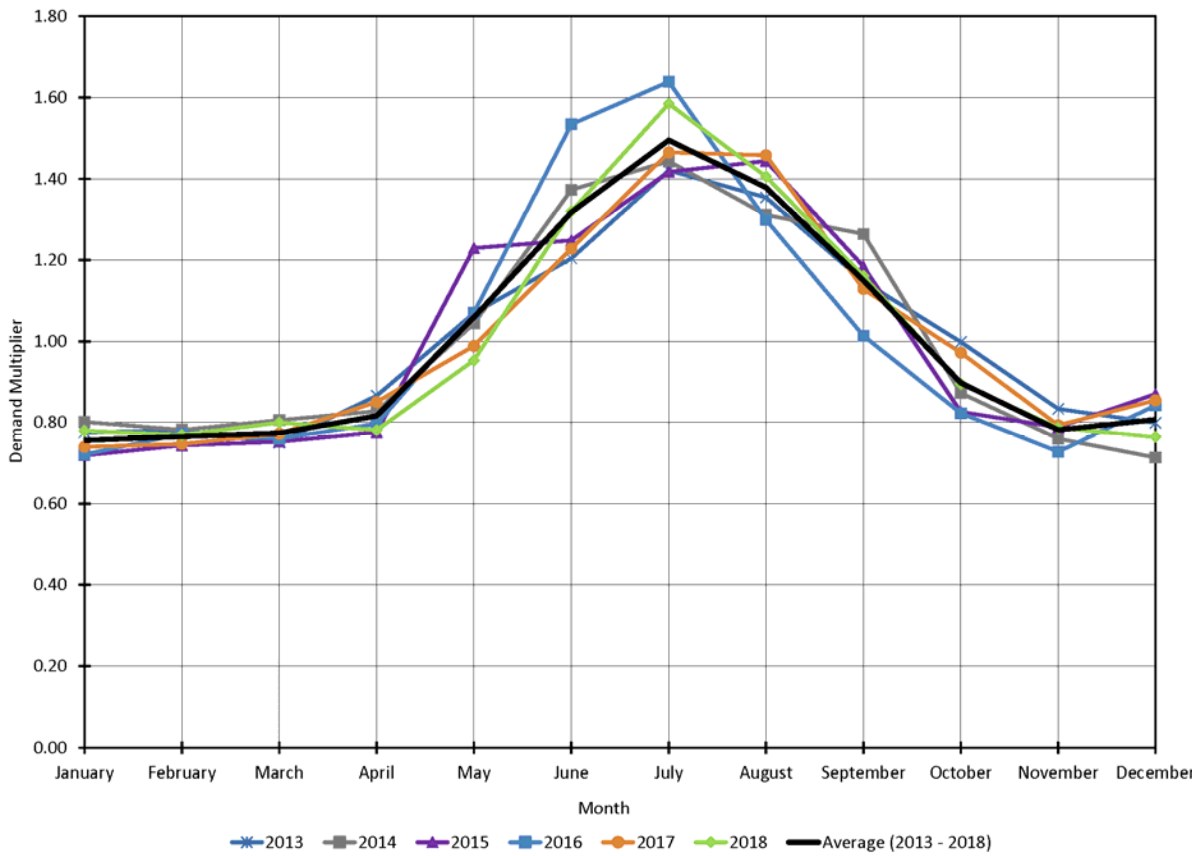
While 68 RGPCD is a representative average, actual residential per capita water usage is seasonally affected and changes throughout the year. Typically, demands increase during the Summer due to outside watering and use of irrigation systems. This Summer demand can continue to be reduced through water conservation measures, educational outreach, and advertising annual water restrictions.

There is insufficient billing data to make any useful assertions regarding the fluctuation of RGPCD by month or season, as the Division only transitioned from semi-annual to quarterly billing in July 2019. Going forward, it may be possible to estimate seasonal fluctuations based on the new quarterly billing data. For the purposes of this analysis, EP estimated the variation in monthly demands by developing a monthly demand multiplier based on the Division's ASR data. For each calendar month, a six-year average demand was calculated from the ASR data. The demand multiplier for each month was estimated by normalizing the monthly demand against the annual average monthly demand. This resulted in demand multipliers ranging from 0.75 to 1.5. Average monthly demands and demand multipliers are summarized in Table 4-8 and illustrated in Chart 4-1. As shown, demand significantly increases during the summer months.

Table 4-8 – Average Monthly Finished Water Demand Summary (2013 – 2018)

Month	Average Monthly Demand (MGD)	Average Demand Multiplier
January	3.24	0.76
February	3.29	0.77
March	3.32	0.77
April	3.50	0.82
May	4.55	1.06
June	5.66	1.32
July	6.41	1.50
August	5.91	1.38
September	4.94	1.15
October	3.85	0.90
November	3.35	0.78
December	3.46	0.81
Average	4.29	1.00

Chart 4-1 – Historic Monthly Demand Multiplier



4.1.7 Unaccounted-for Water

Unaccounted-for water (UAW) is the difference between the finished water pumped from the pump stations or treatment plants and the reported metered water usage. The volume of UAW includes water use that is not quantified for firefighting, water main leaks and breaks, system flushing, and any meter inaccuracies. The residential meter replacement program that was recently completed should help in reducing UAW for meters that were under registering. Additionally, the Division should purchase portable and easy to deploy correlators to assist in identifying areas of potential leaks.

ASR data from 2013 to 2018 shows a six-year average of 12 percent UAW, as shown in Table 4-9 below. Based on the Division's latest WMA Permit this percentage exceeds the allowable UAW threshold of 10 percent. The Division managed to bring UAW below 10 percent in 2018; however, if the UAW does not remain below 10 percent in 2019, the Division will be required to implement a water loss control program in accordance with Appendix B of the March 1, 2019 WMA Permit.

Table 4-9 – Unaccounted for Water Loss (2013 – 2018)

Year	Finished Water Produced (MG)	Total Metered Water Sales (MG)	Authorized Unaccounted for Water Loss (MG)	Unaccounted for Water Loss (MG)	Percent Unaccounted for Water Loss
2013	1,557.3	1,381.3	25.7	150.2	9.6%
2014	1,609.3	1,400.3	17.5	191.5	11.9%
2015	1,598.5	1,376.9	17.8	203.8	12.7%
2016	1,583.5	1,324.9	39.3	219.3	13.8%
2017	1,511.3	1,259.7	31.4	220.2	14.6%
2018	1,547.4	1,384.2	16.8	146.4	9.5%
6-Year Average				**188.6**	**12.0%**

4.1.8 Water Usage by Pressure Zone

As discussed above, the water distribution system consists of six pressure zones (Figure 1-1). Billing information was provided for 2018 metered water usage. The billing information was geocoded and a pressure zone assigned to each account. Table 4-10 presents the total metered water usage for 2018 by pressure zone. The 2018 data is generally representative of current conditions, based on available information provided by the Division to date. A review of the information presented in Table 4-10 suggests that the majority of the Division's water use occurs in the West Plymouth, Plymouth Center, and Manomet Pressure Zones. Note that this data represents metered usage at the user, and therefore does not include UAW or other system losses.

Table 4-10 – Usage by Pressure Zone

Pressure Zone	Approximate Number of Customer Meters	2018 Metered Water Usage (MGY)	Percent of Total Usage
West Plymouth	4,059	477.08	34%
Plymouth Center	3,466	351.20	25%
Manomet	4,845	331.92	24%
Bradford	514	124.17	9%
Cedarville	1,232	80.09	6%
Pine Hills	257	19.83	1%
Total		**1,384.30**	**100%**

4.2 WATER SUPPLY ASSESSMENT

This section summarizes the capacity of the Division's existing water supply sources and their ability to satisfy current water demands within the community.

4.2.1 Water Supply Capacity

Adequacy of supply was evaluated based upon the ability of supply capacity to meet maximum-day demand. The supply capacity was examined in several ways including typical pumping rate, firm capacity, and safe yield.

Well capacity is expressed in the following ways:

DEP Approved Rate – This is the 24-hour pumping rate approved by DEP as part of the source approval process or Zone II delineation. This is typically the safe yield of the well but may be lower due to contamination or other circumstances.

Safe Yield – Defined by MassDEP as, "the maximum dependable withdrawals that can be made continuously from a water source including ground or surface water during a period of years in which the probable driest period or period of greatest water deficiency is likely to occur; provided, however, that such dependability is relative and is a function of storage and drought probability."

Design Capacity – DEP allows the design of well pumps to be up to 150 percent of the approved rate with the provision that the approved daily volume is not exceeded.

Current Operational Capacity – Actual pumping rates vary based on well condition, pump equipment, hydraulics, water quality, and other factors. Operational capacity is based on discussions with water system operators and performance tests conducted by experienced well drillers.

Firm Capacity – The system capacity based on the lesser of the safe yield, design capacity, and current operational capacity with the largest single source out of service.

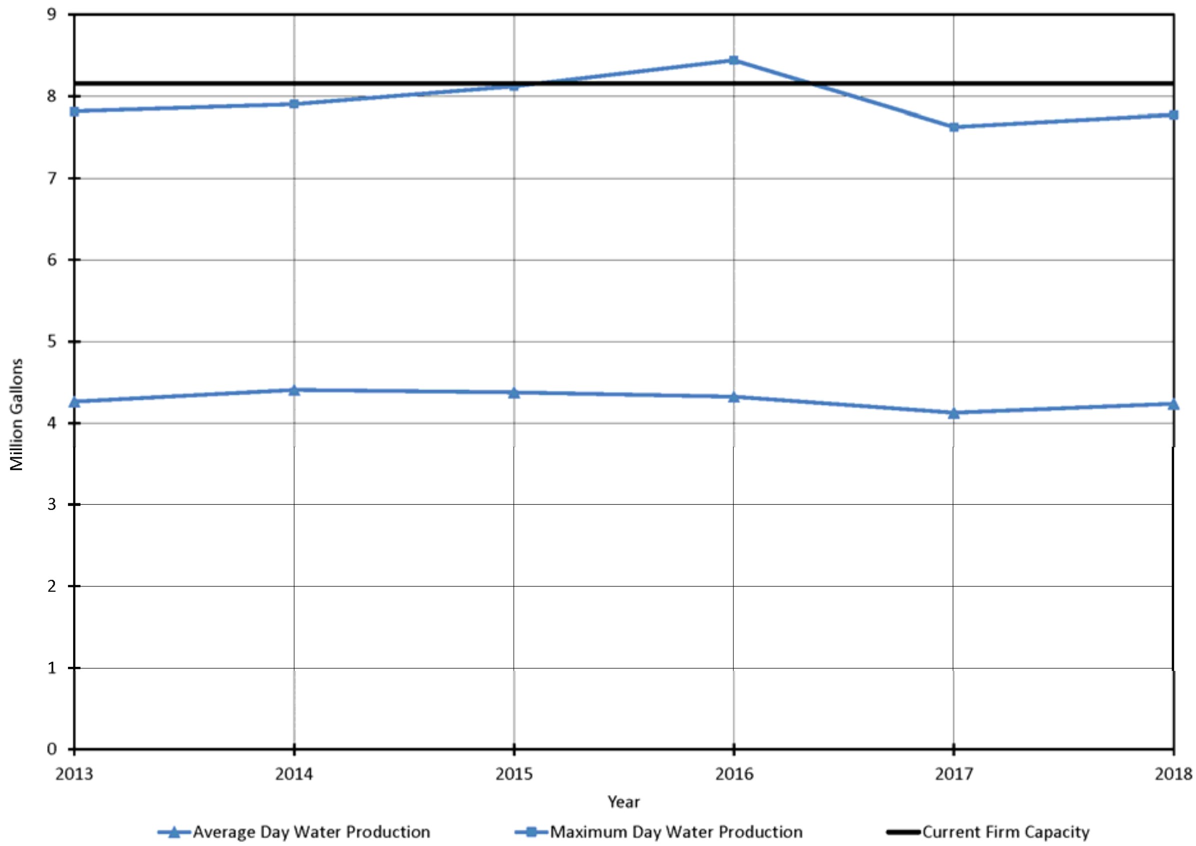
A summary of the Division's water supply sources is provided in Table 4-11 and shown graphically in Chart 4-2. South Pond Well 2 is currently the Division's largest source, and its capacity was excluded from the Firm Capacity calculation.

Table 4-11 – Well Capacities

Pressure Zone	Source	Safe Yield (MGD)	Design Capacity (MGD)	Current Operational Capacity (MGD)	Firm Capacity (MGD)
Bradford	Bradford Well No. 1	1.51[1]	1.01	1.30	1.30
	Bradford Well No. 2		1.01		
Cedarville	Savery Pond Well	1.50	1.73	1.22	1.22
Manomet	Wannos Pond Well	0.94	1.01	0.72	0.72
	Ship Pond Well	0.86	0.94	0.50[2]	0.50
	Ellisville Well	1.12	1.08	1.01[2]	1.01
Plymouth Center	Lout Pond Well	0.72	0.50	0.36	0.36
	South Pond Well No. 1	1.12	1.30	2.74	1.12
	South Pond Well No. 2	1.50	1.44		-
West Plymouth	Federal Furnace Well	0.79	0.72	0.43[3]	0.43
	North Plymouth Well	1.53	1.58	1.30[4]	1.30
	Darby Pond Well	0.80[5]	1.20	1.44	0.20[6]
Total		**5.04[7]**	**13.51**	**11.02**	**8.17**

1. The Bradford Wells have a combined safe yield of 1.51 MGD, for any pumping combination.
2. Ship Pond and Ellisville Well withdrawals are limited due to proximity and CI transmission main.
3. Federal Furnace Well withdrawals are limited due to manganese concentrations.
4. North Plymouth Well withdrawals are limited by water quality concerns.
5. Darby Pond Well is permitted for 0.80 MGD as a monthly average, therefore withdrawals shall not exceed 0.80 MGD for any consecutive 30 days.
6. During the pond level restriction pumping is limited to a maximum of 4 hours per day; 0.20 MGD is based on the approximate 2016 pumping rates when the pond level restriction was in effect.
7. Year 2030 not-to-exceed average day withdrawal limit per WMA Permit. The not-to-exceed average day withdrawal limit is 4.59 MGD in 2019, and 4.71 MGD in 2025.
8. The Forges Field Well was not included and is set to come online in 2020.

Chart 4-2 – Daily Water Production vs Firm Capacity



A review of Table 4-11 above suggests that the current firm capacity, 8.17 MGD, is sufficient to meet the six-year average MDD of 7.97 MGD. However, as discussed above, the water system effectively operates as two independent systems. To the north, operators can typically move water between the Bradford, Plymouth Center, West Plymouth, and Pine Hills Pressure Zones. To the east, operators can move water between the Cedarville and Manomet Pressure Zones. Since the two regions are separated by a permanently closed pressure reducing valve, it is important to assess the firm capacity under these restrictions. Table 4-12 presents the firm capacity of the Northern Pressure Zones.

Table 4-12 – Northern Pressure Zones Well Capacities

Pressure Zone	Source	Safe Yield (MGD)	Design Capacity (MGD)	Current Operational Capacity (MGD)	Firm Capacity (MGD)
Bradford	Bradford Well No. 1	1.51[1]	1.01	1.30	1.30
	Bradford Well No. 2		1.01		
Plymouth Center	Lout Pond Well	0.72	0.50	0.36	0.36
	South Pond Well No. 1	1.12	1.30	2.74	1.12
	South Pond Well No. 2	1.50	1.44		-
West Plymouth	Federal Furnace Well	0.79	0.72	0.43[2]	0.43
	North Plymouth Well	1.53	1.58	1.30[3]	1.30
	Darby Pond Well	0.80[4]	1.20	1.44	0.20[5]
Total			**8.76**	**8.03**	**4.71**

1. The Bradford wells have a combined safe yield of 1.51 MGD, for any pumping combination. It should be noted that both wells must be operational for the Bradford WTP to operate.
2. Federal Furnace Well withdrawals are limited due to manganese concentrations.
3. North Plymouth Well withdrawals are limited by sodium concentrations.
4. Darby Pond Well is permitted for 0.80 MGD as a monthly average, therefore withdrawals shall not exceed 0.80 MGD for any consecutive 30 days.
5. During the pond level restriction pumping is limited to a maximum of 4 hours per day; 0.20 MGD is based on the approximate 2016 pumping rates when the pond level restriction was in effect.
6. The Forges Field Well was not included and is set to come online in 2020.

A review of Table 4-4– Average Day Water Demand by Region, Table 4-6 – Maximum Day Water Demand by Region, and Table 4-12 – Northern Pressure Zones Well Capacities, suggests that under current conditions there is sufficient firm capacity to meet the average day demand. However, there is insufficient capacity to meet the MDD under current conditions in the Northern Pressure Zones. Further, there are operational limits on the Bradford, Federal Furnace, North Plymouth, and Darby Pond water supplies, further discussed below, which adds additional stress to the available water supply.

Table 4-13 presents the firm capacity of the Eastern Pressure Zones.

Table 4-13 – Eastern Pressure Zones Well Capacities

Pressure Zone	Source	Safe Yield (MGD)	Design Capacity (MGD)	Current Operational Capacity (MGD)	Firm Capacity (MGD)
Cedarville	Savery Pond Well	1.50	1.73	1.22	-
Manomet	Wannos Pond Well	0.94	1.01	0.72	0.72
	Ship Pond Well	0.86	0.94	0.50[1]	0.50
	Ellisville Well	1.12	1.08	1.01[1]	1.01
Total			**4.75**	**3.46**	**2.23**

1. Ship Pond and Ellisville well withdrawals are limited due to proximity and CI transmission main.

A review of Table 4-4– Average Day Water Demand by Region, Table 4-6 – Maximum Day Water Demand by Region, and Table 4-13 – Eastern Pressure Zones Well Capacities shows that under existing conditions there is sufficient firm capacity to meet the ADD. However, there is insufficient capacity to meet the maximum day demands under existing conditions in the Eastern Pressure Zones. Further, there are operational limits on the Ship Pond and Ellisville due to their close proximity, as discussed in the Operational Restrictions section below, which stress the available water supply.

By assessing the capacity of the water system in two separate zones based on the physical and operational limitations of the system, it is evident that there is insufficient capacity to meet the maximum day production needs in the Northern and Eastern Pressure Zones. The results of this analysis are summarized in Table 4-14, below.

Table 4-14 – Firm Capacity Deficit

	Firm Capacity (MGD)	Maximum Day Demand (MGD)	Surplus Capacity (MGD)
Northern Pressure Zones	4.71[1]	5.47	-0.76
Eastern Pressure Zones	2.23	2.50	-0.27

1. Firm capacity does not include the Forges Field Well, which will increase the firm capacity to 5.76 MGD once online.

In the Eastern Pressure Zones, the firm capacity is currently limited by the reported operational capacity of the Ship Pond and Ellisville Wells, resulting in a firm capacity output of approximately 2.23 MGD (Table 4-14). However, hydraulic modeling efforts, as discussed in Chapter 7, indicate that achieving the safe yield of 2.92 MGD from the Manomet Pressure Zone sources is possible in a reduced pressure environment. Therefore, while there is a reported firm capacity deficit in the Eastern Pressure Zones, hydraulic modeling results indicate this is due to hydraulic constraints on the Ship Pond and Ellisville Wells that are removed in a firm capacity scenario. Thus, the firm capacity deficit in the Eastern Pressure Zones does not represent a true supply deficit, but rather a lack of sufficient hydraulic capacity to meet the required demands with an adequate pressure profile.

4.2.1.1 Water Supply Capacity by Pressure Zone

Capacity to meet maximum day demands varies considerably by pressure zone, and depends highly on the operational strategy at the zone interconnections, including actuator valves and booster pumping stations. A summary of existing surpluses or deficits in each pressure zone under one example operational strategy is presented below in Table 4-15.

Table 4-15 – Firm Capacity by Pressure Zone

Pressure Zone	Firm Capacity (MGD)	Approximate MDD (MGD)	Interzone Water Received (MGD)	Interzone Water Donated (MGD)	Surplus Capacity (MGD)
Bradford	1.296	0.638	0.000	-0.576	0.082
Plymouth Center	1.480	1.961	0.576	-0.441	-0.346
Pine Hills	0.000	0.109	0.109	0.000	0.000
West Plymouth	1.932[1]	2.611	0.332	0.000	-0.347
Cedarville	0.000	0.486	0.338	0.000	-0.148
Manomet	2.232	2.041	0.000	-0.338	-0.147

1. Assumes the 0.2 MGD pumping restrictions are in place at the Darby Pond Well.

In the Northern Pressure Zones, the South Pond Well No. 2 in the Plymouth Center Pressure Zone is lost to the firm capacity event. The Bradford Pressure Zone can supply approximately 400 gpm through the Nook Road Actuator Valve, yielding up to 0.576 MGD. The Pine Hills Pressure Zone does not produce any water of its own, and must withdraw approximately 0.109 MGD from the Plymouth Center Pressure Zone. This leaves a significant deficit between the Plymouth Center Pressure Zone and the West Plymouth Pressure Zone, which is essentially distributed between them according to how long the Deep Water Booster Pumps are run. In the example above, they are run just long enough to evenly distribute the deficit.

In the Eastern Pressure Zones, the Savery Pond Well in the Cedarville Pressure Zone is lost to the firm capacity event. As Savery Pond is the sole source in the Cedarville Pressure Zone, this leaves a deficit in the Cedarville Pressure Zone, which can be offset or met depending on operations at the Cedarville Booster Pumps. Meeting approximately half of the Cedarville Pressure Zone deficit begins to incur a deficit in the Manomet Pressure Zone, which grows with additional run time at the Cedarville Booster Pumps. In the example above, the booster pumps are operated just long enough to evenly distribute the deficit between the two pressure zones.

While EP does not necessarily recommend this strategy of evenly distributing deficits – various alternate pumping strategies were not developed as part of this report – this example highlights the existing deficits and vulnerabilities of the Plymouth Water System. The West Plymouth Pressure Zone is the pressure zone most in need of water during a firm capacity event, closely followed by the Cedarville Pressure Zone and the Plymouth Center Pressure Zone. On the other hand, the Bradford Pressure Zone has more excess capacity than can be easily moved to the Plymouth Center Pressure Zone.

4.2.2 Operational Restrictions

The following sources have site-specific operational restrictions:

Bradford No. 1 and No. 2 Wells – The average daily withdrawals may not exceed 1.51 MGD from the two Bradford Wells; the wells may be used in any combination. However, both wells must be operational in order for the treatment plant to operate as the backwashing of the filters is dependent on the combined volume of the wells. In addition, pumping at the Bradford Wells is limited by high iron and manganese levels, which clog the well screen.

Darby Pond Well – The maximum monthly withdrawal may not exceed 0.80 MGD for any consecutive 30 day period. In addition, when water in Darby Pond drops below 121.5 feet (NGVD 29), the WMA Permit requires the Division to limit pumping at the facility to no more than 4 hours per day. During 2016, which was considered a drought year, the pond level remained below 121.5 feet for 6 months in a row. The Division should continue to purchase cranberry bogs in the vicinity of Darby Pond and petition to lift the WMA pumping restrictions on the Division's well.

Federal Furnace Well – Manganese levels are elevated at the well. The Division currently utilizes sequestering to stabilize the manganese and attempts to limit use when possible. A water quality study is currently evaluating the use of sequesterant and alternative options to regaining capacity from the Federal Furnace Well.

North Plymouth Well – Sodium and chloride levels are elevated at the well presumably due to roadway deicing constituents, based on a water quality analysis performed by EP in December 2014. The Division should continue to hold annual fall/winter meetings with property owners in the North Plymouth Well Zone II to minimize the use of de-icing compounds and controlling stormwater runoff of these compounds.

Ship Pond and Ellisville Wells – Reduced capacity due to transmission main hydraulic restrictions in the Manomet Pressure Zone, and the operation of the altitude valve at the Indian Hill Tank. Additionally, a water quality study is currently evaluating the use of raw water quality at Ship Pond Wells and evaluating alternative options to regaining capacity from the Ship Pond Wells.

Lout Pond Well – Deteriorating water quality has led the Division to limit pumping at the facility. The water quality is expected to continue to decline due to increased iron content in the source water. A water quality study is currently evaluating the use of raw water quality at the Lout Pond Well and evaluating alternative options to regaining capacity from the well, including piping the raw water to the Bradford WTP.

4.2.3 Available Capacity for Development

As presented in Chapter 1, the WMA Permit limits the average annual daily withdrawal through the year 2019 to 4.59 MGD with very gradual increases in the withdrawal limit over the next decade. Given the recent six-year average ADD of 4.31 MGD plus 0.14 MGD of anticipated ADD from proposed developments, the current remaining permitted average day capacity is only approximately 0.14 MGD until 2020.

In addition, Chapter 2 of MassDEP's Guidelines for Public Water Systems states that a distribution system shall be designed for the MDD. Similarly, American Water Works Association (AWWA) Manual M31 Distribution System Requirements for Fire Protection states that a distribution system is considered reliable if it can meet required fire flows, when the largest pump is out of service, while maintaining the maximum daily demand rate. As shown in Table 4-14 – Firm Capacity Deficit, by these MDD standards there is currently a deficit of 0.76 MGD in the Northern Pressure Zones and a deficit of 0.27 MGD in the Eastern Pressure Zones. If firm capacity is assessed with the largest source online, i.e. the current operational capacity, there would be an excess capacity of 2.30 MGD in the Northern Pressure Zones, and an excess capacity of 0.96 MGD in the Eastern Pressure Zones to meet the maximum day production needs. However, this approach is not recommended as a planning mechanism because it assumes that each source is 100 percent reliable, which has not been the case for the Division or many public water suppliers with aging infrastructure.

Therefore, any system expansion and additional services to the existing system will create a greater capacity deficit during maximum day demand conditions and reduce the reliability of the Division's fire protection.

In conclusion, there is no redundant capacity during MDD in the Northern or Eastern Pressure Zones and limited redundant capacity in the Eastern Pressure Zones. Therefore, there is no available capacity for development at this time without a reduction in current water use during the summer peak use periods, development of an additional well supply, regaining lost pumping capacity from system improvements or other capital projects mentioned later in this report.

4.3 WATER CONSERVATION EFFORTS

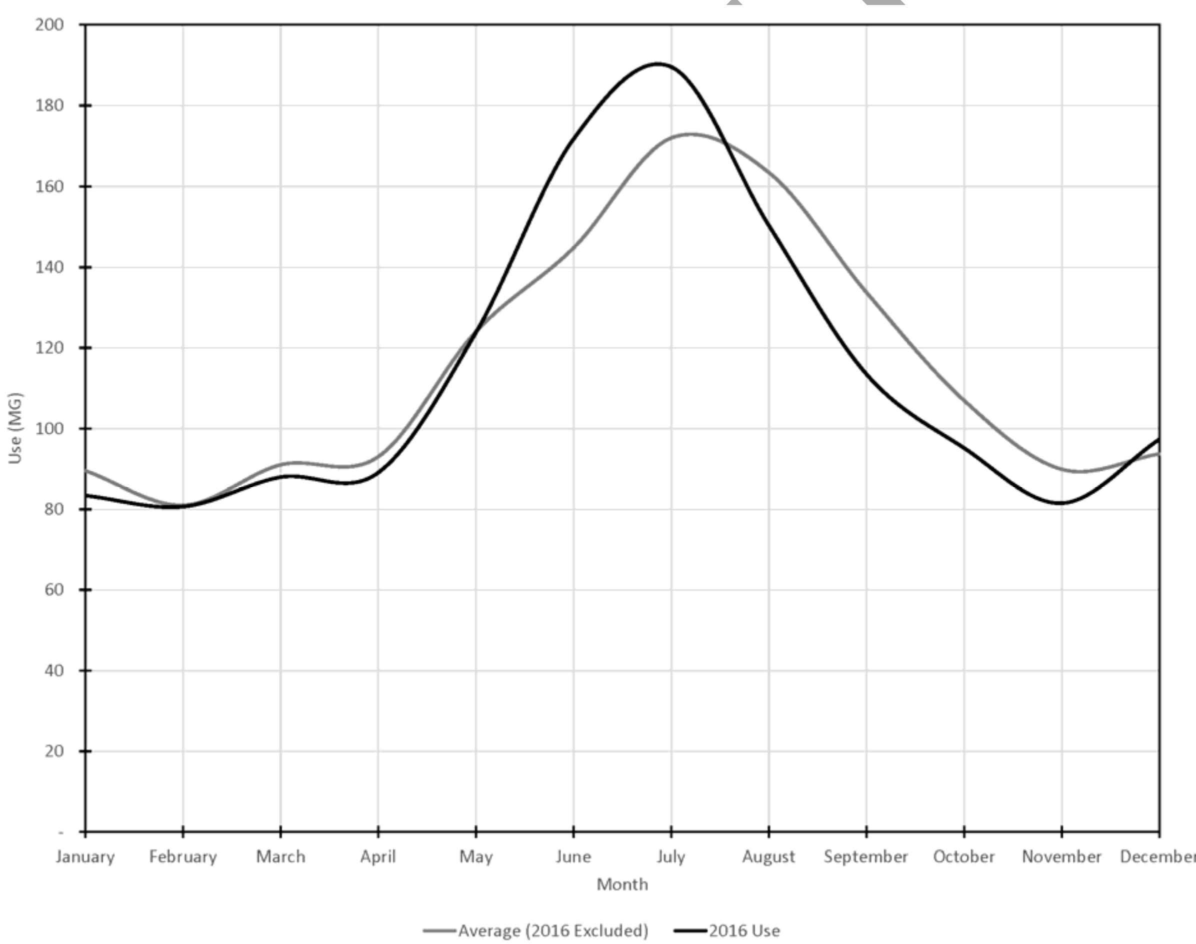
Given the existing firm capacity deficits and small margin of error, water conservation is important in maximizing the ability of the current supplies to meet demands. Over the last few years, the Division has taken a number of steps to improve system-wide water conservation:

- The Division implemented water use restrictions for non-essential outdoor water from May 1st to September 30th, in accordance with the WMA Permit. These restrictions are based on streamflow triggers and limit the time that residents can use outdoor water for non-essential purposes (lawn irrigation, car washing, etc.). Starting on May 21st of 2019, the Division proactively implemented non-essential outdoor water use restrictions to curb summer demands.
- The Division provides free water conservation kits to residents, which are available at the Water Division Office. Each kit contains a low-flow faucet aerator, a low-flow shower head, hand held hose nozzles, leak detection tablets, toilet tank dams, and conservation related literature.
- The Division provides educational literature in their annual Consumer Confidence Report about installing water-saving devices and water conservation savings.
- The Division has worked to lower UAW through a series of leak detection programs.

Additionally, the Division should continue increasing public awareness of water conservation measures particularly to those not connected to the Town of Plymouth's sewer system where an increase in outside watering has been observed.

Historically, the Division implements a voluntary water use restriction for nonessential outdoor water from May 1st to September 30th. During the drought conditions in 2016, the Water Division was faced with increased summer demands, mechanical failure at one well supply, and limited use of water supplies due to the WMA restrictions. A water ban was necessary to maintain storage capacity and meet demands for water use and firefighting. Chart 4- below depicts the monthly metered usage (adjusted for UAW) for 2016 versus the six-year average. During the spring of 2016, the region was experiencing drought conditions, which likely contributed to higher than average water use from May through July (increased watering, etc.). In late July 2016, the Division instituted a ban on nonessential outdoor water use, which appears to have driven demands down through the remainder of the summer and into the fall months.

Chart 4-3 – Monthly Use, 2016 vs 2013-2018 Average

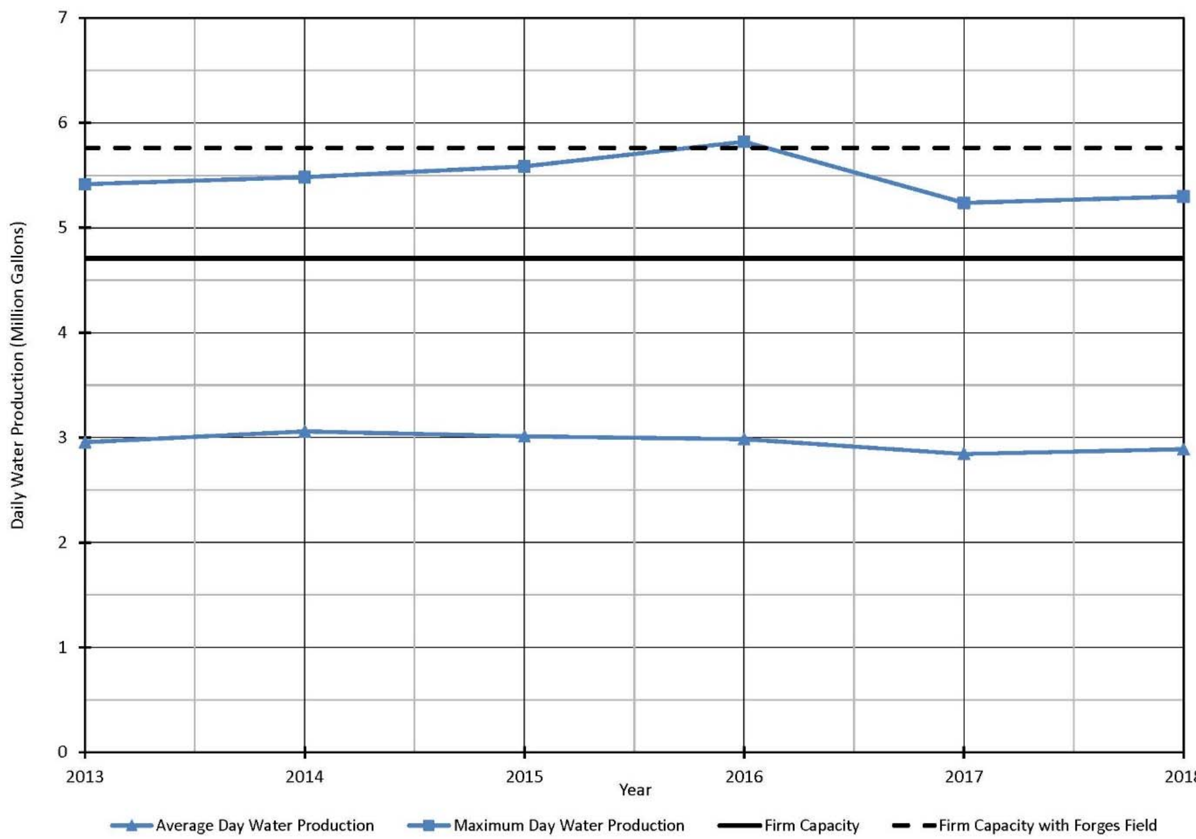


4.4 UPCOMING WATER SYSTEM IMPROVEMENTS

As referenced above, the Division is in the process of developing an additional source at the Forges Field site near Jordan Road. The future production well at the Forges Field Site is being constructed with an average daily withdrawal rate of up to 1.05 MGD. The well is designed to pump into the Bradford Pressure Zone and a valve control station will allow for a second point of connection between the Bradford and Plymouth Center Pressure Zones. The proposed well is remote from the existing service area, so a transmission main is being constructed to connect this water supply to the system. In addition, a few residents along Jordan Road near Forges Field Road will be added to the water system. The addition of this new groundwater source, transmission main, and valve control station will provide redundancy, reduce the stress on existing sources in the Northern Pressure Zones, and alleviate the firm capacity deficit in the Northern Zones in the short-term. These improvements are expected to come online in 2020.

Lastly, the installation of the Forges Field Well is anticipated to provide 1.05 MGD of redundant supply in the Northern Pressure Zones, increasing the overall firm capacity in the Northern Pressure Zones to 5.76 MGD as shown in Chart 4-4 below. Refer to Section 4.5 for the long-term firm capacity projections with Forges Field online.

Chart 4-4 – Daily Water Production vs Firm Capacity



The Division continues to need additional capacity to meet current peak demand periods either through regaining lost pumping capacity from system improvements or other capital projects mentioned later in this report. As previously referenced, the eastern pressure zones have a current water supply deficit of 0.27 MGD; the currently proposed Forges Field Expansion Project does not address the lack of redundancy in the Eastern Pressure Zones. In the Northern Zones, the Forges Field expansion project is beneficial but insufficient to resolve the entire current water supply challenge. If the Division is able to lift the Darby Pond Well pumping restrictions and increase the allowable withdrawal, the additional supply from this existing well would help resolve the firm capacity deficit in the Northern Zones.

4.5 WATER SYSTEM DEMAND FORECAST

This section evaluates the ability of the Division's water supply capacity to meet projected water demands. Future water demands were estimated based on historic water-use patterns and projections of the population served. Demand forecasting through the year 2040 is based on the methodology outlined by the Massachusetts Water Resources Commission (WRC), Policy for Developing Water Needs Forecasts for Public Water Suppliers and Communities and Methodology for Implementation (Rev. March 9, 2017).

4.5.1 Population Forecast

The estimated population served relies on census extrapolation estimates as well as growth estimates by the Metropolitan Area Planning Council (MAPC) and the University of Massachusetts Donahue Institute (UMass). A summary of the Town of Plymouth population data considered in this master plan is summarized in Table 4-16 below.

Table 4-16 – Town of Plymouth Population Data & Forecasts

Estimating Organization	2010	2015[1]	2020	2025[1]	2030	2035[1]
US Census Bureau	56,468	-	-	-	-	-
MAPC (Status Quo)	-	-	60,161	-	62,605	-
MAPC (Strong Migration)	-	-	60,929	-	64,182	-
UMass	-	59,974	63,339	66,433	68,816	70,278
Average	56,468	-	61,476	-	65,201	-

1. Not used in this forecast. Provided for reference only.

The population forecast relies on the average values in the table above and assumes linear growth during each decade through 2030. Since only the UMass forecast is available beyond 2030, the rate of growth in the UMass forecast between 2030 and 2035 (292 people per year) is used to project population from 2030 to 2040. Based on the data provided, the average seasonal population was assumed to remain constant at approximately 800 people per summer through 2040. A summary of the population forecast is provided in Table 4-17 below, which provides population estimates in five-year increments from 2020 to 2040.

Table 4-17 – Population Forecast

Year	Year-Round Population	Percentage Served by the Division	Service Population	Service Population Growth
2020	61,476	68.5%	42,134	3,326
2025	63,339	71.0%	44,950	2,816
2030	65,201	73.4%	47,856	2,906
2035	66,663	75.8%	50,549	2,693
2040	68,125	78.3%	53,313	2,764

Because population counts are typically completed by municipality, it is necessary to estimate the fraction of the population that is actually served by the water system. According to the latest ASR, the Division currently provides water to approximately 68 percent of the town's population. The percentage of the Town's population served by the Division grew steadily from 2014 to 2018 by a total of 2.43 percent, or an average annual rate of 0.49 percent. It was assumed that the percent of the population served would continue to increase at this rate through 2040 in accordance with the WRC forecasting methodology.

4.5.2 Employment Forecast

To forecast the growth of commercial water demands, historical employment data from the Office of Labor and Workforce for the years 2010 to 2018 was reviewed, as shown in Table 4-18.

Table 4-18 – Town of Plymouth Employment Data

Year	Total Labor Force	Employed Labor Force	Unemployed	Unemployment Rate
2010	29,963	27,221	2,742	9.2
2011	29,825	27,524	2,301	7.7
2012	29,726	27,698	2,028	6.8
2013	30,076	27,982	2,094	7.0
2014	30,465	28,633	1,832	6.0
2015	30,719	29,186	1,533	5.0
2016	31,104	29,876	1,228	3.9
2017	31,861	30,628	1,233	3.9
2018	32,974	31,818	1,156	3.5

The total labor force growth rate was extrapolated linearly into the year 2040, resulting in a projected total labor force of 40,078. It was assumed that the current unemployment rate, 3.5 percent, is unusually low and likely unsustainable. Instead, the Town of Plymouth average of 5.9 percent from 2010 to 2018 was used to project the employed labor force, as presented in Table 4-19.

Table 4-19 – Employment Forecast

Year	Total Labor Force	Employed Labor Force
2020	32,895	30,957
2025	34,691	32,648
2030	36,486	34,338
2035	38,282	36,028
2040	40,078	37,718

4.5.3 Demand Forecast

The demand forecast considers population growth, employment projections, and added demand from known future developments. According to the Town of Plymouth Planning Department, there are several developments currently in the planning or early construction stages. Estimated demand for these known future developments is listed in Table 4-20.

Table 4-20– Known Future Developments

Development	Additional ADD (GPD)	Expected Completion
Fairfield Inn	7,675	2020
Commerce Way Plaza (#43)	16,301	2020
Cordage Park	97,866	2020
Summer Reach[1]	17,280	2020
Forges & Bradford Expansion	11,595	2020
800 Colony Place	27,907	2025
Newfield Estates	6,900	2025
150 Water Street	7,200	2025
Tonya Stump School	6,000	2025
Home Depot Drive	35,728	2025
104 Carver Road	9,190	2025
Plaza Way Hotel	7,489	2025
#1 Commerce Way	13,008	2025
30 Prestige Way	2,125	2025
Village at Sawmill Woods	41,760	2025
Beaver Dam Road	7,320	2025
Cordage Park Future	58,860	2025
Home Depot Drive Future	21,457	2025
Entergy[2]	(72,000)	2025
Total	323,661	

1. The Summer Reach development is partially completed and some consumption was reported in the Division's 2018 billing data. The ADD in this table is reflects the full estimated demands for the development.
2. The Entergy Nuclear Power Plant is one of the Division's largest customers and expected to significantly reduce water consumption by 2025 as they work toward decommissioning the plant.

The Plymouth Planning Department has indicated that the recent growth within the Division's water system coverage area is not sustainable and is expected to slow, as the area is nearing full build-out. There are some opportunities for future development within the service area, which includes a total of approximately 1,700 acres owned by Entergy (one 200-acre parcel, another 1,500-acre parcel) and some Chapter 61 lands. The Planning Department indicated that the 200-acre Entergy parcel is not expected to be available for development within the next 20 years. The 1,500-acre Entergy parcel may be available for development, though that land is zoned to allow for a maximum of one unit per every three acres. The Chapter 61 lands are subject to Board of Selectman approval for any new development, which makes it an unlikely candidate for future developments. Although most parcels adjacent to the Plymouth Water System have already been built out, there remains the possibility that changes in land use could lead to denser development and increasing water demands.

For demand forecasting, the WRC forecasting methodology requires future residential demands be calculated assuming 65 RGPCD. Using similar reasoning, the WRC methodology requires a UAW assumption of 10 percent each year. A summary of the demand forecast for the years 2020 to 2040 is provided in Table 4-21 below.

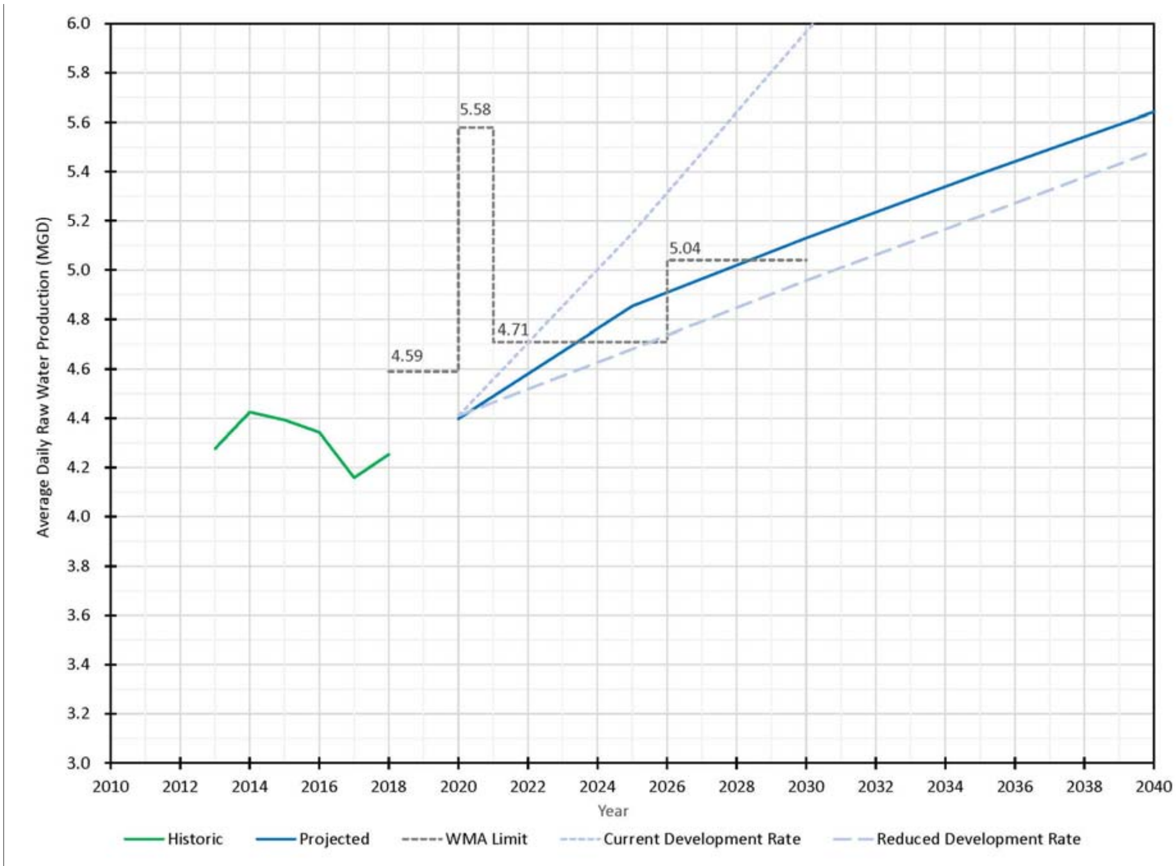
Table 4-21 – Demand Forecast

Year	Projected Residential ADD (GPD)	Projected Non-Residential ADD (GPD)	Projected UAW (GPD), 10%	Known Development ADD (GPD)	Projected Treatment Plant Losses (GPD)	Projected Total ADD (GPD)
2020	2,738,710	1,084,328	420,534	150,717	15,793	**4,410,082**
2025	2,921,719	1,143,528	447,177	323,661	17,380	**4,853,466**
2030	3,110,612	1,202,727	474,467	323,661	18,370	**5,129,838**
2035	3,285,656	1,261,927	500,234	323,661	19,304	**5,390,783**
2040	3,465,319	1,321,126	526,509	323,661	20,257	**5,656,873**

The forecast estimates that the water system will see an average net increase in demand of approximately 314,000 gpd every five years. However, this average, and the values shown in Table 4-21, only includes demands from known developments, all of which are anticipated to be complete by 2025. As a result, demand projections beyond 2025 calculated by the Office of Water Resources (OWR) method assume no future development beyond 2025. Chart 4-5 shows the WMA Permit limits, historic, and projected demands. There are three projected demand lines included in the chart:

- Projected Demands represents the rate at which demands would increase based on population growth and the additional demands from the future known developments listed in Table 4-20.
- Current Development Rate represents the rate at which demands would increase based on population growth and if current development rates held fast. This development rate is based on reviews completed by EP for the Division, which is likely unrealistic.
- Reduced Development Rate represents the rate at which demands would need to increase in order to remain in compliance with the current WMA Permit withdrawal limits.

Chart 4-5 – Plymouth Raw Water Usage and WMA Limits



Upon reviewing Chart 4-, the demands are estimated to meet or exceed the new WMA withdrawal limits in 2023 until the permit limit increases to 5.04 MGD in 2026. Shortly thereafter in 2028, the demands are estimated to exceed the 5.04 MGD limit.

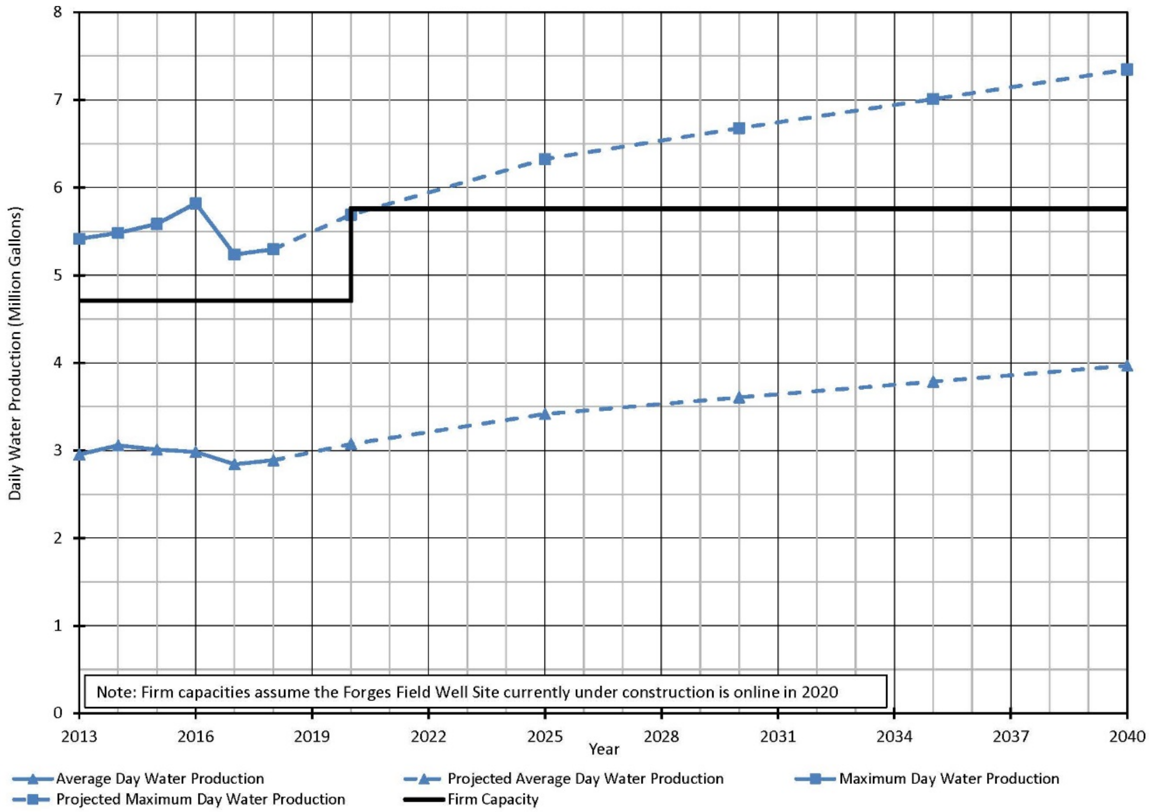
Based on these projections, even if no additional developments are approved beyond 2020, the Division is on track to exceed the WMA Permit limit near the end of 2025, just before the limit is increased in 2026.

4.5.4 Firm Capacity and Projected Demands

EP evaluated historical and projected water demands against the Division's firm capacity in the Northern Pressure Zones (Chart 4-6) and Eastern Pressure Zones (Chart 4-). Because the Northern and Eastern Pressure Zones are hydraulically disconnected, they operate as separate water systems and were evaluated as such under current conditions. For this analysis, Forges Field was added to the baseline firm capacity, as it will be online in 2020.

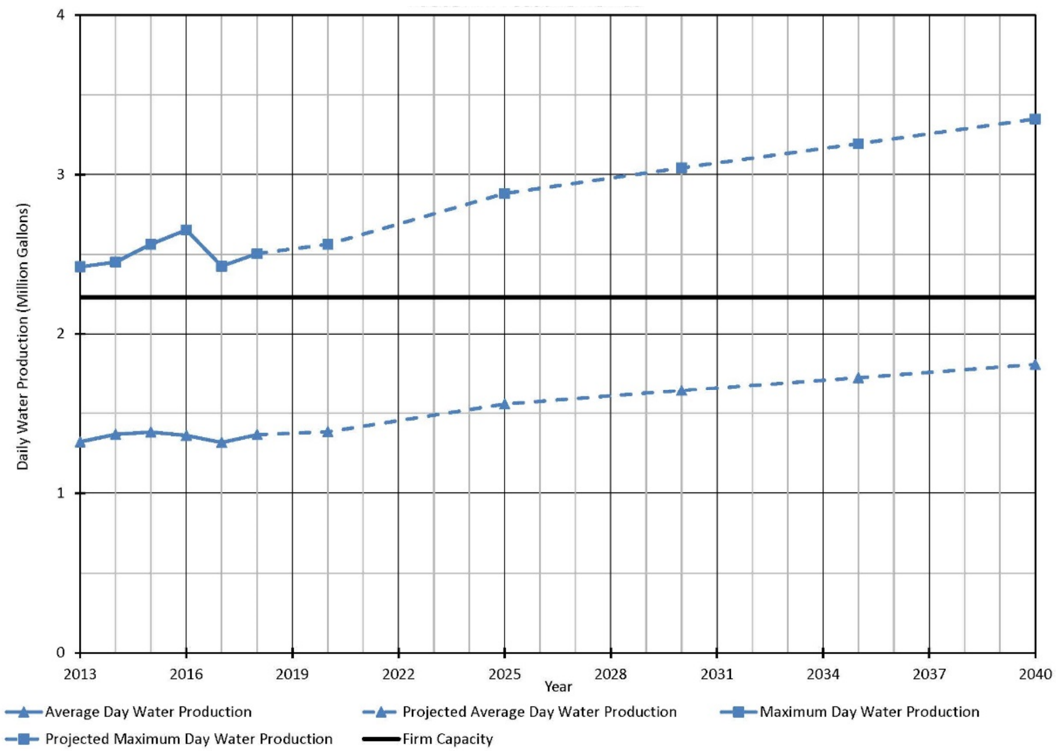
In the Northern Zones, the MDD is shown to have exceeded the firm capacity since 2013. The addition of the Forges Field WPS to the firm capacity will briefly help the Division meet demands in 2020, but a firm capacity deficit is expected soon thereafter as shown in Chart 4-6.

Chart 4-6 – Projected Daily Water Production vs Firm Capacity Northern Pressure Zones



In the Eastern Zones, the MDD is shown to have exceeded the firm capacity since 2013, which will worsen with continued growth as shown in Chart 4-7.

Chart 4-7 – Projected Daily Water Production vs Firm Capacity Eastern Pressure Zones



These deficits should to be addressed immediately, as a failure of one or more of the Division's water supply sources may result in a supply deficit. It should be noted that these projections do not take into consideration worsening water quality issues at the Division's existing supplies, which will reduce the projected firm capacity and further exacerbate the supply deficit.

4.6 RECOMMENDATIONS

The Division should continue to pursue lifting the Darby Pond WPS production restrictions. By lifting the restrictions at Darby Pond, the firm capacity of the Northern Zones could increase by as much as 0.9 MGD. This is equivalent to siting and constructing a new source at a much lower capital cost.

In parallel with lifting the Darby Pond production restrictions, the Division should continue to explore options for connecting all portions of their water system to maximize operational flexibility and redundancy. An interconnection between the Northern and Eastern Pressure Zones would improve overall system flexibility and redundancy; such as an interconnection between the Pine Hills and Manomet Pressure Zones, as described in Chapter 9.

In addition, the Division should continue to identify and develop new water supply sources as soon as possible to provide sufficient firm capacity for current maximum-day demands. While there are some recommendations within this report to improve firm capacity without adding any new sources, the demand projections suggest the Division needs additional new sources, particularly in the Eastern Pressure Zones. It is recommended that the Division continue to screen sites for the development of new sources, including a feasibility study of the Great and Little South Ponds (currently permitted as emergency sources) as potential active surface water sources.

It is strongly recommended that, if development is to continue, the Division will need to strictly enforce water use restrictions, including non-essential outdoor water use. Restrictions for non-essential outdoor water use should be in place from May 1st to September 30th and limit use to two days per week, before 9 a.m. and after 5 p.m. Additional conservation efforts could include implementing a water use restriction by-law to help limit non-essential outdoor water use, implementing a water banking system to help fund conservation efforts, and initiating land use controls for future developments. Additionally, a targeted water audit program could be developed for the Division’s top fifteen water users. Site visits can be performed to survey each facility and discuss water use practices with each user to educate them on water usage and the potential for water savings.

Additional work can be performed to minimize nonrevenue water through demand management and leak detection in the Eastern Pressure Zones. Consideration should be made to budget annual surveys in the West Plymouth, Plymouth Center, and Manomet Pressure Zones, with particular attention to the West Plymouth Pressure Zone. As shown in Table 4-15, this pressure zone has the single highest water supply deficiency and would benefit most from reduction of unaccounted-for water. In addition to leak detection in the distribution system, leaks on private property should be remedied as soon as possible. The Division should work with home-owners to mitigate private leaks.

The latest WMA Permit also will require annual AWWA M36 water audits and implementation of a water loss control program should UAW exceed 10 percent over the next two years. The AWWA M36 methodology takes economic factors into consideration to develop a well-balanced, but fiscally responsible plan for minimizing nonrevenue water. AWWA M36 water audits are an industry best practice; it is recommended the Division conduct these audits on a regular basis regardless of permit requirements. As a part of the water loss control program, EP recommends the Division conduct an annual review of metered water usage by pressure zone and compare that to the total water provided to the zone.

Lastly, the Division should work with the Plymouth Planning Department to develop a strategy to ensure sustainable and smart growth. Any new development should look to minimize its water use through water saving devices. Options for water saving devices include water-less urinals and low-flow shower heads. In addition, the Division could expand its current public outreach on providing water-saving devices and rain barrels to the consumers to increase public awareness of water conservation. The latest WMA Permit lists additional water efficiency practices including irrigation controls, the adoption and enforcement of efficiency ordinances, and adjustments to billing policies. Since the water system has historically experienced elevated residential per capita usage, the Division should particularly stress water efficiency on proposed residential developments to maintain compliance with the 65 RGPCD standard.

Chapter 5 – New Source Site Screening & Preliminary Well Exploration

5.1 SUMMARY

The 2006 Water System Master Plan for the Division recommended that at least three new groundwater supplies be developed over the next 10 years to meet water supply deficits and anticipated growth. EP has worked with the Division to develop and permit the Forges Field new source water supply, which is approved by MassDEP and will be online in Spring 2020. The well is permitted for 1.05 MGD. The first step in the new source water supply development process is the screening desktop study in which potential public water supply well sites are identified for further investigation. For the most part, the desktop study focused on Town-owned parcels, but could be expanded to include potential private large parcels of land for purchase. This desktop study included:

- Review 2006 Water System Master Plan Sites (Wright-Pierce)
- Review 2006 – 2009 Plymouth Water Supply Exploration Reports (Horsley Witten)
- Compile Town Owned Parcels that can support a 400-foot Zone I Buffer
- Evaluate Sites with Respect to Receptors and Potential Sources of Contamination
- Evaluate Sites with Respect to Other Criteria (i.e., geologic conditions, proximity to coastline, land use restrictions etc.)
- Review of deeds for conservation restrictions

Figure 5-1 is a preliminary site screening map showing potential public water supply sites. The potential sites are assigned a number and the map includes a grid for referencing the site locations. Following is a summary of the desktop study results.

1. A total of 70 potential sites were reviewed, as shown on Figure 5-1.
2. The majority of potential water supply parcels were eliminated from further consideration because of proximity to environmental receptors.
3. The following Town-owned sites, as shown on Figure 5-2, were identified as potential water supply sites for further consideration and evaluation:
    a. Sites #27 and #28 Parting Ways parcel in North Plymouth (location A2)
    b. Site #3 Micajah Pond in West Plymouth (location B2)
    c. Site #20 Briggs Site (location D3)
    d. Site #23 (location E4)
    e. Site #31(location D3)
    f. Site #57 Indian Brook (location E3)
    g. One or a combination of Sites #14, #17 (200-Acre Site), #19, #23 or #31 in South Plymouth (locations C4, D3, E4). These sites are not located in proximity to the Town's water system infrastructure; therefore, a large quantity well is needed to justify developing a public

water supply. These sites are considered individually or in combination, because site-screening criteria indicate the potential presence of good aquifer material that would allow for development of a single well, large water supply source; however, the wells are located in proximity to kettle ponds, most of which are considered sensitive environmental receptors. As such, pumping two or three wells at a lower pumping rate would spread the drawdown over a larger area with less drawdown at any one location.

4. The Division should consider evaluating the Entergy parcels (Site #30, location D2) near Manomet Hill
5. Sites #24 and #25/#63/#69/#70 (locations E4, C5, D5) were not considered further because of the long distance to existing water system infrastructure. The Division should consider evaluating these sites further to determine if the parcels should be preserved for potential future water supply development.

Based on the results of the Desktop Study, the next steps for the New Source process is to further evaluate the most favorable sites with a subsurface groundwater exploration test well drilling program. In July 2019, EP conducted a subsurface exploration study at the Parting Ways Site (Site #28 South Parting Ways parcel) in North Plymouth that included installation of a test well and observation well and conducting a short-term, 2-hour pumping test to evaluate potential wellfield yield. The test well location is approximately 2,000 feet from a 12-inch water main in the West Plymouth Zone, approximately 1.75 miles from the North Plymouth Well, and approximately 0.6 miles from the Darby Pond Well and, as such, could be tied into the West Plymouth Pressure Zone. Based on this subsurface investigation, the test site estimated potential well yield was approximately 285,000 gpd.

Should the Division proceed with a water supply well at the South Parting Ways site, additional observation wells should be installed and tested to optimize the production well location and well yield. Although groundwater exploration and testing indicates that the Site #28 South Parting Ways has a relatively low potential well yield of 285,000 gpd, EP recommends that the Division preserve this site for potential future development.

The scope, methodology and results of the new source water supply desktop study and exploration results are discussed in more detail below and in Appendices A, B, and C.

5.2 BACKGROUND

In addition to recommending that the Division develop at least three new water supply wells over the next 10 years, the 2006 Water System Master Plan had the following recommendations, which although not the focus of this desktop study, the Division should continue to address as part of the Division's new source program.

1. The consideration of wastewater and stormwater reuse for aquifer recharge, industrial process water, and irrigation of recreational facilities is another important aspect of efficient management of valuable water resources. The more efficient the Division becomes in its use, management, and

planning of water resources, the more receptive the Commonwealth will be to requests for additional supplies needed to plan for population growth and system expansion.

2. Land use protection of all additional potential water supply sites is recommended in order to preserve additional water supply options for the future.

3. In order to preserve existing and potential future water supplies, it is imperative that the Division obtain control over the Zone 1 area for the priority sites. In addition, the Division should institute and enforce protective land use measures for the watersheds and Zone 2 and 3 areas for all potential water supply sites. The water resources in Plymouth are finite and preservation of the remaining available groundwater areas is critical for the sustenance of future generations.

4. Negotiations with the Massachusetts Department of Environmental Protection are recommended to explore opportunities for revisions to the Darby Pond level restrictions

Between 2007 and 2009, Horsley Witten conducted preliminary subsurface investigations for a new source water supply at five sites as follows:

1. Site # 13 – Forges Field Site
2. Site #17 – 200-Acre Site
3. Site #20 – Briggs Site
4. Site #6 –Rocky Pond Road
5. Site #23 – Treetop Way

The scope of these additional investigations included installation of a test well and observation well, conducting a short-term pumping test, compiling and evaluating the results for development of a new source water supply. The results of these five investigations were incorporated into the desktop study for identifying a potential new source water supply site.

EP has worked with the Division to develop and permit the Site #13 Forges Field new source water supply, which is scheduled to be online in Spring 2020.

EP also conducted an extensive site screening, subsurface investigations and five-day pumping test at Site #17 – 200-Acre Site. The 200-Acre Site is not located near existing water system infrastructure and significant investment is required to develop a new water supply source at this location. The site also has a conservation restriction on the parcel that may pose limitations on water supply development. However, excellent aquifer material is identified at the 200-Acre Site, with a potential well yield of over 2 MGD. Groundwater modeling was performed for the site to delineate a Zone II Area and to evaluate potential pumping impacts to nearby kettle-hole ponds (Six Ponds) using the USGS Modflow groundwater flow model for the Plymouth-Carver-Kingston-Duxbury Aquifer (Masterson et al. 2009), updated with site-specific hydrogeologic data. Impacts to nearby ponds were evaluated under pumping rates ranging from 0.25 MGD to 2 MGD. Higher pumping rates result in greater lowering of water levels in the Six Ponds. For comparison, at a pumping rate of 1 MGD the groundwater model results indicate that water level drawdown at the Six Ponds could range from 0.1 feet at Halfway Pond to 1.1 feet at Little Long Pond.

Permitting of a public water supply site at Site #17 (200-Acre Site) is currently on hold; however, may be re-considered at a future date, either as a single source or in conjunction with nearby Sites #14, #19 or #23 (discussed below).

5.3 DESKTOP SITE SCREENING METHODOLOGY

5.3.1 Initial Screening

EP conducted a new source water supply screening desktop study for the Division. As an initial screening, Town owned parcels were compiled to determine if the Town owned and controlled the Zone I, which is the MassDEP required protective radius required around a public water supply well. The applicable Zone I radius for all water supply wells that produce more than 100,000 gpd is 400-feet. MassDEP Drinking Water Regulations 310 CMR 22.21 require that the Zone I of the proposed well be owned or controlled by the supplier of water and current and/or future land uses within the Zone I must be limited to those directly related to the provision of public drinking water or will have no significant adverse impact on water quality. Town owned parcels were compiled on a map and a 400-foot buffer mapped on each parcel. The open space area inside this 400-foot buffer is the area owned by the Division that could support a public water supply well. Town owned parcels with the 400-foot Zone I are shown on Figure 5-1. As shown on Figure 5-1, a total of 70 parcels were identified as potential water supply parcels and were evaluated further based on the following criteria:

- Proximity to Environmental Receptors
- Potential Sources of Contamination
- Other Additional Criteria (i.e., geologic conditions, land use restrictions, proximity to coastline, etc.)

5.3.2 Proximity to Environmental Receptors

The Town of Plymouth is located in a unique coastal plain setting, with hundreds of ponds, vernal pools, rivers and streams, wetlands, and cranberry bogs. Proximity to environmental receptors was the first criteria used to screen those parcels in which the Town owns and controls a 400-foot Zone I radius and to identify potential new source water supply sites. The MassDEP GIS database was used to identify the following sensitive environmental receptors:

- Areas of Critical Environmental Concern (ACEC)
- Natural Heritage and Endangered Species Program (NHESP) Priority Habitats of Rare Species
- NHESP Estimated Habitats of Rare Wildlife
- Vernal Pools (Certified and Potential)
- Wetlands and Cranberry Bogs

According to the *Estimated Hydrologic Budgets of Kettle-Hole Ponds in Coastal Aquifers of Southeastern Massachusetts,* USGS 2011, *"the coastal plain of southeastern Massachusetts, including the Town of Plymouth, contains numerous freshwater ponds that are important ecological and recreational resources* *for the region. These coastal ponds, known as kettle-hole ponds are in hydraulic connection with the underlying aquifer and, therefore, receive water from and contribute water to the aquifers. Therefore, for potential water supply sites located in close proximity to kettle-hole ponds pumping effects to the aquifer and ecological habitats need to be considered."*

The 2006 Water System Master Plan noted *"TNC* [The Nature Conservancy] *has identified several complexes of coastal plain ponds in the PCA* [Plymouth-Carver Aquifer] *area. These pond complexes support some of the best remaining examples of coastal plain pond shore communities on Earth. This merits specific, increased concern for coastal plain ponds that support numerous rare and threatened species; in particular, Great South Pond Complex, the Widgeon Pond Complex, and the College Pond Complex."* EP discussions with Wildland's Trust and U.S. Fish and Wildlife (USF&W) also identified the Six Ponds Complex as a potential environmentally sensitive area. Proximity to kettle-hole ponds and in particular the Great South Pond, Widgeon Pond, College Pond, and Six Pond Complex were considered when screening potential public water supply well sites. The location of these pond complexes are shown on Figure 5-1 and 5-2.

Finally potential water supply sites within the Eel River Watershed area, a MassDEP cold-water fishery, were excluded from further consideration in the desktop screening, because the new source water supply Forges Field well, is located within the Eel River Watershed.

5.3.3 Potential Sources of Contamination

MassGIS land use maps were examined for potential water supply sites that passed initial screening to determine if any potential sources of contamination to groundwater are located within a ½-mile radius. In accordance with MassDEP *Chapter 4 – Groundwater Supply Development and Source Approval Process* Section 4.3.1.3 MassDEP Site Exam/Pumping Test Proposal Review:

> *"MassDEP may deny a site located within 1/2 mile of potentially serious sources of pollution such as active or abandoned sanitary landfills, major fuel storage and/or transmission facilities, automobile graveyards and junkyards, road salt stockpile areas lacking adequate containment structures, hazardous substances storage areas, etc. Approved sites are subject to such additional monitoring requirements as may be considered necessary by MassDEP."*

Additional potential areas of concern also include agricultural uses, industrial parks, combined sewer overflows and sanitary sewer overflows, and wastewater treatment facilities.

As a final screening for select sites, the MassDEP Massachusetts Contingency Plan (MCP) Waste Site & Reportable Releases database was reviewed for potential oil and/or hazardous materials release sites that could potentially impact water quality.

5.3.4 Additional Site Screening

In additional to environmental receptors and sources of contamination, potential water supply sites were screened based on the following criteria:

1. Land Use Restrictions – For potential water supply sites that passed the initial site screening, Town assessor cards were reviewed and the MassDEP GIS database Protected Open Space maps to

identify potential land use restrictions or conservation restrictions. In addition, the Plymouth County Registry of Deeds online database was reviewed for conservation or other land use restrictions. It should be understood that these records might not identify all conservation or land use restrictions.

2. Proximity to coastline – Potential water supply sites located too close to the Atlantic coastline may have a thin freshwater aquifer and are more susceptible to salt water intrusion or salt water upconing due to pumping. For potentially favorable sites in close proximity to the coastline, the interface was estimated using the Ghyben-Herzberg relation. The Ghyben-Herzberg relationship is an analytical relationship between the freshwater head in a coastal aquifer and the depth from sea level to the freshwater-saltwater interface. Freshwater has a density of about 1 gram per cubic centimeter (g/cm^3), whereas that of seawater is about 1.025 g/cm^3. The Ghyben-Herzberg ratio states, for every meter of fresh water in an unconfined aquifer above sea level, there will be forty meters of fresh water in the aquifer below sea level. The Ghyben-Herzberg relation is a general approximation, subject to simplifying assumptions (e.g., relatively uniform geology, unconfined aquifer, etc.).

3. Geologic conditions - MassGIS aquifer maps and MassGIS surficial geology maps were used to evaluate the potential presence or absence of aquifer material. The MassGIS surficial geology layer is based on USGS surficial geology maps for Massachusetts. Although most of Plymouth is underlain by potentially productive aquifer material, Manomet Hill in particularly is characterized by thin overburden material underlain by dense non-aquifer material.

4. Sustainable Water Management Initiative (SWMI) Basin – The Plymouth WMA Permit includes water withdrawal sources within the South Coastal Basin and Buzzards Bay basin. Permitting a water source outside either of these basins is considered less favorable. Almost all of Plymouth is located within the Buzzards Bay and South Coastal Basins, with only a small area at the very north end of Plymouth located in the Taunton River Basin. Most wastewater in Plymouth is discharged to the Buzzards Bay and South Coastal Basin via either onsite septic systems or treated wastewater effluent. Permitting a well outside the South Coastal or Buzzards Bay watersheds would require an Interbasin Transfer Approval from DCR, with water withdrawal from the Taunton River Basin and wastewater discharge to the South Coastal and Buzzards Bay Basins.

5. Hydraulic Benefit to the Water System – The location of the existing water sources and the topology and geometry of the water system create a varied pressure profile. As a result, certain regions are more water-stressed than others, and the introduction of a water source offers varied benefits depending on location.

6. Previous Investigations – In addition to the 2006 Water System Master Plan, the following subsurface investigation reports, provided by the Division, were reviewed to evaluate subsurface geology and potential aquifer conditions.

   - *Plymouth Water Supply Exploration – Summary of Initial Investigations and Subsurface Drilling Plan*, Horsley Witten Group, December 11, 2006.

- *Plymouth Water Supply Exploration – Summary of Forge's Field Well Investigation*, Horsley Witten Group, June 26, 2007
- *Plymouth Water Supply Exploration – Summary of Plymouth South High School (200-Acre Site) Well Investigation*, Horsley Witten Group, August 21, 2009
- *Plymouth Water Supply Exploration – Summary of Briggs Well Investigation*, Horsley Witten Group, August 13, 2008
- *Plymouth Water Supply Exploration – Summary of Treetop Way Well Investigation*, Horsley Witten Group, October 12, 2007
- *Plymouth Water Supply Exploration – Summary of Rocky Pond Road Well Investigation*, Horsley Witten Group, August 24, 2007

It should be noted that this basic level of screening is based on readily available online databases. The MassGIS assessors database is listed as last updated in 2017. In addition, this study included a preliminary evaluation of potential conservation or deed restrictions that may exist on these Town-owned properties that could exclude the use of this land for public water supply development. Additional research may be required for that purpose. Data from this desktop study may need to be updated if more than six months old.

5.4 DESKTOP SITE SCREENING RESULTS

As shown on Figure 5-1, EP identified 70 Town-owned parcels in which the Town owns and controls the 400-foot Zone I areas. These 70 sites were evaluated based on proximity to potential receptors, potential sources of contamination, proximity to coastline, and potential for aquifer material. The results of this additional screening are summarized in the following Table 5-1 and potential sites are shown on Figure 5-2. Sites are ranked into three categories, as follows:

Favorable – Favorable sites warrant further investigation

Potential – Potential sites may warrant further investigation, but have other limiting factors that make them less favorable

Unfavorable – Unfavorable sites have potential issues or concerns that make permitting a public water supply well difficult

Table 5-1 Desktop Site Screening Summary

Site ID	Site Name	Map Location	Initial Rating	After Desktop Study Rating	Site Conditions
1		**B3**	Unfavorable		Within Eel River Watershed, Zone I would require Easement from Myles Standish State Forest, downgradient/cross-gradient of airport
2		**B2**	Unfavorable		Within Eel River Watershed, Zone I would require Easement from Myles Standish State Forest, downgradient of airport

Site ID	Site Name	Map Location	Initial Rating	After Desktop Study Rating	Site Conditions
3	Micajah Pond	**B2**	Favorable	Potential	Proximity to Federal Furnace Well, infrastructure, and West Plymouth Pressure Zone; however, near Route 3, side-gradient/downgradient of airport. Public Conservation Restriction.
6	Rocky Pond Road	**B3**	Unfavorable		Within Eel River Watershed
7		**C2**	Unfavorable		Within Eel River Watershed
9		**D2**	Unfavorable		Within Entergy parcel, proximity to Nuclear Power Plant
10		**D2**	Unfavorable		Within Entergy parcel, proximity to Nuclear Power Plant
11		**C3**	Unfavorable		Parcel owned by USFWS, within Eel River Watershed
12		**C3**	Unfavorable		Within Eel River Watershed, Forges Field water supply currently being developed
13	Forges Field	**C2**	Favorable	Favorable	Currently being developed
14		**C4**	Potential	Potential	Distance from infrastructure, upgradient/sidegradient of Six Ponds Complex, groundwater modeling required.
15		**C3**	Unfavorable		Proximity to Six Ponds Complex
16		**C3**	Unfavorable		Proximity to Six Ponds Complex
17	200-Acre	**D3**	Potential	Potential	Tested, excellent aquifer material, proximity to Six Ponds complex
18		**D3**	Unfavorable		Proximity to Six Ponds Complex
19		**D3**	Favorable	Potential	Proximity to Six Ponds Complex
20	Briggs	**D3**	Potential	Unfavorable	Located adjacent to 40B with onsite wastewate treatment system, NHESP, Manomet Landfill
22		**D4**	Unfavorable		Proximity to Savery Pond Well
23	Savery Pond	**E4**	Favorable	Favorable	
24	Treetop Way	**E4**	Potential	No Additional Evaluation **	Proximity to ocean and cranberry bogs; distanc from infrastructure
25		**C5**	Potential	No Additional Evaluation **	Long distance from infrastructure.
26		**D5**	Unfavorable		Inside Area of Critical Environmental Concern
27	North Parting Ways	**A2**	Favorable	Potential	Located in Taunton River Basin, Interbasin Transfer issues requiring WMA and DCR approvals.
28	South Parting Ways	**A2**	Favorable	Potential	Tested, low yield, close proximity to West Plymouth Pressure Zone infrastructure
29	Entergy	**D2**	Unfavorable		Proximity to Eel River Watershed, surficial geology, proximity to Entergy Nuclear Power Plant
30	Entergy	**D2**	Potential	Potential	Surficial geology, proximity to Entergy Nuclear Power Plant

Site ID	Site Name	Map Location	Initial Rating	After Desktop Study Rating	Site Conditions
31		**D3**	Favorable	Favorable	NHESP Priority Habitat
32		**B2**	Unfavorable		Vine Hill Cemetery
33		**C2**	Unfavorable		Plymouth North High School
34		**B2**	Unfavorable		Industrial Area
35		**B1**	Unfavorable		Russell Sawmill Pond Conservation Area, Sewer Main
36		**A2**	Unfavorable		West Elementary School
37		**C2**	Unfavorable		WWTP
38		**C2**	Unfavorable		Plymouth Community Intermediate School
39		**C2**	Unfavorable		Plymouth Town Forest, Great South Pond Complex
40		**B2**	Unfavorable		Plymouth Town Forest, Great South Pond Complex
41		**B2**	Unfavorable		Conservation Area, Power Lines, Eel River Watershed
42		**B2**	Unfavorable		Undeveloped, Power Lines, Eel River Watershed
43		**C3**	Unfavorable		Plymouth South High School
44		**C2**	Unfavorable		Undeveloped, Eel River Watershed
45		**C2**	Unfavorable		Russell Mill Pond Conservation Area, Eel River Watershed
46		**C3**	Unfavorable		Eel River Preserver, Eel River Watershed
47		**B3**	Unfavorable		Boot Pond Conservation Area, Eel River Watershed
48		**A2**	Unfavorable		West Plymouth Recreation Area Park, proximity to airport
49		**A2**	Unfavorable		Proximity to Airport
50		**A3**	Unfavorable		Proximity to Airport
51		**A2**	Unfavorable		Proximity to Airport
52		**B2**	Unfavorable		Morton Park, near Little Pond and Billington Sea
53		**B2**	Unfavorable		Morton Park, near Little Pond
54		**B2**	Unfavorable		Billington Sea Wildlife Conservation Easement
55		**B2**	Unfavorable		Eel River Watershed
56		**D3**	Unfavorable		Proximity to landfill
57	Indian Brook	**E3**	Potential	Potential	Indian Brook School, located downgradient / cross gradient of 40B development with onsite wastewater treatment system. Much of parcel is exempt from Conservation Restriction
58		**E3**	Unfavorable		Center Hill Preserve, proximity to ocean
59		**E4**	Unfavorable		Cedarville Landfill, NHESP Priority Habitat
60		**D4**	Unfavorable		Inside Area of Critical Environmental Concern
61		**D5**	Unfavorable		Inside Area of Critical Environmental Concern
62		**D5**	Unfavorable		Long distance from current infrastructure

Site ID	Site Name	Map Location	Initial Rating	After Desktop Study Rating	Site Conditions
63		**D5**	Potential		Long distance from current infrastructure, NHESP Priority Habitat
64		**D4**	Unfavorable		Disturbed ground, sand pit?
65		**D4**	Unfavorable		Power Lines, NHESP Priority Habitat
66		**D4**	Unfavorable		Bloody Pond Conservation Area, next to Bloody Pond
67		**D4**	Unfavorable		Undeveloped land near solar farm
68		**E3**	Unfavorable		Near Ellisville Well
69		**D5**	Potential		Next to Little Rocky Pond, NHESP Priority Habitat, Long distance from current infrastructure
70		**D5**	Potential		Long distance from current infrastructure

In summary, many sites are considered unfavorable for obvious reasons and are not evaluated further, including:

- Located within a sensitive pond complex with existing public water supply well(s) or within a priority resource area;
- Proximity to potential sources of contamination (i.e., cemetery, industrial park, airport, landfill etc.);
- Proximity to coastline.

The following sites are considered favorable or potential and are evaluated further:

a. Site #27 and #28 Parting Ways parcel in West Plymouth Pressure Zone (location A2)
b. Site #3 Micajah Pond in the West Plymouth Pressure Zone (location B2)
c. Site #20 Briggs Site (location D3)
d. Site #23 (location E4)
e. Site #31 (location D3)
f. Site #57 Indian Brook (location E3)
g. One or a combination of Sites #14, #17 (200-Acre Site), #19, #23 or #31 in South Plymouth (locations C4, D3, E4). These sites are not located in proximity to the Town's water system infrastructure; therefore, a large quantity well is needed to justify developing a public water supply. These sites are considered individually or in combination, because site-screening criteria indicate the potential presence of good aquifer material that would allow for development of a single well, large water supply source; however, the wells are located in proximity to kettle ponds, most of which are considered sensitive environmental receptors. As such, pumping two or three wells at a lower pumping rate would spread the drawdown over a larger area with less drawdown at any one location.

Sites #24 and #25/#63/#69/#70 (locations E4, C5, and D5) are considered potential public water supply sites, but because these sites are located further from the existing water system infrastructure, an additional desktop screening was not performed for these parcels, but could be performed at a later date. The Division should consider evaluating these sites further to determine if the parcels should be preserved for potential future water supply development.

As part of the desktop study, six sites that were considered favorable or potential public water supply sites were evaluated in more detail and the results of this analysis are discussed in the following sections. The Division specifically requested that EP evaluate the Site #20 Briggs to determine if the Town should maintain ownership and control of this property for potential public water supply development.

5.4.1 Sites #27 and #28 - Parting Ways Site

The Parting Ways site is owned by the Town of Plymouth and consists of two parcels identified as North Parting Ways and South Parting Ways, which are bisected by Plympton Road (Figure 5-3). Following is a summary of the desktop study results for the Parting Ways property.

- The North Parting Ways parcel was eliminated from further consideration, because the site is located within the Taunton River drainage basin (Figure 5-4). The Division's WMA Permit includes water supply sources in the Buzzards Bay Basin and South Coastal Basin, but not the Taunton River basin. Most wastewater in Plymouth is discharged to the Buzzards Bay and South Coastal Basin via either onsite septic systems or treated wastewater effluent. Permitting a well outside the South Coastal or Buzzards Bay watersheds would require an Interbasin Transfer Approval from DCR, with water withdrawal from the Taunton River Basin and wastewater discharge to the South Coastal and Buzzards Bay Basins. Under the SWMI, the Taunton River Basin Groundwater Withdrawal Category is >10-25% depleted. Buzzards Bay and South Coastal Basins do not have a category at this time. For these reasons, permitting this parcel could be difficult.
- The South Parting Ways site appears to have favorable aquifer material based on surficial geology maps; limited nearby sensitive environmental receptors; and no identified potential sources of contamination nearby (Figures 5-5 and 5-6).
- Land uses in the vicinity of the South Parting Ways consist primarily of forest and medium density residential, with some participatory recreation and cranberry bogs (Figure 5-7)
- Multiple groundwater supply wells are located within a 0.5-mile radius of the Site (Figure 5-8). Four water supply well couplets (eight wells total) are located northwest of the Site on property owned by the Congregation of the Sisters of Divine Providence, with the nearest wells located approximately 0.34 miles northwest of the Site. The Site is located inside an Interim Wellhead Protection Area and sits just outside multiple DEP Approved Zone IIs including three in Kingston and two in Plymouth.

- EP conducted a site walkover at the Parting Ways site and a couple trails exists from Plympton Road to the proposed drilling location at the South Parting Ways site (where the Town has ownership and control of the 400-foot Zone I radius).
- Possible concerns with the Parting Ways site is that the parcel is listed as a Protected Open Space. Portions of the site are listed on the National Register of Historic Places. The Parting Ways Cemetery is located on the North Parting Ways parcel adjacent to Plympton Road. The property deed for North Parting Ways parcel notes that the in 1977 the Town of Plymouth granted approximately 15 acres of the property to Parting Ways The Museum of Afro-American Ethnohistory, Inc. for purposes of archaeological research and excavations and for construction an historical museum and educations resource center for African American Studies.

  At the Parting Ways Cemetery, there is a brief narrative about the history, origins, and significance of Parting Ways. Approximately 28-acres, including the cemetery, are listed on the National and State Registry of Historical Landmarks. The site is an African American settlement with four families, dating back to the Revolutionary War. The Parting Ways cemetery is where the African American soldiers were buried. Archaeological excavations have been conducted at Parting Ways that have discovered artifacts, building foundations, etc.
- The National Register of Historic Places indicates that the Parting Ways Archeological District was added in 1979 and includes 1,063 acres. Total acreage for the Parting Ways Site as studied is approximately 75 acres. This discrepancy needs to be understood.
- Although site conditions are favorable for additional exploration, the Division should get more information on the Protected Open Space and historical restrictions. Protected open space and historical restrictions could apply not only to the proposed drilling location, but also to the water main and access routes.
- Information readily available on the internet indicate that in 1975 and 1976 archeological excavations at the Parting Ways Site were led by Deetz, a Brown University archeologist and Plimoth Plantation's assistant director. This study is comparatively recent and could provide relevant information on the location of areas of archeological significance and historic restrictions.
- This water source would fall in the West Plymouth Pressure Zone, between the Darby Pond and North Plymouth Wells. Existing residual pressures in this region are adequate, and available fire flows are sufficient. However, carrying capacity in the surrounding trunk mains is limited in this region of the pressure zone, and significant water main upgrades may be required to allow transmission of water to the rest of the pressure zone without creating excessively high pressures in the vicinity of the well.

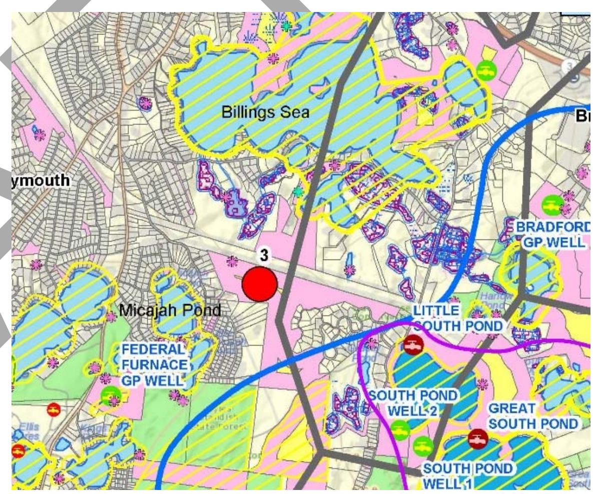
In July 2019, EP conducted a subsurface investigation at Site #28 South Parting Ways parcel. The results of the subsurface investigation are presented in Appendix A. In summary, a subsurface exploration study was conducted that included installation of a test well and observation well and conducting a short-term, 2-hour pumping test to evaluate potential wellfield yield. The test well location is approximately 2,000 feet from a 12-inch water main in the West Plymouth Zone, approximately 1.75 miles from the North Plymouth Well, and approximately 0.6 miles from the Darby Pond Well and, as such, could easily be tied into the West Plymouth zone, but upgrades to the infrastructure may be required. Based on this subsurface investigation:

- Depth to groundwater at the site is approximately 45 to 50 feet bgs
- Refusal was encountered at 114 feet bgs
- Potential aquifer material was identified between 90 and 103 feet bgs, and
- The test site estimated potential well yield was approximately 285,000 gpd.

Should the Division proceed with a water supply well at the South Parting Ways site, additional observation wells should be installed and tested to optimize the production well location and well yield. Although groundwater exploration and testing indicates that the Site #28 South Parting Ways has a relatively low potential well yield of 285,000 gpd, EP recommends that the Division preserve this site for potential future development

5.4.2 Site #3: Micajah Pond

Site #3 Micajah Pond is located in the West Plymouth Pressure Zone and should be considered as a secondary alternative to Parting Ways Site. Readily available information regarding Site #3 indicate that the Site is located:

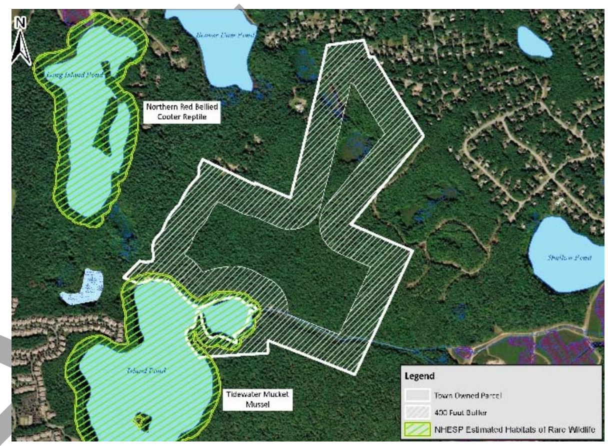


- Within an area mapped as a potentially productive high yield aquifer.
- In proximity to the Federal Furnace well and to the following surface water features – Micajah Pond and South Pond complexes, which are listed as NHESP Priority Habitat of Rare Species and approximately 0.5 miles upgradient of the Billington Sea, listed as a NHESP Estimated Habitat of Rare Wetland Wildlife.
- Adjacent to Route 3, a powerline easement and less than 0.5 miles from a heavily residential area.
- Side-gradient/downgradient of the Plymouth Airport.
- No significant MassDEP state listed hazardous waste sites of concern are identified within a ½-mile radius of the Site #3; the nearest release sites include a residential above ground storage tank release and a residential transformer release.
- Property deed indicates the parcel is to be maintained under the Conservation Commission and that the land shall be held in trust in perpetuity for public conservation purposes.
- Water from this source would likely be introduced to the West Plymouth Pressure Zone, just north of the Federal Furnace Well. Depending on the yield, this could allow for the decommissioning of

the Federal Furnace Well, which has experienced declining water quality. However, if both sources were operated in tandem, this would likely result in competing pressures suppressing the output of each well slightly. If this source were capable of producing high flows, it may warrant trunk main upgrades along Federal Furnace Road to allow for more efficient transmission of water to the rest of the pressure zone.

his site should be considered for further evaluation as a potential public water supply site. However, proximity to potential sensitive environmental receptors, as well as proximity to Route 3, a powerline easement, and the Plymouth Airport could adversely affect the approvable yield and/or water quality. In addition, the presence of a potential conservation restriction should be explored.

5.4.3 Site #20 – Briggs Site



Site #20 Briggs Site Desktop Study Results

The 2006 Water System Master Plan listed Site #20 – Briggs Site (shown on Figure 5-9) as a top tier site because:

a. Initial modeling indicated drawdown at Great Island Pond would be less than 2 feet (between 1 to 2 feet); and,
b. Preliminary borings install in the 1970's by Metcalf and Eddie (M&E) indicated favorable hydrogeology in the area.

In 2007, HW conducted a subsurface investigation at the Briggs site and identified potential aquifer material at the Site. A test well was installed and screened from 115 to 130 feet bgs and depth to water was measured at 38 feet bgs. The report identified favorable aquifer material with potential well yield of up to 2.5 MGD. The well specific capacity during the short-term pump test was 10.5 gpm/foot of drawdown. Assuming 70 feet of available water, the well yield would be approximately 1 MGD.

The Sawmill Woods affordable housing development is located adjacent to the Briggs Site, with construction beginning in 2019. The Sawmill Woods Development as proposed includes a centralized on-site wastewater treatment plant that would be located near the edge of the Zone II for a well at the Briggs Site. At the request of the Division, a desktop study was performed for Site #20 – Briggs Site to evaluate whether the Town should maintain this parcel as a potential public water supply site. The Briggs Site desktop study of readily available information indicates the following.

- The Briggs Site abuts the Manomet Zone water distribution system and is located within the Zone II area for the Wannos Pond public water supply well (Figure 5-1).

- The Briggs parcel is located in close proximity to four kettle-hole ponds (Figure 5-9). The parcel abuts Great Island Pond, is less than 1,000 feet from Long Island Pond and Beaver Dam Pond, and approximately 1,500 feet from Shallow Pond. Island Pond and Long Island Pond are listed as NHESP Estimated Habitats of Rare Wildlife.

- Wetlands are located on the north end of the parcel and nine certified vernal pools and two potential vernal pools are located within a ½-mile radius of the Briggs Site (Figure 5-10).
- Cranberry bogs are located approximately 1,000 feet from the Briggs parcel (Figure 5-10).
- The Site is located within an area mapped as a potentially productive high yield aquifer and surficial geology maps indicate that the Briggs site should have favorable aquifer material consisting of coarse stratified glacial deposits (Figure 5-11).
- Land uses within the vicinity of the Briggs Site consist predominately of forest and grasslands, with some medium and low density residential properties, ponds, and cranberry bogs (Figure 5-12). The Briggs parcel is located approximately 1,500 feet downgradient and to the east of the Plymouth Manomet Landfill.
- No state listed oil or hazardous waste release sites were identified within a ½-mile radius of the Briggs Site.
- The Site is located in an area designated as protected open space.
- The property deed indicates that there is a Conservation Restriction on the property in perpetuity to protect and maintain the property in its natural state. The deed restriction covers Site #20 Briggs, Site #31, and Site #57 Indian Brook (although most of Site #57 is excluded from the Conservation Restrictions). The deed allows for the development of only one (1) public water supply well, which would be located on Site #20 Briggs Site, with three possible locations designated. The Conservation Restriction requires that groundwater modeling analysis must be conducted to evaluate long-term impacts to nearby environmental receptors, with a maximum withdrawal of 3 MGD.
- Water from the Briggs Site would enter the Manomet Pressure Zone, just south of the existing hydraulic restrictions near the Wannos Pond Well (refer to Chapter 7). At present, water from this source would likely exacerbate existing high-pressure surges in the southern extents of the Manomet Pressure Zone. However, proposed water main upgrades in this region would likely mitigate these effects. Alternatively, water could potentially be routed via Beaver Dam Road, which would provide a much-needed boost to residual pressures and available fire flow, while also assisting the Wannos Pond Well in preferentially filling the controlling South Pine Hills Tank. Depending on the yield and associated controls strategy, this may improve hydraulics of the Manomet Pressure Zone considerably.

EP submitted a Request for State-listed Species Information from the NHESP for the Briggs Site and nearby kettle-hole ponds. The Massachusetts Fish & Wildlife response letter dated June 4, 2019 indicates that the following state-listed rare species are identified near the Briggs Site:

- Long Island Pond – the Northern Red-Bellied Cooter, reptile listed as an Endangered species; and
- Island Pond – the Tidewater Mucket, mussel, listed as a species of Special Concern

These species are protected under the Massachusetts Endangered Species Act (MESA) and the state's Wetlands Protection Act (WPA).

The Division requested that EP conduct a preliminary groundwater modeling study to evaluate the potential impacts to nearby environmental receptors, should a public water supply well be developed at Site #20 Briggs. The results of the groundwater modeling are summarized below and the results are included in Appendix B.

Site #20 Briggs Site Groundwater Modeling Results

At the request of the Division, EP with McLane Environmental, LLC (McLane) conducted preliminary groundwater modeling to evaluate potential impacts to nearby environmental receptors from groundwater pumping. The modified USGS Plymouth-Carver-Kingston-Duxbury MODFLOW model utilized to develop a Zone II for the Forges Field site and to evaluate pumping affects from the 200-Acre Site was used to evaluate pumping impacts to nearby kettle-hole ponds at the Briggs Site (Figure 5-13). The model grid was refined in the area of the Briggs Site and the results of the 2007 HW subsurface investigation were used to update the model layers and aquifer characteristics in the area of the Briggs Site. The updated model was run transient for 15 years to set up initial model conditions. The updated model was then used to evaluate the following conditions:

1. Preliminary Zone II Areas assuming 180 days of pumping with no recharge to the aquifer for the range of pumping rates anticipated at the Briggs Site – 0.5 MGD and 2 MGD.
2. 15 year transient model runs with last 10 years pumping at 0.5 MGD and 1 MGD, to evaluate potential affects to the water table and pond stage levels at nearby kettle-hole ponds.

The preliminary Zone II areas were delineated using forward particle tracking, by releasing particles from the water table, tracking them forward through time until they reached a discharge point, and delineating the area of particles captured by the pumping well. The modeled preliminary Zone II areas pumping at 0.5 MGD and 2 MGD are shown on Figure 5-14. As shown, the Zone II area for both pumping rates encompasses most of Island Pond.

To evaluate potential impacts to nearby kettle-hole ponds, 15 year transient models with transient seasonal recharge were run. Based on previous modeling at 200-Acre site, modeled water level conditions generally stabilize after the first five years. After 5 years, pumping was initiated at the Briggs Site (assuming a well at the south end of the parcel) and water level impacts evaluated at two different pumping rates – 0.5 MGD and 1.0 MGD. Graphs showing water levels over 10 years of pumping at 1 MGD were constructed for Island Pond (Figure 5-15), Long Island Pond (Figure 5-16), Shallow Pond (Figure 5-17) and Beaver Dam Pond (Figure 5-18). These graphs show the seasonal impact of pumping at each pond. As shown in these figures, the largest drawdown affect is at the closest kettle-hole pond, Island Pond; therefore, a graph showing water levels over 10 years of pumping at a lower pumping rate of 0.5 MGD was also constructed for Island Pond (Figure 5-19). The groundwater model assumes that the kettle-hole ponds are in complete hydraulic connection with the aquifer and, therefore, drawdown in the ponds corresponds to drawdown at the groundwater table. Drawdown at the groundwater table at each pond, assuming a pumping rate of 1 MGD, is summarized below.

- Island Pond – 2.5 feet
- Long Island Pond – 0.97 feet
- Shallow Pond – 0.2 feet
- Beaver Pond – 0.1 feet

For comparison, if the pumping rate is reduced from 1 MGD to 0.5 MGD, then drawdown to the groundwater table at Island Pond is approximately 1.2 feet.

Pond bathymetry maps (1980) for Long Island Pond and Shallow Pond indicate maximum pond depths of 17 feet and 7 feet, respectively.

The groundwater model was also used to construct a steady state drawdown map assuming that a well at Site #20 Briggs site is pumping at 1 MGD (Figure 5-20). As shown on this map, with a well at Site #20 pumping at 1 MGD, drawdown around nearby kettle-hole ponds ranges from 0.1 feet in the vicinity of the Six Ponds Complex to 2.5 feet at Island Pond.

In summary, based on the results of this desktop study Site #20 Briggs is considered unfavorable for public water supply development, because of potential impacts to nearby NHESP Estimated Habitat of Rare Wetland Wildlife (Island Pond and Long Island Pond) and close proximity to the Sawmill Woods 40B development wastewater treatment system. Should the Town consider exploration for a public water supply well on Site #20 Briggs, EP recommends that exploration be conducted at the south-southeast end of the parcel, away from the Plymouth Manomet Landfill and further from Long Island Pond and Great Island Pond, which are NHESP Estimated Habitat of Rare Wetland Wildlife.

5.4.4 Site #23: South Plymouth

Site #14, #19 and #23 are located in South Plymouth (Figure 5-2). Sites #14 and #19 are located in closer proximity to the Six Ponds Complex than Site #23. Two options should be considered regarding these three sites:

a) Site #23 could be evaluated as a separate new source water supply or

b) Some combination of two or all three sites (or in combination with the 200-Acre well site) could be evaluated as a combined new source, with each site pumping at a reduced rate to spread drawdown out over a larger area and have less impact to any single surface water feature.

Based on discussions with the Division, additional assessment was conducted at Site #23 only (Figure 5-20).

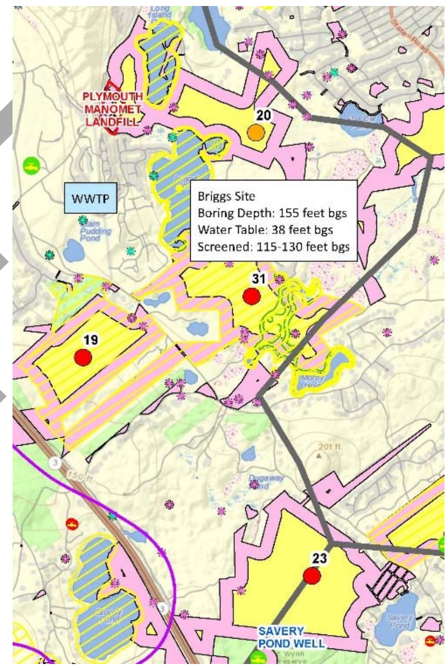
- Potential environmental receptors near Site #23 include potential vernal pools, cranberry bogs, and Savory Pond. The site is located downgradient of Bloody Pond (one of the Six Ponds) (Figure 5-21).
- Land uses in the vicinity of Site #23 consist primarily of forest, with some medium density residential, and cranberry bogs (Figure 5-22).
- Surficial geology maps indicate that Site #23 should have favorable aquifer material consisting of coarse stratified glacial deposits.
- No nearby sources of contamination to groundwater were identified.
- Site #23 is located further from the Six Ponds Complex than Sites #14 or #19 and is located downgradient of the Six Ponds Complex. As such, Site #23 should have less impact to nearby surface water features.
- Site #23 is located in proximity to the Savory Pond and Ellisville Public Water Supply Wells and, therefore, additional assessment should be conducted to evaluate the combined pumping affects to both the water supply sources and environmental receptors from adding a new source water supply in this area (Figure 5-23).
- Site #23 has a Conservation Restriction being implemented in under Conservation Commission Article 97, which prohibits constructing, placing or allowing to remain any temporary or permanent building, asphalt or concrete pavement, sign, fence, conduit, line or other temporary or permanent structure or facility on, above or under the parcel; as well as cutting, removing or otherwise destroying trees, grasses or other vegetation.
- Water from Site #23 would either enter the Cedarville Pressure Zone or the Manomet Pressure Zone. The Cedarville Pressure Zone currently has one water source, so additional redundancy would provide some benefit. However, the Manomet Pressure Zone is comparatively more stressed, so water would likely be routed to the Manomet Pressure Zone, where it would experience high discharge pressures from the competing Ship Pond and Ellisville Wells, suppressing output of all three sources. This would greatly exacerbate the existing high-pressure surges in this region, unless a transmission main were installed to bypass this region and allow for water to enter further north.

Similar to Site #20 Briggs, the USGS groundwater flow model was used to construct a steady state drawdown map with a well at Site #23 pumping at 1 MGD (Figure 5-25). As shown on this map, with a well at Site #23 pumping at 1 MGD, drawdown around nearby kettle-hole ponds is significantly less than observed from a well pumping at Site #20 Briggs. Approximate drawdown at nearby kettle-hole ponds was as follows: Savory Pond and Bloody Pond less than 0.5 feet, Island Pond 0.25 feet, and Long Island Pond and Six Ponds Complex 0.1 feet.

In summary, the results of the desktop study and groundwater modeling for Site #23 indicates that impacts to nearby environmental receptors is relatively minimal and potential sources of groundwater contamination were not identified. Adversely, a Conservation Restriction on the property prohibits cutting of trees, development, and construction and would have to be addressed before a public water supply could be developed on the property

5.4.5 Site #31

A site plan for Site #31 is included as Figure 5-26. Site #31 is located to the south of Site #20 Briggs Site and northeast of Site #23. This Site is further from Island Pond and Long Island Pond than Site #20 Briggs Site and further from the Savory Pond well than Site #23. This site is composed of three Town owned parcels that are combined. Individually each of these parcels cannot support a 400-foot Zone I. Following is a summary of Site #31 screening.



- Surficial geology maps indicate that Site #31 should have favorable aquifer material consisting of coarse stratified glacial deposits.
- No nearby sources of contamination to groundwater were identified.
- Site #31 is located further from the Six Ponds Complex than Sites #19.
- Site #31 is located side-gradient and further from Island Pond and Long Island Pond than Site #20 Briggs Site. As such, Site #31 should have less impact to nearby surface water features.
- The Site is located in an area designated as protected open space and the MassGIS open space protection layer has Site #31 listed as “in perpetuity”.
- The property deed indicates that there is a Conservation Restriction on the property in perpetuity to protect and maintain the property in its natural state. The deed restriction covers Site #31, Site #20 Briggs, and Site #57 Indian Brook (although most of Site #57 is excluded from the Conservation Restrictions). The deed allows for the development of only one (1) public water supply well, which is identified as located on Site #20 Briggs Site, with three possible locations designated. The Conservation Restriction does not allow for development of a public water supply well at Site #31.
- The Briggs Reservoir (which abuts the Site to the south) and Island Pond (which abuts the Site to the north) are listed as NHESP Estimated Habitat or Rare Wetland Wildlife. Both the Briggs Reservoir and Island Pond are located side gradient to Site #31

- The MassGIS open space protection layer has Site #31 listed as “in perpetuity”. Potential land use restrictions should be evaluated further.
- The location of this source presents several hydraulic challenges. It would require a long transmission main to connect to the existing infrastructure of the Manomet Pressure Zone. Further, its proximity to the Ship Pond Well would contribute to the high-pressure surges and likely suppress the output of both the Ship Pond and Ellisville Wells. It may be possible to discharge water further north in the Manomet Pressure Zone, though it would require a longer transmission main and securing an easement through several large properties.

Similar to Site #20 Briggs, the USGS groundwater flow model was used to construct a steady state drawdown map with a well at Site #31 pumping at 1 MGD (Figure 5-26). As shown on this map, with a well at Site #31 pumping at 1 MGD, drawdown around nearby kettle-hole ponds is less than observed from a well pumping at Site #20 Briggs. As shown on Figure 5-26 estimated drawdown at Island Pond is less than 1.5 feet and drawdown at the Six Ponds Complex is approximately 0.1 feet.

In summary, the results of the desktop study and groundwater modeling for Site #31 indicates that impacts to nearby environmental receptors is relatively minimal and potential sources of groundwater contamination were not identified. Adversely, a Conservation Restriction on the property prohibits cutting of trees, development, and construction and would have to be addressed before a public water supply could be developed on the property

If conservation restrictions were addressed, then EP recommends additional assessment for the Site #31, as outlined below, before pursuing a new source water supply in this area:

- Conduct additional groundwater modeling with Site #31 to evaluate various water supply well pumping rates and affects to nearby surface water features.
- Conduct a Request for State-listed Species Information from the NHESP to evaluate potential sensitive environmental receptors.
- Evaluate potential land use restrictions on the parcel parcel to determine if the Conservation Restriction could be modified to allow for development of a public water supply well at Site #31 instead of Site #20 Briggs.

5.4.6 Site #57 – Indian Brook

Site #57 is located in South Plymouth (Figure 5-28) to the north of the Ellisville Well. The Indian Brook Elementary School and Manomet Recreation Area are located on the east side of the parcel. The 400-foot Zone I buffer around the edge of the parcel and around the Elementary School leaves a large area for development of a public water supply well on the west side of the parcel. However, Indian Brook Road traverses the north side of the parcel. If this road is accessible to public travel then the 400-foot Zone I buffer on the north side of the parcel must extend south of Indian Brook Road, as shown on Figure 5-28. Following is a summary of site conditions for Site #57.

- Potential environmental receptors near Site #57 include potential vernal pools, Indian Brook and Indian Brook Reservoir, and cranberry bogs.
- Surficial geology maps indicate that Site #57 should have favorable aquifer material consisting of coarse stratified glacial deposits.
- No nearby sources of contamination to groundwater were identified.
- Shallow Pond and Indian Brook / Indian Brook Reservoir are located in proximity to Site #57, neither of which are identified as a NHESP Priority Habitats of Rare Species or Rare Wildlife. Site #57 is also located further from the Island Pond and Long Island Pond than Sites #20 or #31. As such, Site #57 should have less impact to nearby surface water features.
- Site #57 is located within the Indian Brook Conservation Area; however, portions of Site #57 are exempt from the conservation restrictions. The exempt portions are considered areas for public water supply well development.
- Water from Site #57 would enter the Manomet Pressure Zone near the Indian Brook School on State Road. This is further north than Sites #31 and #20 (Briggs Site), so its impact on high-pressure surges would likely be less severe. However, depending on the ultimate yield, it would likely allow for an adjusted controls strategy that preferentially withdraws from this site and the Wannos Pond Well over the Ship Pond Well and possibly the Ellisville Well. This could offer significant hydraulic improvements to the Manomet Pressure Zone.

In summary, the results of the desktop study for Site #57 indicates that impacts to nearby environmental receptors should be relatively minimal and potential sources of groundwater contamination were not identified. The site is exempt from the surrounding Conservation Restrictions. EP recommends that preliminary groundwater modeling be performed to evaluate potential impacts to nearby surface water features from production well pumping. In addition, a subsurface exploration and testing program should be conducted to determine if Site #57 is suitable for development of a public water supply well.

5.4.7 Site #30 - Entergy Parcels

With the closing of the Entergy Pilgrim Power Plant in Plymouth on May 31, 2019, the Entergy parcels were identified as a potential area for new source water supply exploration. The Entergy parcels have fewer environmental receptors nearby, relative to other potential water supply sites identified.

Environmental Partners reviewed the Entergy owned land and delineated those areas that could support a 400-foot Zone I radius. The 400-foot Zone I buffer was applied to property boundaries and to any roadway, powerline easements, etc. Figure 5-29 attached is an aerial photo of the Entergy parcel with 400-foot Zone I buffers. Several fire roads are identified within the Entergy parcel. A 400-foot Zone I buffer is not drawn around these roadways, as they were considered non-essential roadways that could be acquired by the Division to maintain ownership and control of the Zone I area. This assumption would be evaluated further if a potential water supply wellsite were identified where there is a fire road crossing.

The available Entergy parcels that could support ownership and control of the 400-foot Zone I were further evaluated based on the additional desktop screening criterial.

Areas along the east side of the Entergy parcel (generalized on Figure 5-1 and 5-2 as Site #29) were not considered for a potential water supply source, because of environmental receptor issues. The east side of the Entergy parcel is located within or adjacent to the Eel River Watershed (a designated cold water fishery) and the Forges Field new source water supply site, currently being developed by the Division, is located within the Eel River Watershed. Screening of potential sites is discussed below.

Five potential parcels were identified along the west side of the Entergy Parcel (generalized on Figure 5-1 and 5-2 as Site #30). Each of these five parcels were evaluated in detail based on surficial geology, potential for aquifer material, land uses, environmental receptors, potential release sites, and elevation. Based on the detailed desktop study of the five potential parcels, Site #5 was identified as a potential water supply. This detailed analysis of the Entergy Parcels is included in Appendix C. The results of the detailed desktop study for Entergy Site #5 is discussed in detail below.

Surficial Geology – Figure 5-30 attached is a USGS Surficial Geology Map (2018) with the Entergy parcels outlined. As shown on this map in green, much of the Entergy land is underlain by (sandy till (non-aquifer material). Site #5 is located within the area identified as sandy till, but in close proximity to an area mapped as coarse deposits. The rationale being that the sandy till boundary may not be exact on the map or alternatively, some coarse deposits may underlie the till.

Land Uses – Figure 5-31 is a land use map. Site #5 is located in a forested area and a public water supply well could be located such that the well and associated 400-foot Zone I consists completely of forest. Land uses within ½-mile of the site consist primarily of forest, cranberry bogs, low density and multifamily residential, and powerline easement.

Environmental Receptors – Figure 5-32 is a site plan showing environmental receptors within ½ mile of the potential sites. Potential environmental receptors within ½-mile of Site #5 include three potential vernal pools and some cranberry bogs.

Aquifers – Figure 5-33 is a map showing aquifer zones. Site #5 is shown as being underlain by high yield aquifer material.

Release Sites – In addition to the Energy Nuclear Power Plant, two additional hazardous waste sites of concern are identified in the vicinity of the Entergy Parcels, shown on Figure 5-26. The two sites are MassDEP MCP state release sites, and discussed in detail in Appendix C. Both sites are located approximately 4,000 feet downgradient from Site #5 and are not anticipated to impact water quality at Site #5. However, to evaluate potential impacts from these two state hazardous waste sites, any exploration at Site #5 should include analysis for petroleum hydrocarbons and 2-methyl naphthalene.

Elevations – Figure 5-33 is a map showing elevations. Areas with higher elevations tend to have thicker sandy till, which is considered non-aquifer material. In addition, the depth to the water table is deeper in the areas with higher elevations. Sites #1 and #2 are all located at an elevation less than 100 feet. Site #5 is located at an elevation of approximately 225 feet, which is higher than three of the other four sites. Subsurface exploration would be required to determine if Site #5 is underlain by coarse glacial aquifer material or sandy till (non-aquifer material).

Hydraulic Benefit – The location of Site #30 could offer a significant hydraulic benefit to the Manomet Pressure Zone. Water from this site would likely enter the Manomet Pressure Zone much closer to the South Pine Hills Tank than the other sources in the Manomet Pressure Zone. Depending on the production capacity of this source, it could allow for the controlling South Pine Hills Tank to fill at a similar rate as the Indian Hill Tank, eliminating the pressure surges that occur after the Indian Hill Altitude Valve closes. Further, the introduction of water at the northern extent of the Manomet Pressure Zone would likely permit a significantly higher carrying capacity for the Pine Hills Interconnection, once completed. This would improve the Division's ability to meet maximum day demands in the Northern Pressure Zones after the loss of a large water source, such as South Pond Well No. 2.

In summary, five potential water supply sites within the Entergy owned parcels of land were identified for further desktop screening (shown on Figure 5-29). The results of this additional desktop screening indicate that Sites #1, #2, #3, and #4 were considered as having a low potential for public water supply well development. Site #5 is considered a potential water supply. Land uses within a ½-mile radius are consistent with water supply development. This site was selected to be located near the edge of the area mapped as sandy till and at an elevation of approximately 200 feet. Two state listed hazardous waste sites are identified in the vicinity of the Entergy parcels. Both sites are located downgradient of Site #5; however, if testing is performed at Site #5, groundwater samples should be collected for analysis of petroleum related compounds. A subsurface investigation would be required to determine if Site #5 is underlain by coarse deposits suitable for public water supply development.

In summary, five potential water supply sites within the Entergy owned parcels of land were identified for further desktop screening (shown on Figure 5-29). The results of this additional desktop screening indicate that Sites #1, #2, #3, and #4 were considered as having a low potential for public water supply well development. Site #5 is considered a potential water supply. Land uses within a ½-mile radius are consistent with water supply development. This site was selected to be located near the edge of the area mapped as sandy till and at an elevation of approximately 200 feet. Two state listed hazardous waste sites are identified in the vicinity of the Entergy parcels. Both sites are located downgradient of Site #5; however, if testing is performed at Site #5, groundwater samples should be collected for analysis of petroleum related compounds. A subsurface investigation would be required to determine if Site #5 is underlain by coarse deposits suitable for public water supply development.

5.5 CONCLUSIONS AND RECOMMENDATIONS

The 2006 Water System Master Plan for the Division recommended that at least three new groundwater supplies be developed over the next 10 years to meet water supply deficits and anticipated growth. EP has worked with the Division to develop and permit the Forges Field new source water supply, which is approved by MassDEP and will be online in Spring 2020. The well is permitted for 1.05 MGD. EP performed a desktop study and preliminary groundwater modeling to identify potential water supply sites for future development.

A total of 70 potential sites were reviewed, as shown on Figure 5-1. The majority of potential water supply parcels were eliminated from further consideration because of proximity to environmental receptors. Seven Town-owned sites, as shown on Figure 5-2, were identified as potential water supply sites for further consideration and evaluation. Following is a summary of the desktop study results.

- Sites #27/#28 Parting Ways – Site #28 South Parting Ways was identified as a potential water supply site. A subsurface investigation and testing was performed in at South Parting Ways in August 2019, which indicated a potential well yield of 285,000 gpd. This Site is located approximately 2,000 feet from a 12-inch water main in the West Plymouth Zone and could be connected to the water system relatively easily. As such, EP recommends that the Division preserve this site for potential future development. Should the Division proceed with a water supply well at the South Parting Ways site, additional observation wells should be installed and tested to optimize the production well location and well yield. This site is on hold pending future exploration work for a more favorable site

- Site #3 Micajah Pond in the West Plymouth Pressure Zone was identified as potential public water supply site. The desktop study results indicate potential aquifer material at the site and minimal nearby sensitive environmental receptors. In addition, potential sources of contamination that could impact water quality were not identified. Adversely, Site #3 has a conservation restriction on the property that limits public water supply development and would need to be resolved, if possible. Site #3 is on hold due to the conservation restriction.

- Site #23 was identified as potential public water supply sites. The desktop study results indicate potential aquifer material at the sites and few nearby sensitive environmental receptors. Potential sources of contamination that could impact water quality were not identified. Preliminary groundwater modeling indicates that pumping a well at Site #23 would have minimal impacts to nearby environmental receptors. Adversely, Site #23 has a proposed conservation restriction on the property that limits water supply development and would need to be resolved, if possible. This area of the water system currently experiences high pressure surges, and the addition of a water source here would likely exacerbate these surges, further suppressing the operational capacity of the Ship Pond and Ellisville Wells.
- Site #20 Briggs Site and Site #31 were identified as potential public water supply sites. The desktop study results indicate potential aquifer material. Adversely, these sites are located in proximity to sensitive environmental receptors and development of a public water supply well could adversely impact nearby environmental receptors. In addition, the Site #20 Briggs is located in proximity to the Sawmill Woods affordable housing development with a proposed onsite wastewater treatment plant, which could adversely affect water quality. Preliminary groundwater modeling indicates that pumping a well at Sites #20 and #31 could have significant drawdown impacts to nearby kettle-hole ponds. In addition, both parcels have conservation restrictions on the property that limits water supply development, except for three optional site locations at Site #20 Briggs. Water entering the Manomet Pressure Zone from these sites would also likely contribute to existing pressure surges in the Manomet Pressure Zone, further suppressing the operational capacity of the Ship Pond and Ellisville Wells. However, this may be mitigated by routing water north to Beaver Dam Road, and will be offset partially by the water main upgrades discussed in later sections.
- Site #57 Indian Brook was identified as a potential public water supply site. The desktop study results indicate potential aquifer material present; minimal nearby sensitive environmental receptors; and potential sources of contamination that could impact water quality were not identified. Portions of Site #57 have a conservation restriction; however, much of this parcel is excluded from the conservation restriction with enough Town-owned land to support a 400-foot Zone I and development of a public water supply well. This location offers ease of connection with the existing infrastructure in the Manomet Pressure Zone, though it would likely exacerbate existing pressure surges and further restrict the operational capacity of the Ship Pond and Ellisville Wells. Preliminary groundwater modeling should be performed for Site #57 to determine potential impacts to kettle-hole ponds located upgradient. EP recommends exploration and testing be performed at Site #57 Indian Brook.
- Site #30 Entergy parcel southeast side of Manomet Hill was identified as a potential public water supply site. Based on the desktop study, one location, designated Site #5, on the southeast end of Manomet Hill is identified for potential future water supply well exploration and testing. Limited environmental receptors or potential sources of contamination are identified near Site #5. Surficial geology for Manomet Hill is identified as sandy till (non-aquifer) material. Site #5 is located near the edge of the till and in proximity to coarse deposits (potential aquifer material).

Subsurface exploration would be required to determine if potential aquifer material is present at Site #5. The addition of water at this location offers perhaps the strongest hydraulic benefit to the water system, given its proximity to the controlling South Pine Hills Tank. Depending on the production capacity of this source, it could greatly increase the rate at which the South Pine Hills Tank fills, preventing the Indian Hill Altitude Valve from closing, eliminating the majority of high pressures in the Manomet Pressure Zone. The Town does not own this property. EP recommends exploration and testing at Site #30.

- One or a combination of Sites #14, #17 (200-Acre Site), #19, #23 or #31 in South Plymouth (locations C4, D3, E4). These sites are not located in proximity to the Town's water system infrastructure; therefore, a large quantity well is needed to justify developing a public water supply. These sites should be considered individually or in combination, because site-screening criteria indicate the potential presence of good aquifer material that would allow for development of a single well, large water supply source; however, the wells are located in proximity to kettle ponds, most of which are considered sensitive environmental receptors. As such, pumping two or three wells at a lower pumping rate, would spread the drawdown over a larger area with less drawdown at any one location.
- Sites #24 and #25/#63/#69/#70 located in south Plymouth are considered potential public water supply well sites, but were not considered further because of the long distance to existing water system infrastructure. The Division should consider evaluating these sites further to determine if the parcels should be preserved for potential future water supply development.
- EP recommends that the Division continue with the desktop study to evaluate large, non-Town owned parcels that could potentially be purchased for public water supply development.
- The Division should coordinate with the Director of Marine and Environmental Affairs regarding the extensive conservation restrictions and public water supply development.

Chapter 6 – Assessment of Water Distribution Storage

The purpose of this section is to assess distribution system storage with respect to the Division's current storage requirements and to identify any deficiencies that might exist.

6.1 GENERAL

Distribution storage is provided to meet peak demands of short duration, minimize pressure fluctuations during periods of demand changes in the distribution system, and furnish a reserve for firefighting. Storage may also provide an emergency supply in case of temporary breakdown of pumping facilities. Peak hour demand and fire flow storage are typically allocated at specific levels within a storage facility to ensure the storage volume will be available at a hydraulic gradient adequate for the intended purpose. Peak hour demand storage is typically provided within the top portion of the tank while fire storage typically includes the middle or bottom of the tank.

As discussed in Chapter 1, the Division has ten storage tanks in its distribution system located within the Division's six different pressure zones. A summary of pertinent engineering data associated with the Division's water distribution storage tanks is provided in Table 1-20. The following analysis evaluates peak hour demand and fire flow storage requirements under current and future demand conditions for each pressure zone in the Division's water system. Each pressure zone was reviewed individually to evaluate whether the existing storage is sufficient to meet current and projected 2040 peak hour demand and fire flow requirements specific to the pressure zone.

6.1.1 Usable Storage

Prior to evaluating peak hour demand and fire flow storage, the usable storage for each tank was reviewed. In accordance with MassDEP Guidelines for Public Water Systems (Chapter 8.4.1.3), water systems are required to provide customers with a minimum service pressure of 35 pounds per square inch (psi) (81.2 feet). Thus, only the volume of water within a tank that will provide a pressure of 35 psi to the highest customer within the respective pressure zone can be considered usable storage.

Usable storage is based in large part on the highest elevations served by the Division's water system. The highest customer in each pressure zone was determined using the geocoded 2018 metered water usage data in conjunction with light detection and ranging (LIDAR) elevation data from the National Oceanic and Atmospheric Administration (NOAA) database. Based on this information, the location of the highest customers in each pressure zone was determined. The resulting elevations for the highest customers were cross-checked with the contours provided in MassGIS. A summary of the highest customer locations is included in Table 6-1 below.

Table 6-1 – Summary of Highest Customer Locations

Pressure Zone	Highest Customer Elevation (ft NAVD88)	Location of Highest Customer
West Plymouth	234	Armstrong Rd @ North Plymouth Tank
Plymouth Center	147	Braley Road[1]
Bradford	146	Long Pond Road @ Shops at 5 Way
Pine Hills	167	Tower Road @ Entrance Road
Manomet	153	Shore Drive @ Indian Hill Tank
Cedarville	210	Buckskin Path @ Cedarville Tank

1. The location of the highest customers in the Plymouth Center Pressure Zone is Watercourse Place, which is a boosted subdivision. No information was provided regarding the pump, so it was assumed that the booster pumping station was designed properly and the customers in the subdivision have adequate pressure.
2. It should be noted that the Division's water storage tanks were constructed when very few residential houses were built; local codes and Division review at the time of development recommended use of mechanical devices to aid properties at these higher elevations.

Usable storage was evaluated for each tank based on the maximum tank water level, estimated as the tank's overflow elevation, and highest customer in the pressure zone in which the respective tank is located. For example, the highest customer in the West Plymouth Pressure Zone is located at approximately 234 feet. In order to supply 35 psi of water pressure, the tank water level would need to be 315.2 feet. Since this elevation is greater than the maximum tank water level for all of the West Plymouth Pressure Zone tanks, the West Plymouth Pressure Zone exhibits a usable storage deficit. The Division's storage tanks were constructed between the 1950s and 1990s prior to more recent development at higher elevations. It should be noted that the Division recommends mechanical devices to aid properties at these higher elevations to developers.

Under current conditions, the Division is unable to provide 35 psi of water pressure to their highest customers in four of the six pressure zones with the exception of the Pine Hills and Bradford Pressure Zones. It should be noted that low pressures are typically alleviated by household plumbing fixtures which are not taken into account in this analysis. This results in usable storage deficit in four of the six pressure zones, as summarized in Table 6-2 and Table 6-3 below.

Table 6-2 – Summary of Usable Storage by Tank

Pressure Zone	Tank	Hydraulic Grade Line (NGVD29)[1]	Maximum Tank Water Level (ft NAVD88)	Highest Customer Elevation (ft NAVD88)[2]	Usable Storage or (*Deficit*) (gal)
West Plymouth Pressure Zone	Harrington Standpipe	295	294.2	234	*(303,624)*
	North Plymouth Tank		294.2	234	*(595,103)*
	Samoset Street Standpipe		292.0	234	*(174,013)*
Plymouth Center	Lout Pond Tank	187	185.7	147	*(1,147,104)*
	Chiltonville Standpipe		186.2	147	*(688,891)*
Bradford Pressure Zone	Stafford Street Standpipe	250	249.2	146	325,084
Pine Hills Center Pressure Zone	North Pine Hills Tank	300	299.2	167	1,883,688
Manomet Pressure Zone	South Pine Hills Tank	187	186.2	153.3	*(1,191,786)*
	Indian Hill Tank		185.1	153	*(1,237,464)*
Cedarville Pressure Zone	Cedarville Tank	272	271.2	209	*(494,589)*

1. The HGL listed, in NGVD29, is the commonly used HGL by the Division; maximum tank water levels are shown in NAVD88 in order to calculate usable storage based on customer elevations.

2. It should be noted that the Division's water storage tanks were constructed when very few residential houses were built; local codes and Division review at the time of development recommended use of mechanical devices to aid properties at these higher elevations.

Table 6-3 – Summary of Total Usable Storage by Pressure Zone

Pressure Zone	Tank	Usable Storage Surplus or (*Deficit*) (gal)
West Plymouth Pressure Zone	Harrington Standpipe	*(303,624)*
	North Plymouth Tank	*(595,103)*
	Samoset Street Standpipe	*(174,013)*
	West Plymouth Total	***(1,072,739)***
Plymouth Center	Lout Pond Tank	*(1,147,104)*
	Chiltonville Standpipe	*(688,891)*
	Plymouth Center Total	***(1,835,996)***
Bradford Pressure Zone	Stafford Street Standpipe	325,084
	Bradford Total	**325,084**
Pine Hills Center Pressure Zone	North Pine Hills Tank	1,883,688
	Pine Hills Total	**1,883,688**
Manomet Pressure Zone	South Pine Hills Tank	*(1,191,786)*
	Indian Hill Tank	*(1,237,464)*
	Manomet Total	***(2,429,250)***
Cedarville Pressure Zone	Cedarville Tank	*(494,589)*
	Cedarville Total	**(494,589)**

The distribution storage does not provide adequate pressures to the highest customers in four of the six pressure zones as shown by the initial usable storage deficits above. The Division's storage tanks were constructed between the 1950s and 1990s prior to more recent development at higher elevations reducing available pressures and storage. Additionally, low pressures are typically alleviated by household plumbing fixtures which are not taken into account in this analysis. A detailed analysis of low service pressures is provided in Chapter 7 and recommended improvements are provided in Chapter 9.

6.2 PEAK HOUR DEMAND STORAGE

The amount of distribution storage required to meet peak hour demands is a function of both the MDD and the available pumping capacity. If pumping capacity is equal to or greater than the MDD, the storage required to meet peak hourly demands is typically estimated to be 30 percent of the MDD.

The Division's current pumping capacities can meet existing and future MDDs in each of the pressure zones, under the following assumptions:

1. The pumping capacity is calculated as the least of the Safe Yield and the Operational Capacity of each source within each zone.
2. The pumping capacity for each zone includes interzonal flows from booster pump stations and active flow control valves.

6.2.1 Peak Hour Storage – Existing Demands

Under existing demand conditions, the Division's ASR data from 2013 to 2018 was used to obtain an average MDD. Demands were then distributed by pressure zone using geocoded 2018 metered water usage data to estimate the MDD by pressure zone. As discussed above, the peak hour demand for each pressure zone is calculated at 30 percent of MDD.

The peak hour storage was calculated based on the existing usable storage (Table 6-3), peak hour demand, and pumped storage as shown in Table 6-4.

Table 6-4 – Existing Peak Hourly Demand Storage by Pressure Zone

Pressure Zone	Peak Hour Demand Required (gal)	Usable Storage or (*Deficit*) (gal)	Pumped Storage[1,2] (gal)	Peak Hour Storage Surplus or (*Deficit*) (gal)
West Plymouth	824,895	*(1,072,739)*	634,910	*(1,262,724)*
Plymouth Center	607,314	*(1,835,996)*	417,500	*(2,025,810)*
Bradford	215,190	325,084	435,380	545,274
Pine Hills	33,474	1,883,688	92,340	1,942,554
Manomet	573,840	*(2,429,250)*	351,250	*(2,651,840)*
Cedarville	138,678	*(494,589)*	300,640	*(332,627)*

1. The pumped storage does not include flows from the Forges Field Well and Jordan Road Flow Control Valve. The Forges Field Well and Jordan Road Flow Control Valve were included in the Projected Demands analysis.
2. The pumped storage includes interzonal flows from booster pump stations and active pressure reducing valves.

A review of the data presented in Table 6-4 suggests that every pressure zone, with the exception of the Bradford and Pine Hills Pressure Zones, lacks sufficient peak hour storage. The observed deficits can predominantly be attributed to the usable storage deficits discussed above. However, the following should be noted:

- In the West Plymouth, Plymouth Center, and Manomet Pressure Zones, the pumped storage cannot meet the peak hour demand and the peak hour demand exacerbates the existing usable storage deficit.
- In the Cedarville Pressure Zone, the pumped storage exceeds the peak hour demands and the tanks are able to alleviate some of the existing usable storage deficit.
- The Bradford and Pine Hills Pressure Zones provide adequate water storage to meet the peak hour demand for the respective pressure zone.

The peak hour storage deficits are mostly attributed to the development at higher elevations that occurred following the installation of the tanks. Typically, mechanical devices to aid properties at these higher elevations which is not accounted for in this analysis. The formation of a new pressure zone with an elevated hydraulic grade line may alleviate the storage deficits observed.

6.2.2 Peak Hour Storage – Projected Demands

Projected 2040 MDDs, developed in Chapter 4, were distributed by pressure zone using geocoded 2018 metered water usage data to estimate the maximum-daily demands by pressure zone. The projected 2040 peak hour storage was calculated based on the existing usable storage (Table 6-3), projected peak hour demands, and pumped storage as shown in Table 6-5.

Table 6-5 – Projected Peak Hourly Demand Storage by Pressure Zone

Pressure Zone	Projected 2040 Peak Hour Demand Required (gal)	Usable Storage or (*Deficit*) (gal)	Pumped Storage[1,2] (gal)	2040 Peak Hour Storage Surplus or (*Deficit*) (gal)
West Plymouth	1,088,617	*(1,072,739)*	634,910	*(1,526,447)*
Plymouth Center	801,660	*(1,835,996)*	489,500	*(2,148,156)*
Bradford	282,403	325,084	566,630	609,311
Pine Hills	45,549	1,883,688	92,340	1,930,480
Manomet	756,111	*(2,429,250)*	351,250	*(2,834,111)*
Cedarville	182,195	*(494,589)*	300,640	*(376,145)*

1. The pumped storage includes flows from the Forges Field Well and Flow Control Valve (refer to Chapter 1).
2. The pumped storage includes interzonal flows from booster pump stations and active pressure reducing valves.

As shown in Table 6-5, as demands increased in the future the available peak hour storage decreases in every pressure zone with the exception of the Bradford Pressure Zone where the additional flow from the Forges Field Well Station exceeds the projected demand growth. Similar to existing conditions, every pressure zone, with the exception of the Bradford and Pine Hills Pressure Zones, lacks sufficient peak hour storage under the 2040 projected demand scenario. The formation of a new pressure zone with an elevated hydraulic grade line or additional storage facilities may alleviate the storage deficits observed.

6.3 FIRE PROTECTION

The quantity of distribution storage necessary for fire protection is based in part on the fire flow requirements established by the Insurance Services Office (ISO). Criteria established by ISO are used by insurance companies to set fire insurance rates. According to ISO standards, a water system is responsible for providing fire flow up to 3,500 gpm while any property owners with higher fire flow requirements are responsible for the remainder of the flow; however, a water system may elect to provide additional fire flow to areas with elevated requirements.

Table 6-6 provides a summary of the fire flow tests and needed fire flow (NFF) based on existing property development as reported in the most recent ISO report prepared for the Division, dated 2019. The complete report is included in Appendix D.

Table 6-6 – Summary of 2019 ISO Fire Flow Test Results

ISO Test Location Number[1]	Test Location	Pressure Zone	NFF at 20 psi (gpm)
18	Federal Furnace Rd @ School	West Plymouth	3000
19	South Meadow Rd @ Airport Plaza		4500
19.1	South Meadow Rd @ Airport Plaza		2250
20	Lantern Ln @ Flintlocke Ln		750
21	Esta Rd @ Dartmouth Rd		1000
22	Plympton Road @ West Elementary School		3000
23	Aldrin Road @ Armstrong Road		2250
1	Court St @ Hedge Rd	Plymouth Center	7000
1.1	Cordage Park		3000
1.2	Cordage Park		6000
1.3	Cordage Park		6000
2	Court St @ Savory Ln		3500
3	Water Street @ Lothrop Street		4500
3.1	Water Street @ Lothrop Street		1750
3.2	Water Street @ Lothrop Street		4500
4	Court Street @ Main Street		3000
5	Billing Street @ #100		4500
5.1	Billing Street @ #100		1000
6	Union Street @ Lincoln Street		5000
9	Russell Mills Road @ Sandwich Road		500
12	Warren Ave @ Sunrise Ave		3000
10	Bay Shore Dr @ Tower Rd	Pine Hills	1000
7	Obery Street @ High School	Bradford	5000
7.1	Obery Street @ High School		750
8	Long Pond Road @ Camelot Drive		3500
11	Manomet Point Rd @ School	Manomet	3000
13	Provincetown View Rd @ Manomet Beach Rd		1000
14	State Rd @ Indian Brook Elem. School		3000
15	Hillside Dr @ Shore Dr		1000
16	State Rd @ Ellisville Rd	Cedarville	750
17	State Rd @ Old Country Rd		3500

1. ISO Test Location Numbers are included in Appendix D.

The respective maximum ISO fire flow requirement for each pressure zone was used as a basis for the fire flow storage analysis. Additionally, in the Pine Hills Pressure Zone the maximum fire flow requirement per the 2019 ISO report is 1,000 gpm. However, spatial analysis of the residential fire flow requirements yields a maximum NFF of 1,500 gpm within the pressure zone. This was determined using the ISO guidelines for residential fire flow that is the distance between buildings is less than 10 feet, the NFF is 1,500 gpm. While sheds and other small outbuildings are exempt from building distance considerations, 1,500 gpm was conservatively assumed to be the NFF for the Pine Hill Pressure Zone.

The NFF and duration for each pressure zone is summarized Table 6-7 below. The fire durations are based on the ISO Fire Suppression Rating Schedule (2012) and vary depending on the NFF.

Table 6-7 – Needed Fire Flow and Fire Duration by Pressure Zone

Pressure Zone	Maximum NFF Rate (gpm)	Fire Duration (hrs)
West Plymouth	4,500	4
Plymouth Center	7,000	4
Bradford	5,000	4
Pine Hills	1,500	2
Manomet	3,000	3
Cedarville	3,500	3

6.3.1 Usable Fire Flow Storage

As discussed in Section 6.1.1, only a portion of the storage tank volume is considered usable storage. Under normal operating conditions, only the volume of water within a tank that will provide a pressure of 35 psi to the highest customer within the respective pressure zone can be considered usable storage. However, in the event of a fire, water systems are only required to maintain a 20 psi (46 feet) service pressure while providing adequate fire flow. Therefore, usable fire flow storage is defined as the amount of water that will provide a pressure of 20 psi (46 feet) to the highest customer. Any stored water that is less than 46 feet above the highest customer is not considered usable fire flow volume as the water system would not be able to maintain the 20 psi service pressure. Because the Division has six pressure zones, the usable fire flow storage was evaluated for each individual zone as shown in Table 6-8 below.

Table 6-8 – Usable Fire Flow Storage

Pressure Zone	Tank	Usable Fire Flow Storage Surplus and *(Deficit)* (gal)
West Plymouth Pressure Zone	Harrington Standpipe	205,314
	North Plymouth Tank	402,416
	Samoset Street Standpipe	89,821
	West Plymouth Total	**697,551**
Plymouth Center	Lout Pond Tank	*(205,773)*
	Chiltonville Standpipe	*(117,049)*
	Plymouth Center Total	***(322,821)***
Bradford Pressure Zone	Stafford Street Standpipe	834,022
	Bradford Total	**834,022**
Pine Hills Center Pressure Zone	North Pine Hills Tank	3,154,201
	Pine Hills Total	**3,154,201**
Manomet Pressure Zone	South Pine Hills Tank	*(331,680)*
	Indian Hill Tank	*(364,076)*
	Manomet Total	***(695,756)***

Pressure Zone	Tank	Usable Fire Flow Storage Surplus and *(Deficit)* (gal)
Cedarville Pressure Zone	Cedarville Tank	392,184
	Cedarville Total	**392,184**

A review of the data presented in Table 6-8 indicates that the Plymouth Center and Manomet Pressure Zones do not have adequate usable fire flow storage to meet the firefighting needs of the highest customer. These pressure zones start at a deficit, as the tanks within each zone are unable to provide the required 20 psi minimum for fire protection to the highest customer. As noted above, the Division's storage tanks were constructed between the 1950s and 1990s prior to more recent development at higher elevations.

This is a violation of 310 CMR 22.19 (Distribution System Requirements) which states under Section 1, "All service connections shall have a minimum residual water pressure at street level of at least 20 pounds per square inch under all design conditions of flow." It should be noted low pressures are typically alleviated by household plumbing fixtures which are not taken into account in this analysis.

6.3.2 Fire Flow Storage – Existing Demands

The available fire storage was calculated using usable fire flow storage and pumped storage (or firm capacity) for existing demands based on the following assumptions:

- NFF for each pressure zone based on 2019 ISO tests and ISO standards (Table 6-7);
- Fire Flow durations based on NFF and ISO standards (Table 6-7); and,
- Pumped storage includes interzonal flow.

Under the above assumptions, two scenarios were reviewed:

- Scenario 1 – All sources are on-line and no considerations for ADD or MDD are included.
- Scenario 2 – The largest source is off-line, a MDD condition is assumed, and an initial storage depletion equal to 50 percent of the ADD volume.

Assumed fire flow rate and duration requirements vary by zone, as summarized in Table 6-7. Assumptions for each scenario are summarized in Table 6-9 below.

Table 6-9 – Summary of Fire Flow Storage Analysis Scenarios

Assumption	Scenario 1	Scenario 2
Available Fire Flow Storage	X	X
Pumped Storage[1]	X	X
Largest Pressure Zone Sources On-Line	X	
Max Day Demand During Fire[2]		X
Storage Reduction due to Use[3]		X

1. Pumped storage was calculated assuming each source is operating at the least of its Safe Yield, Design Capacity, and Operational Capacity. The total pumped storage includes interzonal flows from booster pumps and active pressure reducing valves. For existing demands, the pumped storage does not include flows from the Forges Field Well or Pressure Reducing Valve.
2. Assumed fire flow rate and duration requirements vary by zone, as summarized in Table 6-7.
3. Water demand during the fire event was assumed to be at the MDD rate.
4. The storage reduction due to use was calculated as 50% of the average daily volume.

Under Scenario 1, where all sources are on-line and no considerations for ADD or MDD are included, Plymouth Center and Manomet Pressure Zones, do not have adequate fire flow storage to meet the firefighting needs of the highest customer and the pumped storage cannot overcome the NFF or the initial deficit of usable fire flow storage as shown in Table 6-10 below.

Table 6-10 – Existing Fire Storage Scenario 1 – All Sources On-Line

Pressure Zone	Fire Flow Storage Needed (gal)	Usable Fire Flow Storage (gal)	Pumped Storage (gal)	Fire Flow Storage Surplus or *(Deficit)* (gal)
West Plymouth	1,080,000	697,551	846,547	464,098
Plymouth Center	1,680,000	*(322,821)*	556,667	*(1,446,155)*
Bradford	900,000	834,022	435,380	369,402
Pine Hills	180,000	3,154,201	61,560	3,035,761
Manomet	540,000	*(695,756)*	351,250	*(884,506)*
Cedarville	630,000	392,184	300,640	62,824

It should be noted that a water system is only responsible for providing fire flow up to 3,500 gpm while any property owners with higher fire flow requirements are responsible for the remainder of the flow. In the case of the Plymouth Center Pressure Zone where the NFF is 7,000 gpm over 4 hours; the pressure zone would still observe a fire flow deficit when the NFF is reduced to 3,500 gpm; however, the pumped storage would exceed the 3,500 gpm NFF.

Under Scenario 2, where largest source in each pressure zone is off-line and usable fire flow storage is reduced due to system demands, four out of the six pressure zones do not have adequate fire flow storage to meet both demands and fire flow requirements as shown in Table 6-11 below. A review of the data presented indicates that the Pine Hills Pressure Zones remains as the only pressure zones with adequate fire flow storage to meet the firefighting needs of the highest customer.

Table 6-11 – Existing Fire Storage Scenario 2 – Largest Source Off-Line and Initial Storage Depletion

Pressure Zone	Fire Flow Storage Needed (gal)	Usable Fire Flow Storage (gal)	Pumped Storage (gal)	Maximum Demand (gal)	Storage Depletion (gal)	Fire Flow Storage Surplus or *(Deficit)* (gal)
West Plymouth	1,080,000	697,551	423,667	458,275	743,475	*(1,160,532)*
Plymouth Center	1,680,000	*(322,821)*	316,667	337,397	547,370	*(2,570,921)*
Bradford	900,000	834,022	162,500	89,663	193,950	*(187,090)*

Pressure Zone	Fire Flow Storage Needed (gal)	Usable Fire Flow Storage (gal)	Pumped Storage (gal)	Maximum Demand (gal)	Storage Depletion (gal)	Fire Flow Storage Surplus or *(Deficit)* (gal)
Pine Hills	180,000	3,154,201	--	9,298	30,170	2,934,733
Manomet	540,000	*(695,756)*	225,000	239,100	517,200	*(1,767,056)*
Cedarville	630,000	392,184	148,140	57,783	124,990	*(272,448)*

Note that even if the usable fire flow storage was equal to zero gallons, the pumped storage would not be sufficient to meet the fire flow and demand requirements.

As noted above, fire flow storage deficiencies noted above are largely attributed to the lack of usable fire flow storage and the fact that the Division's storage tanks were constructed prior to more recent development at higher elevations. The formation of a new pressure zone with an elevated hydraulic grade line may alleviate the storage deficits observed. Additionally, a detailed analysis of fire flow availability is included in Chapter 7.

6.3.3 Fire Flow Storage – Projected Demands

Projected 2040 MDDs, developed in Chapter 4, were distributed by pressure zone using geocoded 2018 metered water usage data to estimate the daily demands by pressure zone. For the projected fire flow storage analysis, only Scenario 2, largest source off-line and MDD conditions, was evaluated as it represents the worst-case scenario as shown in Table 6-12.

Table 6-12– Projected Fire Storage Scenario 2 – Largest Source Off-Line and Initial Storage Depletion

Pressure Zone	Fire Flow Storage Needed (gal)	Usable Fire Flow Storage (gal)	Pumped Storage (gal)	Maximum Demand (gal)	Storage Depletion (gal)	Fire Flow Storage Surplus or *(Deficit)* (gal)
West Plymouth	1,080,000	697,551	423,667	604,787	975,464	*(1,539,034)*
Plymouth Center	1,680,000	*(322,821)*	412,667	445,367	718,333	*(2,753,854)*
Bradford	900,000	834,022	293,750	117,668	253,049	*(142,945)*
Pine Hills	180,000	3,154,201	0	12,652	40,814	2,920,734
Manomet	540,000	*(695,756)*	225,000	315,046	677,519	*(2,003,321)*
Cedarville	630,000	392,184	148,140	75,915	163,258	*(328,848)*

A review of the data presented in Table 6-12 indicates that five of the six pressure zones will not have adequate fire flow storage to meet both MDD and the firefighting needs of the highest customer. With the increased demand, the available fire flow storage decreases. This is offset slightly by considering additional flows from the Forges Field Pump Station and Pressure Reducing Valve, which are expected to come on-line in the spring of 2020.

6.4 CONCLUSIONS AND RECOMMENDATIONS

In both the peak hour and fire flow storage assessments, the distribution storage does not provide adequate pressures to the highest customers in four of the six pressure zones and three of the six pressure zones, respectively, as shown by the initial usable storage deficits above. This is largely due to the Division's storage tanks having been constructed prior to more recent development which has allowed development at higher elevations reducing available pressures and storage. Local codes and development review by the Division typically require mechanical devices to aid properties at these higher elevations. The Division should continue to perform peer review analyses of proposed developments for their impact on the Division's water system and storage facilities. A detailed analysis of low service pressures and fire flow availability is provided in Chapter 7 and recommended improvements are provided in Chapter 9.

When considering the worst-case storage scenarios, the Plymouth Center Pressure Zone has the largest deficit of fire storage. Additionally, the majority of low pressure customers appear to be within the Plymouth Center Pressure Zone. The formation of a new pressure zone with an elevated hydraulic grade line may alleviate the storage deficit observed in the Plymouth Center Pressure Zone. Refer to Chapter 9 for a detailed analysis of this recommendation.

It is worth noting that Plymouth Center also has the highest needed fire flow, according to the ISO report, of 7,000 gpm, which is the largest contributor to the storage deficit. As shown in Table 6-10 and Table 6-11, the adjacent Pine Hills Pressure Zone has the largest surplus of available fire flow storage, the installation of a pressure reducing valve in the Pine Hills Booster Pump Station to allow water to flow from the Pine Hills Pressure Zone to the Plymouth Center Pressure Zone would provide additional flow to help meet fire protection and peak hour demand requirements in the Plymouth Center Pressure Zone. Refer to Chapter 9 for a detailed analysis of this recommendation.

Chapter 7 – Assessment of Water Distribution Hydraulics & Control Strategies

7.1 HYDRAULIC MODEL UPDATE

The Division's hydraulic model of the distribution system was updated to reflect the most current information available. All hydraulic modeling was performed using WaterCAD CONNECT Update 2 by Bentley Systems, Inc. This program solves for the distribution of flows and hydraulic grades using the Gradient Algorithm. This method is an iterative process and is based on two principles:

1. The total flow entering the junction of two or more pipes ("nodes") must equal the flow leaving the junction; and
2. The change in pressure between any two points in the system must be equal by any and all paths connecting the points.

The computer software applies these two principles by assuming an initial flow pattern through the distribution system. Based on the assumed flow pattern, the software calculates head losses between the supply sources and the points of distribution. These head losses are compared and recalculated iteratively until the above stated principles are satisfied.

The computer model is a skeletonized version of the actual finished water system network. The model consists of a series of lines representing pipes, nodes simulating pipe intersections, reservoirs, pumps simulating water supply, and storage tanks. The model contains pipes of 2-inch or larger diameter.

The updates to the hydraulic model, previously updated in 2016, included the following:

- Updating network geometry based on new record drawing and GIS information.
- Assigning new demands based on 2018 metered water usage/customer billing data provided by the Division on April 30, 2019.
- Setting initial controls based on discussions with Division staff and SCADA screenshots showing control setpoints.
- Review of hydrant flow test reports against model performance, including those performed by EP, included in Appendix E.

7.2 DEMAND UPDATE

The 2018 customer billing data was geocoded using ArcGIS, reviewed and corrected as necessary, imported into the model, assigned to the nearest pipe in the hydraulic model, and divided proportionally to the nearest model nodes based on relative distance from each. In several locations, demands were manually adjusted to better reflect their actual spatial location. This included situations where a large collection of user demands were reported at one meter location, or where no model nodes existed to accurately capture a given demand, both of which could negatively impact the accuracy of the hydraulic model. As such, the following demands were manually re-allocated to new model nodes to more accurately reflect the spatial water demands:

- Pinehurst Mobile Home Village
- Plymouth Mobile Estates Co-op
- Entergy Nuclear Operations

The updated maximum day demand multiplier, representing the ratio of maximum day demands to average day demands, of 1.85 as presented in Chapter 4.

The previous 2016 model calibration effort involved assigning hourly demand patterns for each pressure zone by evaluating late April 2017 weekday SCADA data, specifically flow rates and tank levels. It is assumed that these diurnal curves continue to accurately represent hourly fluctuations in demand throughout the respective zones at present.

7.3 EXISTING WATER SYSTEM CONTROLS

Existing controls for the current water system operations are based on the calibrations made with the 2016 version of the model, with minor modifications using information provided by the Division. The current control setpoints for the booster pumps, well pumps, and actuator valves within the system are presented in Table 7-1 and Table 7-2 below.

Table 7-1 – Eastern Pressure Zone Setpoints

(Manomet and Cedarville)

Feature	Controlling Element	On Setpoint	Off Setpoint	Notes
Cedarville Booster Pump No. 1	Cedarville Tank Level	54.0 ft	62.0 ft	Typically inactive
Cedarville Booster Pump No. 2	Cedarville Tank Level	54.0 ft	62.0 ft	Typically inactive
Savery Pond Well Pump	Cedarville Tank Level	54.0 ft	62.0 ft	Relative speed 0.83
Cedarville Actuator Valve	South Pine Hills Tank Level	NA	NA	Run manually, typically 250 gpm
Ellisville Well Pump	South Pine Hills Tank Level	33.5 ft	38.0 ft	31.0 feet during summer months
Ship Pond Well Pump	South Pine Hills Tank Level	34.0 ft	38.0 ft	Relative speed 0.89
Wannos Pond Well Pump	South Pine Hills Tank Level	34.0 ft	38.0 ft	500 gpm target flow rate

Table 7-2 – Northern Pressure Zone Setpoints

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Feature	Controlling Element	On Setpoint	Off Setpoint	Notes
Federal Furnace Well Pump	Harrington Tank Level	78.5 ft	83.75 ft	
North Plymouth Well Pump	Harrington Tank Level	78.5 ft	83.75 ft	
Darby Pond Well Pump	Harrington Tank Level	78.5 ft	83.0 ft	Maximum 4 hours per day
Deep Water Booster Pump No. 1	Harrington Tank Level	78.5 ft	83.0 ft	
Deep Water Booster Pump No. 2	Harrington Tank Level	74.0 ft	83.0 ft	
South Pond Well Pump No. 1	Chiltonville Tank Level	54.5 ft	58.25 ft	
South Pond Well Pump No. 2	Chiltonville Tank Level	56.0 ft	60.0 ft	
Lout Pond Well Pump	Chiltonville Tank Level	54.5 ft	55.5 ft	Relative Speed 0.892
Nook Road Actuator Valve	Chiltonville Tank Level	54.0 ft	58.0 ft	250 gpm target flow rate
Bradford Well Pump No. 1	Stafford Street Tank Level	101.0 ft	106.2 ft	
Bradford Well Pump No. 2	Stafford Street Tank Level	101.0 ft	106.2 ft	
Nook Road Booster Pump No. 1	Stafford Street Tank Level	101.0 ft	106.2 ft	Typically inactive
Nook Road Booster Pump No. 2	Stafford Street Tank Level	98.0 ft	101.0 ft	Typically inactive
Pine Hills Booster Pump No. 1	North Pine Hills Tank Level	19.5 ft	26.0 ft	
Pine Hills Booster Pump No. 2	North Pine Hills Tank Level	14.5 ft	20.5 ft	

The pressure reducing valves at Summer Street, Obery Street, Hall Street, and Rocky Hill Road were considered closed for modeling purposes (refer to Chapter 1).

7.4 ASSESSMENT OF WATER DISTRIBUTION HYDRAULICS AND CONTROL STRATEGIES

The hydraulic performance of the distribution system was assessed based on average and maximum day demand conditions under present-day demand scenarios. Criteria for the hydraulic analysis included the ability of the system to provide adequate pressures and storage tank water turnover, consistent with guidelines outlined in the MassDEP Guidelines for Public Water Systems. The analysis in this chapter does not include anticipated demands from proposed developments throughout the Town of Plymouth (these anticipated demands are included when considering the recommendations outlined in Chapter 9.)

Potential modifications to the existing controls were explored that would improve the hydraulic performance of the distribution system and minimize risk or cost to the Division. Several Division-specific factors were considered in this analysis, including reducing reliance on sources with water quality challenges.

An overview of the distribution system is discussed in Chapter 1 and provided in Figure 1-1. The Northern Pressure Zone and the Eastern Pressure Zone were analyzed individually, focusing on existing and proposed controls.

7.5 EASTERN PRESSURE ZONE HYDRAULICS AND CONTROLS

The Eastern Pressure Zones consist of the Manomet and Cedarville Pressure Zones. The Manomet Pressure Zone has two storage tanks: the South Pine Hills Tank and the Indian Hill Tank. Controls for water supplies in the Manomet Pressure Zone are based on the South Pine Hills Tank level. The Indian Hill Tank is equipped with an altitude valve, which is reported to close at a level of approximately 37.9 feet.

The water supply sources for the Manomet Pressure Zone consist of the Wannos Pond Well, Ship Pond Well, Ellisville Well, and the Cedarville Actuator Valve from the Cedarville Pressure Zone. The Cedarville Actuator Valve operates by adjusting headloss to achieve a target flowrate of 250-400 gpm.

The Cedarville Pressure Zone consists of the Cedarville Tank and the Savery Pond Well. Additionally, the Cedarville Booster Pump Station can supply water from the Manomet Pressure Zone if the Savery Pond well is unavailable.

It should be noted that several uncertainties remain to be resolved in the Manomet Pressure Zone pertaining to the connectivity and condition of several key water mains. In particular, there appears to be an unknown hydraulic restriction near Manomet Point Road and some uncertainty regarding the condition of the trunk main on State Road. As a result of these uncertainties, the exact magnitude of the deficiencies discussed below are subject to change, pending the result of further field investigations, pipe conditions testing, and subsequent calibration efforts.

7.5.1 Eastern Pressure Zones – Existing Average Day Demand Conditions

The Manomet and Cedarville Pressure Zones each have sufficient capacity to meet average-day demand conditions. As such, it is not necessary to operate the Cedarville station in either direction. However, operating the Cedarville Actuator Valve during hours of peak demand can improve the hydraulics of the Manomet Pressure Zone, and the booster pumps provide necessary redundancy if the Savery Pond Well is offline.

Modeled maximum pressures in the Eastern Pressure Zones under existing average day demand conditions are shown in Figure 7-1. Results indicate a large number of customers south of the Wannos Pond Well typically exhibits pressures above 80 psi during typical operations. It should be noted that these high pressures may be alleviated by household plumbing fixtures, which are not taken into account in this analysis.

Several locations in the Eastern Pressure Zones also exhibit low pressures dropping below 35 psi and 20 psi, particularly near the storage tanks. Similarly, it should be noted that these low pressures may be alleviated by household plumbing fixtures, which are not taken into account in this analysis. Minimum pressures under existing average day operations are shown in Figure 7-2. Existing average day demand conditions for the Manomet and Cedarville Pressure Zones are discussed individually in the following sections.

Table 7-3 below summarizes the existing tank turnover in the Eastern Pressure Zones under average day demand conditions. Both the Indian Hill and Cedarville Tanks appear to fall below the MassDEP minimum guideline of 20% daily turnover.

Table 7-3 – ADD Eastern Pressure Zone Tank Turnover

(Manomet and Cedarville)

Pressure Zone	Tank	ADD Daily Turnover (feet)	ADD Daily Turnover (%)
Manomet	South Pine Hills	8.1	20%
Manomet	Indian Hill	5.6	14%
Cedarville	Cedarville	9.9	15%

Table 7-4 below summarizes the existing source run times in the Eastern Pressure Zones under average day demand conditions.

Table 7-4 – ADD Eastern Pressure Zone Source Run Times

(Manomet and Cedarville)

Pressure Zone	Pump	Approximate ADD Daily Run Time (hours)
Manomet	Ship Pond Well Pump	15.6
Manomet	Ellisville Well Pump	2.6
Manomet	Wannos Pond Well Pump	15.6
Manomet	Cedarville Actuator Valve	13.7
Cedarville	Savery Pond Well	8.4
Cedarville	Cedarville BPS 1	0.0
Cedarville	Cedarville BPS 2	0.0

7.5.1.1 Manomet Pressure Zone – Existing Average Day Demand Conditions

As shown in Figure 7-1, the majority of the water supplies for the Manomet Pressure Zone are in the southern portion of the zone, south of the Indian Hill Tank. Given the existing controls, hydraulic capacity of the distribution system, and the altitude valve setpoint at the Indian Hill Tank, the Indian Hill Tank fills at a faster rate than the South Pine Hills Tank, as shown in Figure 7-3.

After the Indian Hill Altitude Valve closes, the water sources continue to run until the South Pine Hills Tank reaches the off setpoint. This results in pressure surges above 80 psi along the Manomet Zone, particularly near the Ship Pond and Wannos Pond Wells.

The average daily turnover in the South Pine Hills Tank is approximately eight feet per day, which represents approximately 20 percent of the total storage volume of that tank. The average daily turnover in the Indian Hill Tank is approximately 14 percent of total volume, slightly below the recommended 20-30 percent outlined in the Guidelines for Public Water Systems.

7.5.1.2 Cedarville Pressure Zone – Existing Average Day Demand Conditions

In the Cedarville Pressure Zone, the Cedarville Tank experiences a daily turnover of approximately 24 percent of the total storage volume. Typical pump and tank trends in the Cedarville Pressure Zone are shown in Figure 7-4.

Several areas in the Cedarville Pressure Zone exhibit pressures above 80 psi during average day demand operations, with some areas over 100 psi, particularly in the lower elevation areas along the southern and eastern extents of the zone. Pressures also drop below 35 psi in the high elevation areas near the Cedarville Tank.

The average day demand in the Cedarville Pressure Zone is approximately 182 gpm. In the event that the Savery Pond well is offline, the Cedarville booster pumps have sufficient capacity to meet these demands, with a combined capacity of over 900 gpm under typical operating conditions. However, such a scenario was not modeled as part of this analysis.

7.5.2 Eastern Pressure Zones – Existing Maximum Day Demand Conditions

Overall maximum pressures in the Eastern Pressure Zones increase under maximum-day demand conditions in comparison to average day demand conditions and are shown in Figure 7-5. Several points in the Eastern Pressure Zones also exhibit low pressures and drop below 35 psi and 20 psi, particularly near the storage tanks. It should be noted that these low pressures may be alleviated by household plumbing fixtures, which are not taken into account in this analysis. Minimum pressures under maximum-day operations are shown in Figure 7-6. Maximum day demand conditions for the Manomet and Cedarville Pressure Zones are discussed in the following sections.

Table 7-5 below summarizes the existing tank turnover in the Eastern Pressure Zones under maximum day demand conditions. All tanks appear to fall below the MassDEP minimum daily turnover guideline of 20 percent. The Indian Hill Tank turnover is particularly low, as the increased run time of the sources at the southern extent of the Manomet Pressure Zone prevent the Indian Hill Tank from draining.

Table 7-5 – MDD Eastern Pressure Zone Tank Turnover

(Manomet and Cedarville)

Pressure Zone	Tank	MDD Daily Turnover (feet)	MDD Daily Turnover (%)
Manomet	South Pine Hills	8.5	21%
Manomet	Indian Hill	3.0	8%
Cedarville	Cedarville	10.2	16%

Table 7-6 below summarizes the existing source run times in the Eastern Pressure Zones under maximum day demand conditions.

Table 7-6 – MDD Eastern Pressure Zone Source Run Times

(Manomet and Cedarville)

Pressure Zone	Pump	Approximate MDD Daily Run Time (hours)
Manomet	Ship Pond Well Pump	20.9
Manomet	Ellisville Well Pump	17.7
Manomet	Wannos Pond Well Pump	20.9
Manomet	Cedarville Actuator Valve	13.7
Cedarville	Savery Pond Well Pump	14.4
Cedarville	Cedarville BPS 1	0.0
Cedarville	Cedarville BPS 2	0.0

7.5.2.1 Manomet Pressure Zone – Existing Maximum Day Demand Conditions

Under existing maximum-day demand conditions, the South Pine Hills Tank is drawn down an additional 4-5 feet in comparison to average day demand conditions, as shown in Figure 7-7. This actually slightly increases the turnover to 21 percent. The increased operations of the southern sources causes the Indian Hill tank to remain full for a longer period of time, reducing its daily turnover to 8 percent.

Despite the Indian Hill Actuator Valve being closed for longer, it appears the increased demands are sufficiently high to suppress the HGL, decreasing the number of customers experiencing pressures above 80 psi. However, it should be noted that the Cedarville Actuator Valve is reported to be operated manually, and pressures in the Manomet Zone appear to be highly sensitive to operations at the Cedarville Actuator Valve.

Furthermore, the comparison of average day and maximum day scenarios shows the extent to which operational capacity at the wells is restricted by each other. As the Ellisville Well Pump turns on, the output at the Ship Pond Well is reduced by approximately 40 percent. This is largely responsible for the current firm capacity deficit in the Eastern Pressure Zones, as operational capacity is currently far below the safe yield of the wells. The addition of further demands, however, suppresses the HGL of the Manomet Pressure Zone, which then allows for increased output at the Ellisville and Ship Pond sources.

Thus, as demands increase, the Manomet Pressure Zone may have the capacity to meet future maximum day demands. However, the HGL suppression required to achieve those flows is untenable, and would result in widespread low pressures throughout the zone. As discussed in later sections of the report, it is more prudent to decrease headlosses in the Manomet Pressure Zone, reducing the output pressure required to fill the South Pine Hills Tank, and thus tapping into additional capacity at these sources.

7.5.2.2 Cedarville Pressure Zone – Existing Maximum Day Demand Conditions

Operations in the Cedarville Pressure Zone are largely similar to average day conditions, though the increased demands result in a marginal increase in daily turnover in the Cedarville Tank. The Savery Pond Well has sufficient capacity to meet existing maximum day demands in the Cedarville Pressure Zone with a very similar pressure profile to the average day demand conditions. The Cedarville Tank hydraulic grade and the Cedarville source flows under maximum day demand conditions are shown in Figure 7-8.

With a maximum day demand of roughly 337 gpm, the Cedarville booster pumps possess sufficient capacity to meet demands in the Cedarville Pressure Zone should the Savery Pond well need to be taken offline. However, this scenario was not included in the scope of this analysis.

7.5.3 Eastern Pressure Zones – Fire Flow Analysis

A fire flow analysis of the Division's water system was performed by comparing modeled available fire flows to needed fire flows, as determined by the Insurance Services Office, Inc. (ISO). The majority of the needed residential fire flows were inferred based on residential house spacing, as outlined in Chapter 7 of the ISO's Guide for Determination of Needed Fire Flow document, edition 06-2104. Needed fire flows are also supplemented with 37 test locations outlined in the Public Protection Classification document provided by ISO to the Plymouth Water Division on June 24, 2019 (Appendix D). These supplementary tests are primarily at locations with particularly high needed fire flows due to special occupancy or construction types, such as schools.

Ideally, available fire flows would be calculated with 20 psi of residual pressure at the testing hydrant and 20 psi of residual pressure at all other points in the distribution system within the pressure zone. However, many points in the distribution system experience less than 20 psi of residual pressure under normal operating conditions. As such, the available fire flow in the Manomet Pressure Zone would be 0 gpm if calculated in this way.

While that is important information, an analysis such as the above would not reveal new information about the carrying capacity and hydraulic restrictions of the existing water system. EP instead opted to calculate available fire flow with 20 psi of residual pressure at the test hydrant and 0 psi of residual pressure throughout the remainder of the pressure zone. This provides more in-depth information about the areas of the water system most in need of improvements to carrying capacity.

It should be noted that the analysis below reviews instantaneous fire flow, rather than sustained fire flows, and is independent of the fire flow storage analysis provided in Chapter 6.

7.5.3.1 Manomet Pressure Zone – Existing Conditions Fire Flow Analysis

When assessing the existing fire flow availability in the Manomet Pressure Zone, all sources were assumed off, and an average water level of 35 feet at the South Pine Hills Tank and 36.2 feet at the Indian Hill Tank were assumed. Based on these assumptions, EP identified fire flow deficiencies near the Indian Hill Tank, at the dead end on Beaver Dam Road, and along the entire northern coast of the Manomet Pressure Zone, as shown in Figure 7-9.

Near Indian Hill, the available fire flow is 0 gpm, as the static pressures in this area are below 20 psi under normal operation conditions. In all other areas, flows are restricted by system hydraulics. However, it is worth noting that there were discrepancies in the northern extent of the Manomet Pressure Zone during calibration. As the supplementary data necessary to resolve these discrepancies has yet to be collected, any results in this area are subject to change, pending further investigations.

There are also four ISO Test Sites in the Manomet Pressure Zone, as shown on Figure 7-9. Consistent with the 2019 ISO Public Protection Classification document, EP found deficiencies at Test Sites 11 and 14. However, EP also found a deficiency at Test Site 15, near the Indian Hill Tank, where the ISO reported an available flow of 2,300 gpm, which exceeds the needed fire flow of 1,000. EP reports 0 gpm in this area due to pressures below 20 psi.

A closer examination of pressures at this location show very large pressure swings depending on the status of the Indian Hill Altitude Valve. EP made the conservative assumption that tank levels were slightly depressed during the FF analysis. Based on the ISO field test data, it appears that during the ISO test, the Indian Hill Actuator Valve was likely closed, and the Manomet Pressure Zone was being pressurized as the southern wells attempted to fill the South Pine Hills Tank. The pressure at this location appears to fluctuate between roughly 17 and 40 psi, with everything above 20 psi occurring when the altitude valve is closed. This would account for the elevated fire flow reported by ISO in the field.

Therefore, while it appears the maximum available fire flow can surpass the required amount near the Indian Hill Tank, it is only under relatively extreme circumstances, and should therefore not be used as an expected fire flow for fire suppression purposes.

7.5.3.2 Cedarville Pressure Zone – Existing Conditions Fire Flow Analysis

When assessing available fire flows in the Cedarville Pressure Zone, it was assumed the Savery Pond Well Pump was off, the Cedarville Actuator Valve was active at 400 gpm, and the Cedarville Tank was at a level of 57.8 feet.

These conditions resulted in adequate residential fire flows throughout the entire Cedarville Pressure Zone based on the needed fire flows calculated from building spacing alone, as shown in Figure 7-9. In addition, there are two ISO Test Sites in the Cedarville Pressure Zone along State Road.

At Test Site 16, the available fire flow greatly surpassed the 750 gpm required by ISO. At Test Site 17, EP found a deficiency; the needed fire flow of 3,500 gpm was not met. ISO found 1,700 gpm at this location, and EP found 2,000 gpm.

7.6 EASTERN PRESSURE ZONES – PROPOSED CONTROL STRATEGY

A proposed control strategy was developed to stabilize the hydraulic grade in the Eastern Pressure Zones, particularly under maximum-day demand scenarios. Both average-day demand and maximum-day demand conditions were evaluated, as the proposed control strategies are meant to be implemented year-round.

As discussed in the existing conditions section above, the clustering of the water sources in the southern portion of the Manomet Pressure Zone contributes to pressure surges as they fill the Indian Hill Tank and continue to run after the altitude valve closes. To alleviate this issue, it is advisable to operate the Wannos Pond Well as much as possible and as close to 100 percent speed as possible, as its proximity to the South Pine Hills Tank will better distribute flow and stabilize the hydraulic grade throughout the Manomet Pressure Zone. This will make it such that sources furthest from the South Pine Hills Tank are only operated when hydraulic grades in the Manomet Pressure Zone are low, and will allow the Indian Hill Tank to cycle more frequently.

At present, the Wannos Pond Well is operating with a target flow rate of 500 gpm, which is considerably lower than the design capacity of the well and pump station. Based on the most recent pump curve data, it appears it is possible to provide closer to 650 gpm from the Wannos Pond Well. Additionally, the Wannos Pond Well is permitted for up to 0.94 MGD, or 652 gpm, under the Water Management Act and it is desirable to achieve this increased flow for as long as possible. Therefore, the on setpoint for the Wannos Pond Well should be the highest of the Manomet sources. Which will occasionally result in it operating on its own during periods of low demands. However, this "off" setpoint should be lowered to approximately 35.5 feet under current demands to ensure the Wannos Pond Well has adequate down time per day to recover.

The next highest priority source should be the Ellisville Well, as its high capacity allows it to meet periods of high demands while minimizing the duration of pressure surges. However, hydraulics are considerably improved if the Ellisville Well Pump is run at 93 percent speed to reduce the discharge head slightly. The Cedarville Actuator Valve and Ship Pond Well would be lower priority sources, and would have the shortest run times.

Further, the Division is reportedly operating the Savery Pond Well Pump at 83 percent of full speed, due to recurring damage to the motors. EP recommends the Savery Pond Well Station be upgraded as necessary to ensure full capacity is available in the future.

Table 7-7 includes a summary of proposed changes to the controls for the water sources in the Manomet Pressure Zone. No changes are proposed to the Cedarville Pressure Zone.

Table 7-7 – Proposed Manomet Pressure Zone Setpoints

Feature	Controlling Element	Current Level Setpoints (ft)		Proposed Level Setpoints (ft)		Details
		On	Off	On	Off	
Wannos Pond Pump	South Pine Hills Tank Level	34.0 ft	38.0 ft	32.5 ft	35.5 ft	Relative speed 1.0
Ellisville Pump	South Pine Hills Tank Level	33.0 ft	38.0 ft	31.5 ft	35.5 ft	Relative speed 0.93
Ship Pond Pump	South Pine Hills Tank Level	34.0 ft	38.0 ft	31.5 ft	35.0 ft	Relative Speed 0.890
Cedarville Actuator Valve	South Pine Hills Tank Level	34.0 ft	38.0 ft	31.0 ft	35.0 ft	400 gpm

7.6.1 Eastern Pressure Zones – Proposed Average Day Demand Conditions

Figures 7-1 and 7-2 show the resulting maximum and minimum pressures in the Eastern Pressure Zones under this revised control strategy during average day demand scenarios. The number of points in the Manomet Pressure Zone exhibiting system pressures above 80 psi is reduced from 125 to 53. Performance is largely unaffected in the Cedarville Pressure Zone. Resulting projected tank turnover in the Eastern Pressure Zones is presented in Table 7-8 below.

Table 7-8 – ADD Eastern Pressure Zone Tank Turnover

(Manomet and Cedarville)

Pressure Zone	Tank	Existing ADD Daily Turnover (%)	Proposed ADD Daily Turnover (%)
Manomet	South Pine Hills	20%	24%
Manomet	Indian Hill	14%	24%
Cedarville	Cedarville	15%	12%

As shown in the above table, the average daily turnover in the Indian Hill Tank is brought into the acceptable range under the MassDEP Guidelines for Public Water Systems. Turnover in the Cedarville Tank is reduced slightly, though not to a dangerously low level. Further, the Cedarville Tank is equipped with a static mixing system, which should allow for complete mixing of incoming fresh water.

Table 7-9 below summarizes the existing source run times in the Eastern Pressure Zones under maximum day demand conditions.

Table 7-9 – ADD Eastern Pressure Zone Source Run Times

(Manomet and Cedarville)

Pressure Zone	Pump	Approximate Existing ADD Daily Run Time (hours)	Approximate Proposed ADD Daily Run Time (hours)
Manomet	Ship Pond Well Pump	15.6	10.1
Manomet	Ellisville Well Pump	2.6	11.2
Manomet	Wannos Pond Well Pump	15.6	16.4
Manomet	Cedarville Actuator Valve	13.7	0.0
Cedarville	Savery Pond Well Pump	8.4	5.6
Cedarville	Cedarville BPS 1	0.0	0.0
Cedarville	Cedarville BPS 2	0.0	0.0

A summary of the resulting changes in high and low pressures in the Eastern Pressure Zones is shown below in Table 7-10.

Table 7-10 – ADD Eastern Pressure Zones Pressure Profile

Pressure Zone	Number of Nodes per Pressure Range							
	Existing Controls				Proposed controls			
	100+	80-100	20-35	<25	100+	80-100	20-35	<25
Manomet	0	126	7	6	0	60	9	6
Cedarville	11	15	11	0	11	14	11	0
Total	**11**	**141**	**18**	**6**	**11**	**74**	**20**	**6**

As shown in the above table, the number of pressures above 80 psi is reduced considerably under the proposed controls, which should allow for more efficient operations of the water sources, and may reduce leaks and extend the service life of the water system components.

7.6.1.1 Manomet Pressure Zone – Proposed Average Day Demand Conditions

Figure 7-3 shows the hydraulic performance of the Manomet Pressure Zone under this revised control strategy in comparison to the existing controls strategy.

With its elevated "on" setpoint, the Wannos Pond Well would run approximately 16 hours per day, with the Ellisville Well and Ship Pond Well staggered behind it at 11 and 10 hours, respectively. The Cedarville Actuator Valve would not need to be operated during average day demand conditions. While tank levels in the South Pine Hills Tank are lower by 2-3 feet for much of the day when compared to current average day demand controls, the resulting impact on low pressures is negligible. Further, the Indian Hill Altitude Valve is projected to be open for approximately four hours longer per day, which helps shorten the duration of any pressure surges above 80 psi. The turnover in both tanks in the revised controls strategy is improved slightly.

7.6.1.2 Cedarville Pressure Zone – Proposed Average Day Demand Conditions

The reduced operation of the Cedarville Actuator Valve increases the cycle time of the Cedarville Tank to approximately 24 hours, which would reduce the average daily turnover to approximately 12 percent. Projected Cedarville tank and source operations under average day demand conditions are shown below in Figure 7-4.

7.6.2 Eastern Pressure Zones – Proposed Maximum Day Demand Conditions

The resulting maximum pressures under the revised controls strategy are shown in Figure 7-5. The number of points in the Manomet Pressure Zone distribution system exhibiting pressure surges above 80 psi would decrease from 83 to 74 compared to the existing control strategy.

The number of points in the Manomet Pressure Zone distribution system exhibiting minimum pressures below 35 psi is approximately the same as the existing controls strategy. The resulting minimum pressures are shown in Figure 7-6. Proposed maximum day demand conditions for the Manomet and Cedarville Pressure Zones are discussed in the following sections.

Resulting projected tank turnover in the Eastern Pressure Zones is presented in Table 7-11 below.

Table 7-11 – MDD Eastern Pressure Zone Tank Turnover

(Manomet and Cedarville)

Pressure Zone	Tank	Existing MDD Daily Turnover (%)	Proposed MDD Daily Turnover (%)
Manomet	South Pine Hills	21%	21%
Manomet	Indian Hill	8%	11%
Cedarville	Cedarville	16%	12%

Table 7-12 below summarizes the existing source run times in the Eastern Pressure Zones under maximum day demand conditions.

Table 7-12 – MDD Eastern Pressure Zone Source Run Times

(Manomet and Cedarville)

Pressure Zone	Pump	Approximate Existing MDD Daily Run Time (hours)	Approximate Proposed MDD Daily Run Time (hours)
Manomet	Ship Pond Well Pump	20.9	14.5
Manomet	Ellisville Well Pump	17.7	19.7
Manomet	Wannos Pond Well Pump	20.9	20.9
Manomet	Cedarville Actuator Valve	13.7	13.9
Cedarville	Savery Pond Well Pump	14.4	16.9
Cedarville	Cedarville BPS 1	0.0	0.0
Cedarville	Cedarville BPS 2	0.0	0.0

A summary of the resulting changes in high and low pressures in the Eastern Pressure Zones is shown below in Table 7-13.

Table 7-13 – MDD Eastern Pressure Zones Pressure Profile

Pressure Zone	Number of Nodes per Pressure Range							
	Existing Controls				Proposed controls			
	100+	80-100	20-35	<25	100+	80-100	20-35	<25
Manomet	0	87	10	6	0	78	12	6
Cedarville	11	14	12	0	11	14	12	0
Total	**11**	**101**	**22**	**6**	**11**	**92**	**24**	**6**

7.6.2.1 Manomet Pressure Zone – Proposed Maximum Day Demand Conditions

Under existing maximum day demand conditions, demands cannot be met without the support of the Ship Pond Well and/or Cedarville Actuator Valve operating. As discussed above, the distance of these sources from the controlling South Pine Hills Tank results in the Indian Hill Tank filling several hours before the South Pine Hills Tank under the current controls strategy. This, in turn, causes the Indian Hill Altitude Valve to close, which contributes to high pressures in the southern portion of the Manomet Pressure Zone.

The proposed control strategy lowers both the on and off setpoints of the Manomet sources. This helps to curtail high pressure surges by lowering the operating range of the South Pine Hills Tank by 2-3 feet.

Figure 7-7 shows the hydraulic performance of the Manomet Pressure Zone under the proposed control strategy discussed above.

7.6.2.2 Cedarville Pressure Zone – Proposed Maximum Day Demand Conditions

The proposed controls strategy results in very little change to operations in the Cedarville Pressure Zone. The hydraulic performance of the Cedarville Pressure Zone is shown in Figure 7-8.

7.7 NORTHERN PRESSURE ZONE HYDRAULICS AND CONTROLS

The Northern Pressure Zones include the West Plymouth, Plymouth Center, Bradford, and Pine Hills Pressure Zones. Water storage tanks and water supply sources for the respective zones are shown in Tables 7-14 and 7-15 below. A layout of the Northern Pressure Zones can be seen in Figure 1-1.

Table 7-14 – Northern Pressure Zone Storage

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Storage Facilities	Notes
West Plymouth	Harrington	Controlling Tank
West Plymouth	North Plymouth	
West Plymouth	Samoset	Option to control Deep Water. Altitude valve closes at 65'.
Plymouth Center	Lout Pond	Can control Nook Road Actuator Valve
Plymouth Center	Chiltonville	Controlling Tank

Pressure Zone	Storage Facilities	Notes
Bradford	Stafford	Controlling Tank
Pine Hills	North Pine Hills	Controlling Tank

Table 7-15 – Northern Pressure Zone Sources

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Water Source	Notes
West Plymouth	Darby Pond	Withdrawal restrictions
West Plymouth	North Plymouth	
West Plymouth	Federal Furnace	Water quality concerns
West Plymouth	Deep Water Booster Pump 1	Booster Pump
West Plymouth	Deep Water Booster Pump 2	Booster Pump
Plymouth Center	Lout Pond	Water quality concerns
Plymouth Center	South Pond No. 1	
Plymouth Center	South Pond No. 2	
Bradford	Bradford Well No. 1	
Bradford	Bradford Well No. 2	
Pine Hills	Pine Hills Booster Pump 1	Booster Pump
Pine Hills	Pine Hills Booster Pump 2	Booster Pump

7.7.1 Northern Pressure Zones – Existing Average Day Demand Conditions

The Northern Pressure Zones have several hydraulic limitations. As shown in Figure 1-1, the Pine Hills Pressure Zone has no independent source and relies on water from the Plymouth Center Pressure Zone to fill the North Pine Hills Tank via the Pine Hills Booster Pump Station. Secondly, while the West Plymouth Pressure Zone does have three independent water sources (North Plymouth Well, Federal Furnace Well, and Darby Pond), two of those sources have limitations on their production, so the West Plymouth Pressure Zone must occasionally receive water from the Plymouth Center Pressure Zone via the Deep Water Booster Pump Station. The Darby Pond Well has limited withdrawals based on impacts to surrounding water bodies; the Water Division reports they limit its total daily production to approximately 0.3 MGD during lower demand scenarios. The Lout Pond Well exhibits high iron levels, so it is currently operating under modified controls that limit its use to only when necessary.

Lastly, at present, the Plymouth Center Pressure Zone can receive water from its two independent sources, as well as from the Bradford Pressure Zone via the Nook Road Actuator Valve. The Nook Road station is a two-way station. However, under normal operations, the Nook Road Booster Pumps are set to the “off” position, as there is more need for water to flow by gravity to the Plymouth Center Pressure Zone.

Several customers throughout the Northern Pressure Zones routinely and consistently experience high pressures. Overall maximum pressures in the Northern Pressure Zones under average day demand conditions are shown in Figure 7-10. Several points in the Northern Pressure Zones also drop below 35 psi and 20 psi, particularly near the storage tanks. Minimum pressures under average day operations are shown in Figure 7-11. Existing average day demand conditions for each Northern Pressure Zone are discussed in the following sections.

It should be noted that the Bradford Pressure Zone Expansion project, which consists of the Forges Field Well and Jordan Road FCV, was not included in the existing average-day demand conditions analysis presented below. As discussed in Section 7.7.4, when assessing potential improvements to the controls in the Northern Pressure Zones, it was assumed the Bradford Pressure Zone Expansion project is completed.

Table 7-16 below summarizes the existing tank turnover in the Northern Pressure Zones under average day demand conditions. All tanks appear to fall below the MassDEP minimum daily turnover guideline of 20 percent with the exception of the Lout Pond Tank.

Table 7-16 – ADD Northern Pressure Zone Tank Turnover

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Tank	ADD Daily Turnover (feet)	ADD Daily Turnover (%)
Pine Hills	North Pine Hills	1.3	5%
Bradford	Stafford	15.3	14%
West Plymouth	Harrington	9.5	11%
West Plymouth	North Plymouth	4.8	12%
West Plymouth	Samoset	7.8	11%
Plymouth Center	Lout Pond	8.6	23%
Plymouth Center	Chiltonville	10.9	18%

Table 7-17 below summarizes the existing source run times in the Northern Pressure Zones under average day demand conditions.

Table 7-17 – ADD Northern Pressure Zone Source Run Times

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Pump	Approximate ADD Daily Run Time (hours)
Bradford	Bradford Well Pump No. 1	7.4
Bradford	Bradford Well Pump No. 2	7.4
Bradford	Forges Field Well Pump[1]	0.0
Pine Hills	Pine Hills BPS 1	3.4
Pine Hills	Pine Hills BPS 2	0.0
Plymouth Center	South Pond Well Pump No. 1	4.3
Plymouth Center	South Pond Well Pump No. 2	15.1
Plymouth Center	Lout Pond Well Pump	3.3
Plymouth Center	Nook Road Actuator Valve	3.8
Plymouth Center	Jordan Road Flow Control Valve[1]	0.0
West Plymouth	Darby Pond Well Pump	2.3

Pressure Zone	Pump	Approximate ADD Daily Run Time (hours)
West Plymouth	Federal Furnace Well Pump	16.0
West Plymouth	Deep Water BPS 1	2.2
West Plymouth	Deep Water BPS 2	0.0
West Plymouth	North Plymouth Well	16.3

1. Indicates sources not yet active at the time of data collection.

7.7.1.1 Pine Hills Pressure Zone – Existing Average Day Demand Conditions

As shown in Figure 7-12, under average day demand conditions, the North Pine Hills Tank cycles approximately 4 feet every three days, representing approximately 5 percent daily volumetric turnover. Once the level drops low enough, the Pine Hills Booster Pump No. 1 turns on and fills the tank. The Pine Hills Booster Pump No. 2 is not required to operate under average day demand conditions with current control settings.

7.7.1.2 Bradford Pressure Zone – Existing Average Day Demand Conditions

Similarly, the Stafford Tank in the Bradford Pressure Zone drops to the lower setpoint before the Bradford Wells turn on and fills the tank, as shown in Figure 7-13. This process repeats approximately three times per day, representing a daily volumetric turnover of approximately 14 percent.

The Nook Road Actuator Valve occasionally directs water from the Bradford Pressure Zone to the Plymouth Center Pressure Zone, as needed; impacts on the Stafford Tank are relatively small, as the flows through the Nook Road Station are comparatively low.

7.7.1.3 West Plymouth Pressure Zone – Existing Average Day Demand Conditions

In the West Plymouth Pressure Zone, all three tanks move in relative synchrony, though the Samoset Tank Altitude Valve routinely closes below the maximum operating range of the other tanks, as shown in Figure 7-14. At present, pump controls are all set to the same starting setpoint, so all four sources of water for the West Plymouth Pressure Zone turn on at the same time, with the exclusion of the second booster pump at the Deep Water Booster Pump Station.

The average daily volumetric turnover in the West Plymouth Pressure Zone tanks are 11 percent for the Harrington Tank, 12 percent for the North Plymouth Tank, and 11 percent for the Samoset Tank.

The Darby Pond Well appears to fall below the Division target of 0.3 MGD under average day demand conditions, only running for approximately 2.5 hours. The Federal Furnace and North Plymouth Wells both operate under the same controls, and run for roughly 16 hours per day.

7.7.1.4 Plymouth Center Pressure Zone – Existing Average Day Demand Conditions

With three interconnections with neighboring pressure zones, operations in the Plymouth Center Zone are deeply intertwined with operations of the other zones, as shown in Figure 7-15.

Under average day demand conditions, South Pond Well No. 2 is sufficient to halt the decline in tank levels at the Lout Pond Tank, which then begins to fill with the addition of the South Pond Well No. 1 shortly thereafter. However, it is not until the addition of the Lout Pond Well and the Nook Road Actuator Valve that the Chiltonville Tank levels begin to recover. As both tank levels increase, the Lout Pond Tank reaches sufficient level for the altitude valve to close, resulting in small declines in the output at the operational water sources. The Lout Pond Tank remains full until the Chiltonville Tank reaches sufficient level to turn off the South Pond Well No. 2.

These effects are mostly due to the relative position of tanks in relation to the water sources. The Nook Road Actuator Valve is closer to the Chiltonville Tank, so opening this valve has a more direct effect on Chiltonville Tank Levels. On the other hand, the majority of the water sources, including the South Pond Wells and the Lout Pond Well, are considerably closer to the Lout Pond Tank. As a result, the increase in hydraulic grade line at the Lout Pond Tank happens considerably faster than at the Chiltonville Tank.

Both tanks cycle approximately two times per day during average demand conditions, representing approximately 23 percent turnover for the Lout Pond Tank, and 18 percent for the Chiltonville Tank.

Additionally, closing the altitude valve at the Lout Pond Tank creates a significant pressure surge that results in high pressures for a considerably large number of customers in the Plymouth Center Zone.

7.7.2 Northern Pressure Zones – Existing Maximum Day Demand Conditions

Several maximum system pressures in the Northern Pressure Zones under maximum demand conditions are above 80 and 100 psi, as shown in Figure 7-16. However, the extreme low tank levels during maximum demand conditions also result in low pressures below 35 psi and 20 psi for many customers throughout the Northern Pressure Zones, as shown in Figure 7-17. It should be noted that these low pressures may be alleviated by household plumbing fixtures which are not taken into account in this analysis. Existing maximum day demand conditions for each Northern Pressure Zone are discussed below.

Similarly to the average-day demand conditions, the Bradford Pressure Zone Expansion project was not included in the existing maximum-day demand conditions analysis presented in the following sections. Also, it is assumed the Darby Pond Well production is limited to the schedule provided by the Division, which lists a target daily production of 0.695 MGD.

Table 7-18 below summarizes the existing tank turnover in the Northern Pressure Zones under maximum day demand conditions. Several tanks appear to fall below the MassDEP minimum daily turnover guideline of 20 percent, including the North Pine Hills Tank, the Stafford Tank, the Harrington Tank, the North Plymouth Tank, and the Lout Pond Tank.

Table 7-18 – MDD Northern Pressure Zone Tank Turnover

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Tank	MDD Daily Turnover (feet)	MDD Daily Turnover (%)
Pine Hills	North Pine Hills	2.4	9%
Bradford	Stafford	11.0	10%
West Plymouth	Harrington	15.9	18%
West Plymouth	North Plymouth	6.5	16%

Pressure Zone	Tank	MDD Daily Turnover (feet)	MDD Daily Turnover (%)
West Plymouth	Samoset	19.9	29%
Plymouth Center	Lout Pond	5.8	15%
Plymouth Center	Chiltonville	13.4	22%

Table 7-19 below summarizes the existing source run times in the Northern Pressure Zones under average day demand conditions.

Table 7-19 – MDD Northern Pressure Zone Source Run Times

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Pump	Approximate MDD Daily Run Time (hours)
Bradford	Bradford Well Pump No. 1	16.6
Bradford	Bradford Well Pump No. 2	16.6
Bradford	Forges Field Well Pump[1]	0.0
Pine Hills	Pine Hills BPS 1	4.1
Pine Hills	Pine Hills BPS 2	0.0
Plymouth Center	South Pond Well Pump No. 1	17.4
Plymouth Center	South Pond Well Pump No. 2	20.1
Plymouth Center	Lout Pond Well Pump	16.5
Plymouth Center	Nook Road Actuator Valve	17.2
Plymouth Center	Jordan Road Flow Control Valve[1]	0.0
West Plymouth	Darby Pond Well Pump[2]	7.1
West Plymouth	Federal Furnace Well Pump	18.4
West Plymouth	Deep Water BPS 1	10.0
West Plymouth	Deep Water BPS 2	0.0
West Plymouth	North Plymouth Well	19.1

1. Indicates sources not yet active at the time of data collection.
2. Assumed pumping level restrictions are in effect.

7.7.2.1 Pine Hills Pressure Zone – Existing Maximum Day Demand Conditions

Under existing maximum demand conditions, the North Pine Hills Tank cycles about twice as fast as under average day demand conditions, resulting in a cycle time of roughly 36 hours, for an average daily turnover of 9 percent. The Pine Hills Booster Pump No. 1 must run slightly longer to fill the tank, but tank levels still do not drop low enough for the second booster pump to turn on, as shown below in Figure 7-18.

7.7.2.2 Bradford Pressure Zone – Existing Maximum Day Demand Conditions

In the Bradford Pressure Zone, an increase in demands within the zone, combined with an increase in demands through the Nook Road Actuator Valve, result in short periods of suppressed tank levels at the Stafford Tank, as well as correspondingly longer run times at both Bradford Wells, as shown below in Figure 7-19. This reduces the number of daily tank cycles from three to two, decreasing the daily turnover to 10 percent.

7.7.2.3 West Plymouth Pressure Zone – Existing Maximum Day Demand Conditions

In the West Plymouth Pressure Zone, tank levels follow a similar pattern as average day demand conditions, though the low peaks are 1-2 feet lower. Existing controls result in extended run times at the Federal Furnace Well, which exhibits elevated levels of manganese, and the Deep Water Booster Pumping Station, which puts additional stress on the Plymouth Center Pressure Zone.

The daily turnovers under maximum day conditions are roughly 18 percent, 16 percent, and 29 percent for the Harrington Tank, North Plymouth Tank, and Samoset Tank, respectively. Hydraulic performance of the West Plymouth Pressure Zone is shown in Figure 7-20.

7.7.2.4 Plymouth Center Pressure Zone – Existing Maximum Day Demand Conditions

In turn, the increased flows through the Pine Hills Booster Pump Station and the Deep Water Booster Pump Station result in significant drops in tank levels in the Plymouth Center Pressure Zone. The Lout Pond Tank drops an additional 2-3 feet to a low hydraulic grade of approximately 178 feet, while the Chiltonville Tank drops an additional 10 feet to a new low hydraulic grade of approximately 166 feet, as shown in Figure 7-21. Corresponding pump and valve operations are also shown in Figure 7-21.

As these figures illustrate, the hydraulic connectivity between the main water sources in the Plymouth Center Pressure Zone and the Lout Pond Tank is generally much greater than that of the Chiltonville Tank. As the South Pond Wells and Lout Pond Well turn on, the Chiltonville Tank continues to drop, while the Lout Pond Tank slowly fills. The operation of the South Pond and Lout Pond sources while the Lout Pond Tank is full results in an area of high pressures similar to average day demand conditions.

It isn't until the Pine Hills and Deep Water Booster Pumps turn off, and demands subside, that the Chiltonville Tank levels recover, all sources turn off, and the Lout Pond Tank is allowed to decline.

Resulting turnover during maximum demand conditions for the Lout Pond Tank and Chiltonville Tank are approximately 15 percent and 22 percent, respectively.

7.7.3 Northern Pressure Zones – Fire Flow Analysis

The instantaneous fire flow analysis performed for the Eastern Pressure Zones, as described in Section 7.5.3, was also performed for the Northern Pressure Zones as discussed below.

Similar to the Eastern Pressure Zones, many points in the distribution system experience less than 20 psi of residual pressure under normal operating conditions. As such, the available fire flow in the West Plymouth, Plymouth Center, and Pine Hills Pressure Zones would be 0 gpm if calculated in this way. EP instead opted to calculate available fire flow with 20 psi of residual pressure at the test hydrant and 0 psi of residual pressure throughout the remainder of the pressure zone.

7.7.3.1 Pine Hills Pressure Zone – Existing Conditions Fire Flow Analysis

When assessing the existing fire flow availability in the Pine Hills Pressure Zone, EP assumed an average water level of 22.8 feet in the North Pine Hills Tank, and assumed the Pine Hills Booster Pumps were off. With these inputs, EP identified fire flow deficiencies along the eastern extent of Bay Shore Drive, as shown in Figure 7-22.

There is also an ISO Test Site (Site 10) at the western intersection of Tower Road and Bay Shore Drive. While the ISO reported sufficient fire flow availability at this location, EP found a slight deficiency, likely due to the initial conditions of the analysis. ISO may have conducted the fire flow test when the North Pine Hills Tank was nearly full, and the booster pumps were still running. This would represent a slight overestimation of the reasonably expected available fire flow at this location.

Fire flow availability in the Pine Hills Pressure Zone appears to meet ISO standards, with the exception of the eastern end of Bay Shore Drive. However, the extent and nature of the upgrade will need to be coordinated with the Pine Hills Interconnection project, which has the potential to significantly impact the hydraulic performance of the region result in considerable changes in available fire flow in this pressure zone. Therefore, EP recommends the Division re-assess fire flow in the context of the final design of that project, and consider any necessary water main upgrades to meet fire flow requirements at that time.

7.7.3.2 Bradford Pressure Zone – Existing Conditions Fire Flow Analysis

When assessing the existing fire flow availability in the Bradford Pressure Zone, EP assumed both Bradford Well Pumps were off, and assumed an average tank level of 103.5 feet at the Stafford Tank. With these inputs, EP identified no residential fire flow deficiencies in the Bradford Pressure Zone.

However, EP did find deficiencies consistent with ISO reports at Test Sites 7 and 8. Test Site 7 is the High School off Obery Street, where the required fire flow is 5,000 gpm. EP found 3,675 gpm available in the water system, which is above the 3,500 gpm threshold for which the Water Division is responsible. Therefore, the Division should consult with the fire chief and the school regarding methods for increasing the available flow on the school property itself.

7.7.3.3 West Plymouth Pressure Zone – Existing Conditions Fire Flow Analysis

When assessing the existing fire flow availability in the West Plymouth Pressure Zone, EP assumed all sources were off, including the Deep Water Booster Pumps, and assumed initial elevations of 78.5 feet at the Harrington Tank, 65.3 ft at the Samoset Street Standpipe, and 35.0 feet at the North Plymouth Tank. With these inputs, EP identified fire flow deficiencies along Megansett Drive, as shown in Figure 7-22.

There are also several ISO Test Sites in the West Plymouth Pressure Zone. Consistent with ISO testing, EP found sufficient fire flow availability at Test Site 20 at the intersection of Lantern Lane and Flint Locke Lane, Test Site 21 at the intersection of Esta Road and Dartmouth Road, and Test Site 23 at the intersection of Aldrin Road and Armstrong Road. Also consistent with ISO testing, EP found deficiencies at Test Site 18 at Federal Furnace Elementary School, Test Site 19 & 19.1 at the airport plaza on South Meadow Road, and Test Site 22 at West Elementary School.

7.7.3.4 Plymouth Center Pressure Zone – Existing Conditions Fire Flow Analysis

When assessing the existing fire flow availability in the Plymouth Center Pressure Zone, EP assumed an initial level of 49 feet at the Chiltonville Tank and 29 feet at the Lout Pond Tank. Additionally, the Deep Water and Pine Hills Booster Pump No. 1 were on, to simulate a high-stress scenario. However, South Pond Well Pump No. 2 and Nook Road sources are both active in this scenario, as they would likely be under such high demands with the current control strategy. Using these inputs, there are several areas with deficient fire flows based on house spacing, including:

- The end of Saw Mill Drive
- The end of Magoni Terrace
- Several dead ends in the neighborhood east of the Vine Hill Cemetery, including Highland Place, Margerie Street, and Sever Street
- The end of Braley Road
- The end of Coles Lane
- Several high points near the Chiltonville Tank, including Lauren Road, Harborlight Circle, and Kenwood Drive
- The end of Jacob's Ladder Road off Doten Road
- Doten Road east of Jacob's Ladder Road
- The end of Hayden Ridge
- Jordan Road south of Sandwich Road
- All of Russel Mills Road

In addition, there are several ISO Test Sites in the Plymouth Center Pressure Zone, including Test Sites 1, 1.1, 1.2, 1.3, 2, 3, 3.1, 3.2, 4, 5, 5.1, 6, 9, and 12. EP and ISO found sufficient fire flow at Test Sites 3.1, 4, 5.1, 9, and 12, and found deficient fire flow availability at all other sites, as shown in Figure 7-22. It should be noted that the fire flow found by EP at Test Sites 3, 3.2, 5, and 6 were below the ISO required amount, but above the 3,500 gpm threshold for which the Division is responsible for achieving in the water system itself. Therefore, deficiencies at these locations may need to be addressed by the property owners.

It should also be noted that the addition of the proposed Forges Field Well and Jordan Road FCV are anticipated to mitigate several of the existing fire flow deficiencies, as discussed later in this section.

7.8 NORTHERN PRESSURE ZONES – PROPOSED CONTROL STRATEGY

When assessing potential improvements to the controls in the Northern Pressure Zones, it was assumed the Bradford Pressure Zone Expansion project is completed. The project includes the development of an additional source at the Forges Field site near Jordan Road. The future production well at the Forges Field Site is currently under construction with a withdrawal rate of up to 1.05 million gallons per day (MGD). The well is designed to pump into the Bradford Pressure Zone and a valve control station on Jordan Road will allow for a second point of connection between the Bradford and Plymouth Center Pressure Zones.

In addition to the Bradford Pressure Zone Expansion project, there are several recommended modifications to controls in the Northern Pressure Zones that can improve system hydraulics, as discussed below.

7.8.1 Northern Pressure Zones – Proposed Average Day Demand Conditions

Overall maximum and minimum system pressures in the Northern Pressure Zones under the proposed average day demand conditions are shown in Figures 7-10 and 7-11, respectively. The proposed control strategy decreases by nearly 60 percent the number of nodes in the Northern Pressure Zones that experience pressures over 80 psi during average demand conditions, primarily in the Plymouth Center Pressure Zone.

Proposed average-day demand conditions for each Northern Pressure Zone is discussed in the following sections. A summary of pressure profiles is shown in Table 7-20 below:

Table 7-20 – ADD Northern Pressure Zones Pressure Profile

Pressure Zone	Number of Nodes per Pressure Range							
	Existing Controls				Proposed controls			
	100+	80-100	20-35	<25	100+	80-100	20-35	<25
Bradford	0	7	0	0	0	7	0	0
Pine Hills	0	16	0	2	0	16	0	2
Plymouth Center	0	136	123	8	0	1	107	9
West Plymouth	14	94	11	0	12	85	10	0
Total	**14**	**253**	**134**	**10**	**12**	**109**	**117**	**11**

Table 7-21 below compares the existing and proposed tank turnover in the Northern Pressure Zones under average day demand conditions.

Table 7-21 – ADD Northern Pressure Zone Tank Turnover

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Tank	Existing ADD Daily Turnover (%)	Proposed ADD Daily Turnover (%)
Pine Hills	North Pine Hills	5%	4%
Bradford	Stafford	14%	16%
West Plymouth	Harrington	11%	12%
West Plymouth	North Plymouth	12%	9%
West Plymouth	Samoset	11%	21%
Plymouth Center	Lout Pond	23%	25%
Plymouth Center	Chiltonville	18%	10%

Table 7-22 below summarizes the existing source run times in the Northern Pressure Zones under average day demand conditions.

Table 7-22 – ADD Northern Pressure Zone Source Run Times

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Pump	Approximate Existing ADD Daily Run Time (hours)	Approximate Proposed ADD Daily Run Time (hours)
Bradford	Bradford Well Pump No. 1	7.4	7.5
Bradford	Bradford Well Pump No. 2	7.4	7.5

Pressure Zone	Pump	Approximate Existing ADD Daily Run Time (hours)	Approximate Proposed ADD Daily Run Time (hours)
Bradford	Forges Field Well Pump[1]	0.0	18.8
Pine Hills	Pine Hills BPS 1	3.4	6.3
Pine Hills	Pine Hills BPS 2	0.0	0.0
Plymouth Center	South Pond Well Pump No. 1	4.3	5.6
Plymouth Center	South Pond Well Pump No. 2	15.1	1.0
Plymouth Center	Lout Pond Well Pump	3.3	0.0
Plymouth Center	Nook Road Actuator Valve	3.8	18.8
Plymouth Center	Jordan Road Flow Control Valve[1]	0.0	18.8
West Plymouth	Darby Pond Well Pump[2]	2.3	3.4
West Plymouth	Federal Furnace Well Pump	16.0	1.9
West Plymouth	Deep Water BPS 1	2.2	2.5
West Plymouth	Deep Water BPS 2	0.0	0.0
West Plymouth	North Plymouth Well	16.3	18.9

1. Indicates sources not yet active at the time of data collection.
2. Assumed pumping level restrictions are in effect.

7.8.1.1 Pine Hills Pressure Zone – Proposed Average Day Demand Conditions

In the Pine Hills Pressure Zone, the current pumping rate of approximately 400 gpm from the Plymouth Center Pressure Zone through the Pine Hills Booster Station creates unnecessarily high stress on the Chiltonville Tank; average- and maximum-day demands in the Pine Hills zone are low, and do not necessitate the high pumping rate. Therefore, it is recommended the lead Pine Hills Booster Pump be run with a relative speed factor of 0.85 to reduce the impact on the Plymouth Center Pressure Zone.

Additionally, the North Pine Hills Tank has a maximum water level of 28.0 feet, yet the current "off" setpoint is 26.0 feet. As pressures in the vicinity of the tank are quite low, it is advisable to increase the average water level as much as possible to reduce the risk of excessively low or negative pressures. The proposed operational controls include raising all Pine Hills Booster Pump setpoints by two feet, as shown below in Table 7-23.

Table 7-23 – Proposed Pine Hills Pressure Zone Setpoints

Feature	Controlling Element	Current Level Setpoints (ft)		Proposed Level Setpoints (ft)		Details
		On	Off	On	Off	
Pine Hills Booster Pump No. 1	North Pine Hills Tank Level	19.5 ft	26.0 ft	21.5 ft	27.9 ft	Relative speed factor of 0.85
Pine Hills Booster Pump No. 2	North Pine Hills Tank Level	14.5 ft	20.5 ft	16.5 ft	22.5 ft	

Under these proposed controls, the North Pine Hills Tank fills at a slower rate and reaches a slightly higher level, which has a small, but important impact on minimum pressures in the vicinity of the tank. However, it does decrease the average daily turnover slightly to 4 percent. While low, it is not anticipated this proposed turnover will result in any adverse effects at this site, especially considering the North Pine Hills Tank reportedly received a passive mixing system in 2013.

Hydraulic performance of the Pine Hills Pressure Zone is shown in Figure 7-12.

7.8.1.2 Bradford Pressure Zone – Proposed Average Day Demand Conditions

In the Bradford Pressure Zone, the addition of the Forges Field Well and Jordan Road Flow Control Valve (FCV) under the Bradford Pressure Zone Expansion project creates the potential for significant improvements to system hydraulics. The high pressures in the Plymouth Center Pressure Zone are a result of the sources continuing to run to fill the Chiltonville Tank long after the Lout Pond Tank Altitude Valve has closed. By increasing the duration of operations at the Nook Road Actuator Valve, and supplementing with additional flows from the Jordan Road FCV, the hydraulics in the Plymouth Center Pressure Zone can be improved significantly.

Assessments as part of the Bradford Pressure Zone Expansion projected revealed that opening the Jordan Road FCV can result in low pressures along Jordan Road if both the Forges Field and Bradford WTP sources are off. Additionally, operating the Forges Field Well with the Jordan Road FCV closed can result in high system pressures in the same region. It should be noted that high and low pressures may be alleviated by household plumbing fixtures which are not taken into account in this analysis.

Therefore, using the Jordan Road FCV to supplement the Chiltonville Tank levels mandates the following logic:

1. Jordan Road FCV opens when Chiltonville Tank levels are low, and Forges Field Well turns on to prevent low pressures along Jordan Road; and
2. Jordan Road FCV turns off when Chiltonville Tank levels are high, and Forges Field Well turns off to prevent high pressures along Jordan Road.

In the open position, the anticipated flow through the Jordan Road FCV is approximately 375 gpm with a design flow of 725 gpm at the Forges Field Well. Therefore, the remaining 350 gpm flows into the Bradford Pressure Zone from the Forges Field Well. However, EP is proposing the Division increase the output of the Nook Road Actuator to 400 gpm. Thus the combined flows leaving the Bradford Pressure Zone will be 775 gpm (375 gpm through the Jordan Road FCV and 400 gpm through Nook Road). This results in a net flow of 50 out of the Bradford Pressure Zone when the Forges Field Well is operating. Thus, it effectively falls on the Bradford Wells to produce the water required to meet demands in the Bradford Pressure Zone itself. No modifications to the controls of the Bradford Wells are required to facilitate this strategy. Hydraulic performance of the Bradford Pressure Zone is shown in Figure 7-13.

To meet demands, the Bradford Wells would run in short increments of 2-3 hours 3-4 times per day. Alternatively, it may be possible to operate the Bradford WTP at a reduced flowrate, such as by running one well at a time, and thus extend the operating time of the pump. However, the modifications required at the treatment plant to operate using only one well would likely not be worth the cost.

Lastly, operating the Forges Field Well based on the Jordan Road FCV, which in turn is operated based on the Chiltonville Tank, means the Forges Field Well is effectively operating based on a tank in a different pressure zone. Therefore, in the event the Bradford WTP were to be taken offline or in the event of emergency, the Forges Field Well, Jordan Road FCV, and Nook Road Actuator Valve would likely need to be run using a different control set. As such, an alternate control scheme for the Forges Field Well and Jordan Road FCV would need to be developed to address emergency scenarios.

7.8.1.3 West Plymouth Pressure Zone – Proposed Average Day Demand Conditions

In the West Plymouth Pressure Zone, it is possible to operate under average day demand conditions without the use of either the Deep Water Booster Pumps nor the Federal Furnace Well; there is sufficient capacity at the Darby Pond Well and North Plymouth Well to meet average demands. However, due to the location of the sources relative to the tanks, this results in unfavorable hydraulics. The resulting drops in the Samoset Tank levels would create excessively low pressures in the nearby areas of high elevation.

On the other hand, the Deep Water and Federal Furnace sources are both hydraulically close to the Samoset Tank, which has an altitude valve. As such, extended operation of these sources results in the Samoset Tank filling before the controlling Harrington Tank, which can result in pressures in excess of 80 and even 100 psi in some areas.

To mitigate these effects, the altitude valve setting on the Samoset Street Standpipe should be raised by two feet, to a level of 67.0 feet. Additionally, the "off" setpoints sources close to the Samoset Tank should be staggered below the North Plymouth Well and Darby Pond Well, to reduce the likelihood and frequency of the Samoset Tank Altitude Valve closing for extended periods of time. Lastly, the "off" setpoint for the Darby Pond Well should be staggered slightly below the North Plymouth Well to help ensure the well can operate when needed, rather than exhausting all of its allotted capacity in the morning. These revised controls are summarized in Table 7-24 below.

Table 7-24 – Proposed West Plymouth Pressure Zone Setpoints

Feature	Controlling Element	Current Level Setpoints (ft)		Proposed Level Setpoints (ft)		Details
		On	Off	On	Off	
North Plymouth Pump	Harrington Tank Level	78.5 ft	83.75 ft	79.5 ft	82.5 ft	
Darby Pond Pump	Harrington Tank Level	78.5 ft	83.0 ft	78.5 ft	81.0 ft	Maximum 0.3 MGD
Deep Water Booster Pump No. 1	Harrington Tank Level	78.5 ft	83.0 ft	78.5 ft	80.5 ft	
Federal Furnace Pump	Harrington Tank Level	78.5 ft	83.75 ft	78.5 ft	80.0 ft	
Deep Water Booster Pump No. 2	Harrington Tank Level	74.0 ft	83.0 ft	76.5 ft	80.5 ft	

Using these revised controls, average day operations in the West Plymouth Pressure Zone are shown in Figure 7-14. Tank turnover for the Samoset Tank is increased to roughly 21 percent. However, turnover in the North Plymouth Tank decreases to 9%. The turnover in the Harrington Tank is largely the same.

Low pressures in the vicinity of the tanks preclude extending the operating ranges to lower elevations. As such, the North Plymouth Tank should be assessed for water quality residuals and the possibility of installing mixing systems. It is reported that both other tanks in the West Plymouth Pressure Zone are already equipped with passive mixing systems.

It should be noted that it is possible the withdrawal from the Darby Pond Well may be even further increased in the near future. If that is the case, EP recommends the Division revisit and potentially update this control scheme. It may become possible to run the Darby Pond Well at a lower speed, and use it to offset flows at the North Plymouth Well, which has comparatively poor water quality.

Lastly, EP did preliminarily model average day scenarios without the use of the Federal Furnace Well, and results suggest the above controls will function adequately if the Federal Furnace Well is simply turned off during average-day demand conditions (e.g. if water quality further declines and the well is taken offline for maintenance). It may also be possible to achieve acceptable hydraulics without the use of the Deep Water Booster Pumps, should the Division prefer to operate the West Plymouth Pressure Zone independently. However, EP would recommend the Division revisit the hydraulic model and further refine the controls strategy if this route is chosen.

7.8.1.4 Plymouth Center Pressure Zone – Proposed Average Day Demand Conditions

In the Plymouth Center Pressure Zone, significant control adjustments are required to accommodate the changes discussed above, as well as to improve system hydraulics (minimize the number of high and low system pressures).

Running the South Pond and Lout Pond Wells after the Lout Pond altitude valve closes results in a significant number of high pressures in the northern extent of the Plymouth Center Pressure Zone. To mitigate this, several modifications are proposed:

- Increase the Lout Pond Altitude Valve setpoint from 36.2 to 37.0 feet;
- Provide extended operations of the Nook Road Actuator Valve and the Jordan Road FCV to supplement Chiltonville Tank levels;
- Increase the flow rate through the Nook Road Actuator Valve to 400 gpm; and,
- Lower the "off" setpoints of all sources to reduce the occurrence of pressure surges;
- Lower the "on" and "off" setpoints of the Lout Pond Well, which exhibits poor water quality, to reduce operations at this source.
- Stagger the on and off setpoints to allow for a wide range of demands to be met without excessively overpressurizing Downtown Plymouth

Table 7-25 below summarizes the proposed changes to operational controls in the Plymouth Center Pressure Zone:

Table 7-25 – Proposed Plymouth Center Pressure Zone Setpoints

Feature	Controlling Element	Current Level Setpoints (ft)		Proposed Level Setpoints (ft)		Details
		On	Off	On	Off	
Nook Road Actuator Valve	Chiltonville Tank Level	54.0 ft	58.0 ft	56.0 ft	58.0 ft	Increase target flow rate to 400 gpm
Jordan Road FCV	Chiltonville Tank Level	-	-	56.0 ft	58.0 ft	
South Pond Pump No. 1	Chiltonville Tank Level	54.5 ft	58.25 ft	55.5 ft	58.0 ft	
South Pond Pump No. 2	Chiltonville Tank Level	56.0 ft	60.0 ft	55.0 ft	57.5 ft	
Lout Pond Pump	Chiltonville Tank Level	54.5 ft	55.5 ft	53.0 ft	55.0 ft	Relative Speed 0.892

Under these modified controls, the sudden, large dips in the Chiltonville Tank levels, as observed under existing conditions, are eliminated, even when the Pine Hills Booster Pump runs to fill the North Pine Hills Tank. Further, the average operating level at the Lout Pond Tank is lowered slightly, preventing the altitude valve from closing under normal operations, as shown below in Figure 7-15. The resulting turnover in the Lout Pond Tank and Chiltonville Tank are 25 percent and 10 percent, respectively. Subsequently, EP recommends the Division consider a mixing system for the Chiltonville Tank, especially considering it is water from this tank that will contribute to that entering the Pine Hills Pressure Zone, which also exhibits low turnover.

Additionally, the proposed controls were developed to reduce the use of the Lout Pond Well as it currently has not been in operation during 2019. Under these proposed controls, Lout Pond Well does not run under average day demand conditions (refer to Figure 7-15); it only operates under very high day demand conditions, as discussed in the following sections.

Most importantly, these controls have a dramatic effect on high pressures throughout the pressure zone. The number of points in the Plymouth Center Pressure Zone experiencing pressures above 80 psi during average day demands is decreased from 132 to 1. This has the potential to greatly reduce the risk of water main breaks and other system failures in the pressure zone. Maximum and minimum pressures in the Northern Pressure Zones during average day demand scenarios are shown in Figures 7-10 and 7-11.

7.8.2 Northern Pressure Zones – Proposed Maximum Day Demand Conditions

Overall maximum and minimum system pressures in the Northern Pressure Zones under the proposed maximum day demand conditions are shown in Figures 7-16 and 7-17, respectively. The proposed controls strategy results in significant decreases in the both the number of points in the distribution system with pressures above 80 psi and those with pressures below 35 psi. Proposed maximum day demand conditions for each Northern Pressure Zone is discussed below.

Proposed average day demand conditions for each Northern Pressure Zone are discussed in the following sections. A summary of pressure profiles is shown in Table 7-26 below:

Table 7-26 – Northern Pressure Zones Pressure Profile: Maximum-Day Demand

Pressure Zone	Number of Nodes per Pressure Range							
	Existing Controls				Proposed controls			
	100+	80-100	20-35	<25	100+	80-100	20-35	<25
Bradford	0	7	0	0	0	7	0	0
Pine Hills	0	16	0	2	0	16	0	2
Plymouth Center	0	214	180	21	0	31	122	10
West Plymouth	16	93	11	0	12	85	12	0
Total	**16**	**330**	**191**	**23**	**12**	**139**	**134**	**12**

Table 7-27 below compares the existing and proposed tank turnover in the Northern Pressure Zones under average day demand conditions.

Table 7-27 – MDD Northern Pressure Zone Tank Turnover

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Tank	Existing MDD Daily Turnover (%)	Proposed MDD Daily Turnover (%)
Pine Hills	North Pine Hills	9%	7%
Bradford	Stafford	10%	15%
West Plymouth	Harrington	18%	16%
West Plymouth	North Plymouth	16%	15%
West Plymouth	Samoset	29%	37%
Plymouth Center	Lout Pond	15%	32%
Plymouth Center	Chiltonville	22%	16%

Table 7-28 below summarizes the existing source run times in the Northern Pressure Zones under average day demand conditions.

Table 7-28 – MDD Northern Pressure Zone Source Run Times

(West Plymouth, Plymouth Center, Bradford, and Pine Hills)

Pressure Zone	Pump	Approximate Existing MDD Daily Run Time (hours)	Approximate Proposed MDD Daily Run Time (hours)
Bradford	Bradford Well Pump No. 1	16.6	13.1
Bradford	Bradford Well Pump No. 2	16.6	13.1
Bradford	Forges Field Well Pump[1]	0.0	19.7
Pine Hills	Pine Hills BPS 1	4.1	7.8
Pine Hills	Pine Hills BPS 2	0.0	0.0
Plymouth Center	South Pond Well Pump No. 1	17.4	17.1

Pressure Zone	Pump	Approximate Existing MDD Daily Run Time (hours)	Approximate Proposed MDD Daily Run Time (hours)
Plymouth Center	South Pond Well Pump No. 2	20.1	12.4
Plymouth Center	Lout Pond Well Pump	16.5	6.8
Plymouth Center	Nook Road Actuator Valve	17.2	19.7
Plymouth Center	Jordan Road Flow Control Valve[1]	0.0	19.7
West Plymouth	Darby Pond Well Pump[2]	7.1	11.1
West Plymouth	Federal Furnace Well Pump	18.4	7.1
West Plymouth	Deep Water BPS 1	10.0	12.3
West Plymouth	Deep Water BPS 2	0.0	0.0
West Plymouth	North Plymouth Well	19.1	21.2

1. Indicates sources not yet active at the time of data collection.
2. Assumed pumping level restrictions are in effect.

7.8.2.1 Pine Hills Pressure Zone – Proposed Maximum Day Demand Conditions

In the Pine Hills Pressure Zone, performance is largely similar, save for the slightly longer fill time produced by the reduced pumping rate at the Pine Hills Booster Pump Station, as shown in Figure 7-18. The resulting daily turnover in the North Pine Hills Tank is approximately 7 percent.

7.8.2.2 Bradford Pressure Zone – Proposed Maximum Day Demand Conditions

In the Bradford Pressure Zone, the high demand from the Chiltonville Tank results in the Nook Road Actuator Valve and Jordan Road FCV operating over 19 hours per day. However, this triggers the Forges Field Well to operate, offsetting these demands almost entirely and mitigating the impact this has on the Stafford Tank. The number of cycles per day at the Stafford Tank thus increases, as shown in Figure 7-19. The resulting average turnover is approximately 15 percent.

7.8.2.3 West Plymouth Pressure Zone – Proposed Maximum Day Demand Conditions

In the West Plymouth Pressure Zone, tank trends are similar to those under existing controls, though with lower maximum elevations, and without the high pressure surges that come with the Samoset Tank Altitude Valve closing. Rather than remaining closed for approximately 9.5 hours per day under existing controls, the Samoset Tank Altitude Valve should remain open at all times. The resulting daily turnovers at the Harrington Tank, North Plymouth Tank, and Samoset Street Standpipe are 16 percent, 15 percent, and 37 percent, respectively. Also, the staggered controls allow for the Darby Pond Well to access considerably more of the capacity available to it under the withdrawal schedule proposed by the Division, and reliance on the Federal Furnace and Deep Water pumps is correspondingly reduced. Performance of the West Plymouth Pressure Zone is shown in Figure 7-20.

7.8.2.4 Plymouth Center Pressure Zone – Proposed Maximum Day Demand Conditions

The greatest improvement in maximum day demand performance is experienced in the Plymouth Center Pressure Zone, where the minimum hydraulic grade in the Chiltonville Tank is increased from 163 feet to 176 feet. This has a marked improvement on the low pressures in the Plymouth Center Pressure Zone, as seen in Figure 7-17. It should be noted that these low pressures may be alleviated by household plumbing fixtures which are not taken into account in this analysis. This improvement is primarily due to the increased water supply from the Nook Road Actuator Valve and the Jordan Road FCV, ultimately stemming from the Forges Field Well.

The Lout Pond Well will be called to run for approximately 7 hours per day under the proposed control set, which is required to offset peak demands when the Pine Hills and/or Deep Water Booster Pumps are operating. This is fewer than the approximately 18.5 hours of run time under the current controls strategy. It is likely possible to reduce operations at the Lout Pond Well even further, if so desired, though it may require sacrificing some hydraulic performance.

Projected hydraulic performance of the Plymouth Center Pressure Zone is shown in Figure 7-21. While the altitude valve at the Lout Pond Tank is forced to close occasionally, the duration of these occurrences is reduced considerably, as is their effect on the water system. The number of points in the Plymouth Center Pressure Zone experiencing low pressures below 35 psi is reduced from 182 to 132 under the proposed control strategy, and the number of points experiencing high pressures above 80 psi is also reduced from 182 to 132.

Chapter 8 – Emergency Procedures

This Chapter reviews the Division's current emergency procedures and standards for issuing emergency orders as well as evaluates potential actions to minimize the risk of emergency events in the future.

8.1 PLYMOUTH WATER DIVISION EMERGENCY RESPONSE PLAN

Water suppliers are required to prepare an Emergency Response Plan (ERP) in accordance with 310 CMR 22.04(13) and *Massachusetts Drinking Water Guidelines and Policies for Public Water Supplies*, *Chapter 12 – Emergency Response Planning Requirements Guidance* including *Appendix O – Handbook for Water Supply Emergencies.* The ERP must include steps to ensure continuation of service in the event of a potential or actual emergency. The ERP also must include description of procedures, structures, and equipment used to respond to emergencies.

The Plymouth Water Division's ERP was completed in December 2009 and last updated in April 2018. Updates are submitted to MassDEP annually as an attachment to the Division's ASR. Updates typically include revisions to the emergency contact list and a list of emergency response training provided to the Division staff that year. The following sections include a brief summary of key components of the Plymouth ERP.

8.1.1 Defining an Emergency

The ERP identifies events that may cause emergencies including construction accidents, lack of system maintenance, chemical spills, and floods. Each event type has an associated risk - high, medium, or low - and actions that may be taken to minimize risk.

Emergency events are also classified by severity which are measured as Levels I through V. The levels of emergency and examples of each are included in Table 8-1 below. For example, a Level III, or Major Emergency, is a very significant disruption that affects more than 50 percent of the system and is anticipated to require more than 72 hours to resolve. Major emergencies, Level III or greater, may require a Declaration of State of Water Supply Emergency and/or a health advisory including a Boil Water Order, Do Not Drink Order, or Do Not Use Order. Any emergency requiring a health advisory is considered, at a minimum, a Level III emergency. The ERP details the response procedures for each level of emergency including public notifications, sampling requirements, and record keeping requirements.

Table 8-1 – Emergency Levels of Severity

Emergency Levels of Severity		
Emergency Severity Level	**Level Description**	**Examples**
Level I	Normal/ Routine Emergencies	Water main breaks, short-term power outages, minor mechanical problems in pump-houses, minor situations where it is not likely that public health will be jeopardized
Level II	Alert/ Minor Emergencies	Local total coliform bacterial detection, major water main breaks, multiple water main breaks, major mechanical problems at pumping stations/treatment facilities, failure of chemical feed system
Level III	Major Emergencies	Break in major transmission main, loss or failure of treatment facility, loss of source, loss of system pressure, widespread total coliform bacteria outbreak, fecal coliform or E. Coli detection, major acts of vandalism, emergency events requiring a health advisory.
Level IV	Natural Disasters	Hurricanes, tornadoes, earth quakes, floods
Level V	Nuclear Disasters/ Major Terrorist Acts	Nuclear power plant release to the environment, deliberate release of highly toxic materials to a water supply

A water supplier may petition MassDEP for a Declaration of State of Emergency under the Water Management Act, Massachusetts General Law (MGL) c. 21G Section 15, 16 and 17. A water supplier is also required to submit a plan to end the state of emergency. Procedures for petitioning and receiving approval from MassDEP for a Declaration of State of Emergency are detailed in MassDEP's Drinking Water Policy #87-05.

The ERP adequately defines and describes emergencies and their associated risk. Actions to be taken to minimize risk of emergency should be updated and expanded as discussed in the Risk of Emergency Section below.

8.1.2 Emergency Notification

The ERP includes a responsible person and procedures for emergency related notifications. Procedures are in place for notifying all necessary parties. Each notification procedure references a list of emergency contacts which is maintained and kept updated as part of the ERP and ASRs. The emergency contact list includes:

- Plymouth Water Division personnel, including Water Superintendent
- Service and repair contractors
- Local officials, law enforcement, and emergency services workers
- Local media outlets
- Neighboring water systems
- Water testing laboratories
- State officials and emergency services
- MassDEP Southeast Region representatives
- Town of Plymouth employees
- Critical water system users (i.e. hospitals, healthcare facilities, daycares, nursery/elementary schools and other health and human service centers)

Procedures are included in the ERP for notifying customers of an emergency event. The Water Superintendent consults with MassDEP to review steps to be taken during the emergency event. The

Water Superintendent works with staff to develop a uniform response to questions and associated communication strategy including door hangers, signs, media statements, and reverse 911 call.

In the event that water quality and human health are in question, issuing a health advisory may be necessary when health risks are sufficient as determined by the water system, state, or local health officials. If MassDEP requires a health advisory, the water system must be prepared to communicate the message. Basic information on the preparation and delivery of key messages when communicating with the media, customers and others is included in a Communication section of the Plymouth ERP. When additional water quality sampling is required, the Water Quality Sampling Section can be referenced which includes water testing laboratory details, an overview of routine water quality, MassDEP sampling requirements, and the MCL for routine parameters.

MassDEP notification requirements listed in the Emergency Notification section of the ERP are in accordance with the MassDEP Drinking Water Regulations for emergency reporting, 310 CMR 22.15 (9).

8.1.3 Response Actions for Specific Events

For a series of specific emergency events, as listed below, the ERP describes immediate response actions, notifications, and follow up actions:

- Power outage
- Transmission or distribution main break
- Chlorine treatment equipment failure
- Loss of water supply from a source
- Chemical or microbiological contamination
- Chemical overfeed into the distribution system
- Vandalism or terrorist attack

- Drought
- Natural disasters (flood, earthquake, hurricane, etc.)
- Contamination from backflow
- SCADA system failure
- Collapse of a reservoir, reservoir roof for pump house structure
- Staffing shortage
- Imminent depletion of treatment chemical inventory

Once an emergency is resolved, the system is returned to normal operation. A list of actions is included in the Returning to Normal Operation section of the ERP.

8.1.4 Vulnerability Assessment

The ERP also includes a vulnerability assessment. Each facility including wells, booster pump stations and tanks are briefly assessed for security fencing, locks, backup power, Operation and Maintenance (O&M) manuals, on-site chemical storage, SCADA control, and additional concerns. In addition, the Division exercises standby systems weekly and completes flushing every fall and spring. In order to decrease the vulnerability of the water system, the Plymouth Water Division should consider implementing the following:

- Prioritize upgrades for critical well stations and plan them during off-peak season to ensure peak day demands can be met;
- Procure a mechanical valve operator to facilitate and expedite existing system-wide flushing programs already in place to scour/clean water mains and maintain a high quality of water;
- Facilities with no backup power include Cedarville Booster Pump Station. Develop procedures for connecting portable backup power;
- Implement standard operating procedures (SOPs) for exercising interconnections and emergency sources. Execute formal agreements to confirm location and operating conditions for interconnections;
- Develop alternative SCADA controls strategies to optimize system performance in response to the loss of water sources;
- Implement SOP for exercising distribution system valves; and,
- Identify facilities most at risk of flooding, wind damage, etc. Implement climate adaptation program and integrate risk assessment into planned capital improvements.

Some facilities are designated as critical components which are needed to supply the distribution system in an emergency. The vulnerability of the distribution system to supply and demand variations are addressed in Chapter 4.

8.2 EMERGENCY SOURCES OF SUPPLY

Curtailing water usage in the event of an emergency is executed at four levels: (1) voluntary reduction in water use, (2) prohibition of times and types of outside water use, (3) prohibition of all outside water usage, or (4) mandatory reduction or prohibition of all water uses. When curtailing water usage is insufficient in the event of an emergency, the Division may rely on emergency sources of supply. The ERP identifies emergency sources of water to use when the primary and seasonal sources cannot meet demand and should only be utilized when required by extreme, and mostly unpredictable, circumstances.

Emergency sources include Great South Pond and Little South Pond; Lout Pond is identified as an inactive emergency source. Additional emergency sources include interconnections with adjacent communities including two existing interconnections with the Kingston Water Department and the opportunity for a temporary interconnection with the North Sagamore Water District. Suppliers are also identified for situations requiring bottled water and bulk water.

Existing interconnections with Kingston Water Department are recommended before emergency sources can be utilized as a declaration of a state of a water supply emergency is required also prior to activation of an emergency source. A Declaration of a State of Water Supply Emergency is required prior to activating an emergency source or interconnection. MassDEP prioritizes emergency water supply options as follows:

1. Connection to an existing public water supply system
    a. Activation of an existing connection
    b. Creation of a new connection
2. Activation of an abandoned or reserve public water supply
3. Development of a new water supply source in the area served by the public water supplier
4. Development of a new water supply source in a nearby community in the same river basin
5. Development of an out of basin source

Based on the above, the Plymouth Water Division's interconnections with the Kingston Water System would be prioritized first followed by a new connection (potential interconnections are discussed below). Next, MassDEP would look at emergency and inactive water supplies including Little South and Great South Ponds. Emergency water supply sources, including interconnections, are further discussed below.

8.3 PLYMOUTH WATER DIVISION EMERGENCY SOURCES

The Division has multiple emergency sources including Great South Pond and Little South Pond; Lout Pond is identified as an inactive emergency source. Emergency sources of supply are discussed below.

8.3.1 Great South and Little South Ponds

Great South and Little South Ponds were part of the original water supply system for the Division. Water from Great South Pond flows through an open channel to Little South Pond. Raw water flows through a screened intake at the outlet of Little South Pond and then by gravity through a 16- and 18-in transmission main to the Lout Pond Pumping Station. The Lout Pond Pumping Station was constructed in 1903 and is located on Billington Street adjacent to Lout Pond.

Great South and Little South Pond water sources were abandoned in 1992 following new treatment requirements under the 1986 Amendments to the Safe Drinking Water Act. Great South and Little South Pond, although no longer an active source of supply, remain as emergency sources for the Plymouth Water Division. Activating this source under an emergency situation would allow the Plymouth Water Division to keep water in the system and provide additional fire protection, if needed. However, the transmission main is of the jacket type and is reported to be in very poor condition. Therefore, a significant effort may be required to activate the source.

Additionally, an emergency source may not be used without a Declaration of a State of Water Supply Emergency under MCL c. 21G and approval to use the source is received from MassDEP. Since the source is not regularly tested for water quality and does not meet current treatment regulations, using the source under an emergency event would require operating under a Boil Water or Do Not Drink health advisory. Once the emergency source is online, water quality testing must be performed. Since Great South and Little South Pond do not meet current treatment regulations under the Surface Water Treatment Rule, the health advisory would not be lifted.

Based on the level of effort to bring the source online in the event of an emergency and the vulnerability of the distribution system to supply and demand, the Division is considering steps to make the Little South and Great South Ponds active sources. The Plymouth Center Pressure Zone is particularly critical during emergency events as the South Pond Wells are a crucial in the Division's ability to handle these crises. There are very few reliable well sources and future well sites available within the Plymouth Center Pressure Zone and the Little South and Great South Ponds could provide an immediate water supply to this critical pressure zone if they were active sources.

In order to change the status of the Little South and Great South Ponds from emergency to active, significant infrastructure improvements will be necessary. Compliance will be required with the latest version of the Massachusetts Drinking Water Regulations (310 CMR 22), specifically the Surface Water Treatment Rules, which would likely result in the construction of a conventional filtration plant. A feasibility analysis consisting of water quality testing, existing infrastructure review, firm yield study, and permitting review is recommended.

8.3.2 Lout Pond

The Lout Pond Well, originally part of the Division's water system was brought online in 1955 and utilized until mid-1990s and subsequently taken offline due to clogging of the well screen as a result of high levels of iron and manganese. The original well was abandoned and a replacement well was constructed and brought online in 2014. The replacement well is currently permitted as an active source with a maximum day capacity of 0.72 MGD under the Water Management Act while the original well was abandoned and the pond remains as an inactive source according to the ERP. According to the Plymouth Water Division, no infrastructure exists to bring the inactive Lout Pond emergency source online in the event of an emergency.

8.4 EXISTING INTERCONNECTIONS

The Kingston Water Department supplies water to the Town of Kingston on the northern border of Plymouth. The system is supplied by seven wells. A manganese treatment plant constructed in 2014 treats high levels of manganese from one of the wells. Water is also treated at two corrosion control treatment plants. The distribution system consists of three storage tanks and over 112 miles of piping in two pressure zones. The system supplied over 465 million gallons to customers in 2017 with a permitted daily average of 1.28 MGD and approved maximum day withdrawal of 1.44 MGD. Therefore, in the event of an emergency, the Kingston Water Department may not have the available capacity to supply water to the Division.

The Plymouth Water Division has two interconnections with the Kingston Water System. One is an 8-inch connection with the West Plymouth Pressure Zone at Independence Mall Drive. The second is a 12-inch interconnection with the Plymouth Center Pressure Zone on Route 3A. The existing interconnections are detailed in Table 8-2 and shown in Figure 8-1.

Table 8-2 – Existing Interconnections

Existing Interconnections						
Water System	**Size**	**Location**	**Plymouth Pressure Zone**	**Hydraulic Grade Line**	**Kingston Pressure Zone**	**Hydraulic Grade Line**
Kingston Water Department	8-in.	Independence Mall Way/Enterprise Drive	West Plymouth Pressure Zone	295-ft.	Kingston Water System Low Pressure Zone	198-ft.
Kingston Water Department	12-in.	Route 3A	Plymouth Center Pressure Zone	187-ft.	Kingston Water System Low Pressure Zone	198-ft.

The hydraulic grade line of Kingston is 198-ft. (NGVD29) and could potentially supply the Plymouth Center Zone with water in times of an emergency. The interconnection at the Independence Mall would need to be pumped from Kingston into the West Plymouth Zone due to the differing hydraulic grade lines.

8.5 POTENTIAL INTERCONNECTIONS

8.5.1 Plymouth Northern and Eastern Pressure Zone Interconnection

An interconnection between the Northern and Eastern Pressure Zones through the Pine Hills Pressure Zone would increase water supply resiliency while providing flexibility during emergencies and periods of peak water demand. The Pine Hills Pressure Zone could serve as a vital link between the Northern Pressure Zones and the Eastern Pressure Zones; however, the current infrastructure does not have the remote monitoring and control capabilities required to allow for stable and reliable transfer of water.

In the event of an emergency, such as a fire or a mechanical pump failure, in the eastern pressure zones, the Division is at risk of not being able to provide reliable pressurized water service to its customers. The Pine Hills Booster Station, which is the only supply of water for the Pine Hills Pressure Zone, does not have a flow meter. An existing PRV, the Rocky Hill Road PRV, which could allow for the transfer of water from the Pine Hills Pressure Zone to the eastern Manomet Pressure Zone, is currently closed due to operational issues. In addition, there is currently no redundant supply to the Pine Hills Zone, and no ability to transmit water from the eastern pressure zones to the Northern Zones.

Infrastructure improvements to the Pine Hills Pressure Zone are discussed in Chapter 9 and include construction of one new combined flow control valve and pumping station, upgrades to one booster pumping station to include a flow control valve, and the installation of approximately 13,200 linear feet of 12-inch water main as shown. These upgrades will allow operators to remotely control the flow of water to and from the Northern and Eastern Pressure Zones through the Pine Hills Pressure Zone.

8.5.2 Interconnections with Neighboring Water Systems

There are several nearby water suppliers with which the Division could assess interconnecting. Nearby water suppliers and existing interconnections are shown in Figure 8-1. A brief overview of nearby water suppliers is provided below. However, additional information on these systems is necessary to identify any potential operational and water quality challenges with respect to interconnecting.

8.5.2.1 North Sagamore Water District

The North Sagamore Water District supplies water to the Village of North Sagamore in the Town of Bourne on the southern border of Plymouth. The system is supplied by three wells. The Black Pond Well and Church Lane Well supply the James A. Morgan WTP on Church Lane. The James A Morgan WTP treats water with potassium permanganate to oxidize iron and manganese, NaOH for corrosion control and NaOCl for disinfection. The Beach Well on Pilgrim Road is treated only with NaOH for disinfection. Under their WMA Permit, North Sagamore Water District has a permitted and registered 193.45 million gallons annual withdrawal and 0.53 MGD daily average withdrawal. The system has three storage tanks: Bournedale Tank on Scenic Highway, Clark Road Tank and Norris Road Tank for total of 1.7 million gallons of storage. The system also includes two booster stations. Information on the hydraulic grade line of the North Sagamore Water District near the Division was not readily available.

In the ERP, North Sagamore Water District is listed as an opportunity for a temporary connection in the event of an emergency. No interconnection currently exists, however both systems terminate near the Bourne and Plymouth town line on Route 3A. A fire hose or temporary pipelines could be used to connect hydrants from each system in order to create a temporary interconnection.

The opportunity for an interconnection was explored in the 2006 Water System Master Plan. At the time, the North Sagamore system did not have storage facilities and was controlled by booster pumps. With the addition of storage tanks to the North Sagamore Water District, a permanent piping interconnection may improve reliability in the southern extremity of the Division's water system. For example, in the case of a transmission break along Route 3A between just north of Treetop Way and the Bourne Town Line would leave the southern portion of the Cedarville Pressure Zone without water. Limited looping via an interconnection with the North Sagamore Water District may provide system redundancy for the Division. If this interconnection is considered, metering and connection requirements, including SOPs for operating and exercising the interconnection, should be explored between the two water systems.

Alternatively, should new source exploration activities indicate the possibility of a redundant source in Cedarville, strategic planning and design of the new source may alleviate the risk of water shortage during a water main break in the southern portion of the Cedarville Pressure Zone.

8.5.2.2 Pinehills Water Company

Pinehills Water Company was formed in 2001 and provides water to the residents and businesses in the Pinehills community in Plymouth. The Pinehills water system is a 1.4 MGD water system supplied by three wells. The system consists of a two million gallon storage tank, 39 miles of water mains, and two pressure zones. The three wells are located off Beaver Dam Road. The water is treated for pH adjustment and corrosion control.

Under their WMA Permit, the Pinehills Water Company has a permitted 167.9 million gallons annual water withdrawal of, a 0.46 MGD daily average withdrawal, and a 1.4 MGD maximum daily withdrawal. The Pinehills water system daily average withdrawal in 2015, 2016, and 2017 was 0.45, 0.41, and 0.40 MGD, respectively. The system supplies water to approximately 2,160 service connections serving about 6,275 people.

The Pinehills Water Company serves the village of Pinehills located within the Town of Plymouth. Pinehills is situated east of Route 3A and includes areas along Old Sandwich Road from the northern end of Doubleback Road south to Beaver Dam Road, then northeast along Beaver Dam road to Long Ridge Road. The Pinehills distribution system is approximately one mile south of the Plymouth Center pressure zone along Old Sandwich Road, and approximately one mile southwest of the Manomet pressure zone along Beaver Dam Road. Interconnecting with the Pinehills Water Company would require significant investment due to its distance from the Division's water system.

The Division had previously considered a major water system expansion, including a second new source (the 200 Acre Site), a new water storage tank, and additional mains on Long Pond Road and Beaver Dam Road to connect the Northern Pressure Zones to the Eastern Pressure Zones. In addition to providing extra supply and storage, this connectivity would have provided for more flexibility in moving water through the system during maximum demands and in the event of an emergency and the possibility of an interconnection with the Pinehills Water Company along Beaver Dam/Clark Road. During preliminary design and permitting of the 200 Acre Site in 2017, EP and the Division encountered several challenges and potential impacts to adjacent environmental receptors with this potential new source. As a result, the Plymouth Water Division focused its efforts on developing the Forges Field site as a water supply source while looking into other potential new sources.

8.5.2.3 Colonial Water Company

Colonial Water Company, a subsidiary of New England Service Company, is supplied by two wells. One located between Kim Circle and Lynn Circle with a capacity of 0.5 MGD and one at the northern end of the development on Lunn's Way with a 1.05 MGD capacity. The system has a 2 million gallon tank on

Nathan Lane and supplies water to 832 service connections serving about 2,485 people. Colonial Water Company treats raw water with potassium hydroxide for pH adjustment.

The Colonial Water Company service area includes the communities east of Big Sandy Pond along Raymond Road and Lunn's Way. The service area is located to the west of the Division's water system Cedarville pressure zone and Route 3A. The Colonial Water Company distribution system at the intersection of Lunn's Way and Long Pond Road is approximately 1.5 miles west of the Division's 12-inch water main on Hedges Pond Road at Cedarville Park Drive. Interconnecting with the Colonial Water Company would require significant investment due to its distance from the Division's water system.

8.5.2.4 Town of Carver

There are several small water systems in the Town of Carver that supply mobile home parks and other small communities. The North Carver Water District supplies a population of 100 and is located in the north east corner of Carver. The Cranberry Village Inc. is a resident owned mobile home park with a water system. This neighborhood is over three miles from the West Plymouth pressure zone. These systems are not close to the Division and would likely not be feasible opportunities for interconnections.

8.6 RISK OF EMERGENCY

Currently, the Division requires a majority of its water supply facilities to be fully functional in order to meet peak demand periods. Therefore, the Division is becoming more vulnerable to mechanical failures or other disruptions, including routine maintenance, which could cause storage tank levels to drop and customers to lose water service. It should be noted that it is common for water sources to be offline in the Division, or any public water system, whether for routine maintenance or mechanical repairs.

The ERP includes response actions for specific events as discussed above. Of particular concern with respect to the risk of water shortage are:

- Loss of water supply from a source: the procedures listed in the ERP are adequate in addressing emergency response should a major water supply source go offline. However, operational control strategies should be developed to mitigate the impact of the supply loss. Additionally, the Division should continue to pursue opportunities to increase redundancy within the water system through new source exploration.

- Chemical or microbiological contamination: the procedures listed in the ERP are adequate in addressing emergency response should a water supply become contaminated. The Division should consider developing a more comprehensive Aquifer Protection Plan and implementing a groundwater protection district which can provide an additional level of protection against contamination near well sites. Additionally, a desktop study to understand the Division's susceptibility to PFAS would better prepare the Division in the event of a PFAS contamination.

Additionally, as discussed in Chapter 4, as the Town of Plymouth continues to grow, the risk of water shortage for the Division increases as demand increases. Chapter 4 includes recommendations for the Division to manage demand.

8.7 EMERGENCY PREPAREDNESS RECOMMENDATIONS

Effective emergency response planning can minimize the impact from emergency events and in some cases, avoid Declarations of a State of Water Supply Emergency. Table 8-3 includes immediate, short-, and long-term recommendations to improve the Division's resiliency during, and ability to avoid, emergency events. These recommendations are organized based on priority level; high, medium, and low.

Table 8-3 – Emergency Preparedness Recommendations

Emergency Preparedness Recommendations			
Category	**Recommendation**	**Description**	**Term**
High Priority			
	Pine Hills Water Resiliency Upgrades	Interconnect the Northern and Eastern Pressure Zones through the Pine Hills Pressure Zone	Immediate
	System Redundancy	Identify and implement projects to improve water system redundancy. Perform a feasibility assessment to activate Great South and Little South Ponds. Develop alternative SCADA controls strategies to optimize system performance in response to the loss of water sources.	Immediate
	Critical Well Station Upgrades	Prioritize upgrades for critical well stations and plan them during off-peak season to ensure peak day demands can be met.	Short-Term
	PFAS Preparedness	Perform a desktop study to understand the Plymouth Water Division's susceptibility to PFAS.	Long-term
	Water Quality Study	Review water quality and evaluate the efficacy of current treatment practices.	Short-Term
	Update Flushing Program	Update the existing flushing program to scour/clean water mains and maintain high quality water. The update should include a comprehensive valve database and be based on an updated hydraulic model as well as the purchase of a mechanical valve exerciser. Additionally, the flushing program should use updated technology to collect data throughout the flushing program.	Immediate
	Implement strategy to identify and uncover valve boxes	Identify and uncover valve boxes paved over or obscured by brush and debris. Identify valves that are non-operational for replacement.	Short-/ intermediate - term

Emergency Preparedness Recommendations			
Category	Recommendation	Description	Term
	Implement SOP for exercising distribution system valves[1]	Implement SOP for exercising distribution system valves[1]	Long-term
Medium Priority			
	Interconnection operations preparedness	Implement SOPs for exercising interconnections and emergency sources. Execute formal agreements to confirm location and operating conditions for interconnections	Long-term
	Drought management	Prepare and regularly update a Drought Management Plan in the ERP	Long-term
	Security alarms[1]	Add security alarms to water system facilities[1]	Short-term
	Reactivate critical PRVs	Inspect closed and inactive PRVs on Obery Street, Hall Street, and Summer Street, and assess merit of reactivating. If crucial to the Plymouth Center Pressure Zone, develop capital plan for rehabilitating/upgrading as necessary.	Short/ intermediate term
Low Priority			
	Update ERP	Include procedure for petitioning for Declaration of a State of Water Supply Emergency	Short-Term
	Implement procedures for exercising standby systems	Regularly test backup power sources including generators	Long-term
	Portable generator connections at facilities with no backup power	Facilities with no backup power include Cedarville BPS, Darby Pond WPS, and critical controlling tank sites. Develop procedures for connecting portable backup power.	Short-term
	Assess other security risk for facilities	Consider fencing, lockable ladder covers, security cameras, etc. at treatment plants, pump stations, and valve control stations.	Intermediate-term

[1]Recommended in 2018 Sanitary Survey

Chapter 9 – Recommended Improvements

9.1 OVERVIEW

The assessment of the Division's existing water system provided in the previous chapters identifies various deficiencies and performance limiting factors. As water demands increase, these deficiencies have the potential to become greater. Numerous water system improvements are recommended to address these deficiencies. While the majority of this chapter focuses on these new water system improvements, it is important to continue to fund and prioritize existing maintenance practices. A summary of noteworthy ongoing maintenance programs is included in the following table (Table 9-1). This provides a small example of the work that the Division performs on a daily basis to keep the system in working order.

Table 9-1 – Summary of Ongoing Water System Management Programs

Water System Management Program	Program Description
Water Rate Studies	Water rates were last updated July 1, 2019 and should continue to be regularly updated every 3 years.
Leak Detection	Leak detection is performed in two of the six pressure zones each year.
System Flushing	Flushing is performed in four of the six pressure zones each year.
Well Maintenance	Flow meters are calibrated annually and generators are serviced by a third-party periodically.
Tank Maintenance	Two tanks are cleaned and inspected every year.
Water System Impact Reviews	Conducting peer review analyses of proposed developments for their impact on the Division's water system.

9.2 RECOMMENDED IMPROVEMENTS

Recommended improvements include projects such as operational changes, facility upgrades, distribution system upgrades, and new source exploration. To prioritize the recommended water system improvements and to aid the Division in financing the proposed program, the improvements are categorized into three five-year implementation phases (Phases I – III) for the years 2020 through 2035 as presented in Tables 9-2 through 9-4 and on Figures 9-1 and 9-2. The recommendations are generally sorted by need and are targeted toward improving fundamental treatment, storage, and distribution deficiencies identified in the previous chapters. Some recommendations, such as those at opposite ends of the distribution system, are independent of each other and may be completed in parallel. Other recommendations, however, such as the Bradford and Plymouth Center Pressure Zone Boundary Reconfiguration, are dependent on the completion of other recommendations, such as the new source work. These dependencies are depicted in the flow chart (Figure 9-1) that accompanies the table below. More importantly, the Division should address those issues which can be reasonably financed and that respond to local concerns.

Table 9-2 – Summary of Recommended Improvements: Phase I (2020-2024)

Priority No.	Recommendation
1	Operational Controls Strategy Adjustments
2	Lift Darby Pond Well Production Restrictions
3	Water Supply and Management - New Source Exploration
4	Manomet Pipe Upgrades and Pipe Conditions Testing
5	Emergency Power Upgrades - Darby Pond WPS and Cedarville BPS
6	Ongoing Facility Upgrades - Electrical
7	Pine Hills Pressure Zone Interconnection
8	Water Supply and Management - New Source Permitting
9	Emergency Power Upgrades - Controlling Tank Sites
10	Ongoing Facility Upgrades - Mechanical
11	Ongoing Facility Upgrades - Underground Electrical Upgrades
12	Valve and Flushing Plan
13	Groundwater Protection District
14	Water Supply and Management - Water Conservation Measures
15	Water Supply and Management - New Source Design
16	Ongoing Facility Upgrades - Instrumentation
17	Redevelop Well Supplies
18	Great South and Little South Pond Feasibility Study
19	Staffing Evaluation
20	Standard Operating Procedure for Interconnections
21	Storage Tank Improvements
22	Water Supply and Management - New Source Construction
23	Ongoing Facility Upgrades - Treatment
24	Water Main Upgrades - West Plymouth Pressure Zone Group I
25	Ongoing Pipe Replacement
26	PFAS Preparedness

Table 9-3 – Summary of Recommended Improvements: Phase II Improvements (2025 - 2030)

Priority No.	Recommendation
1	Bradford and Plymouth Center Pressure Zone Boundary Reconfiguration
2	Ongoing Facility Upgrades - Site
3	Ongoing Facility Upgrades - Architectural
4	Water Main Upgrades - Plymouth Center Pressure Zone
5	Lout Pond Raw Water Transmission Main to Bradford (or treatment)
6	Emergency Power Upgrades - Non-Controlling Tank Sites
7	Ongoing Pipe Replacement
8	Drought Management Plan

Table 9-4 – Summary of Recommended Improvements: Phase III (2030 – 2035)

Priority No.	Recommendation
1	Water Main Upgrades - Manomet Pressure Zone
2	Water Main Upgrades - Cedarville Pressure Zone
3	Water Main Upgrades - West Plymouth Pressure Zone Group II
4	Ongoing Pipe Replacement
5	SCADA Review
6	Replace critical PRVs

Each recommended improvement is described in detail below. A capital improvement plan is provided at the end of this section.

9.2.1 Operational Controls Strategy Adjustments (Phase I)

Modifications to the Division's existing operational controls are described in detail in Chapter 7. EP recommends the Division adopt the proposed controls strategy to improve hydraulic performance and minimize risk and cost to the Division. As described in Chapter 7, the proposed controls strategy will stabilize the hydraulic grade in the Eastern Pressure Zones, particularly under Maximum Day Demand scenarios, and improve system hydraulics in the Northern Pressure Zones. EP recommends implementing the proposed control strategy as soon as possible.

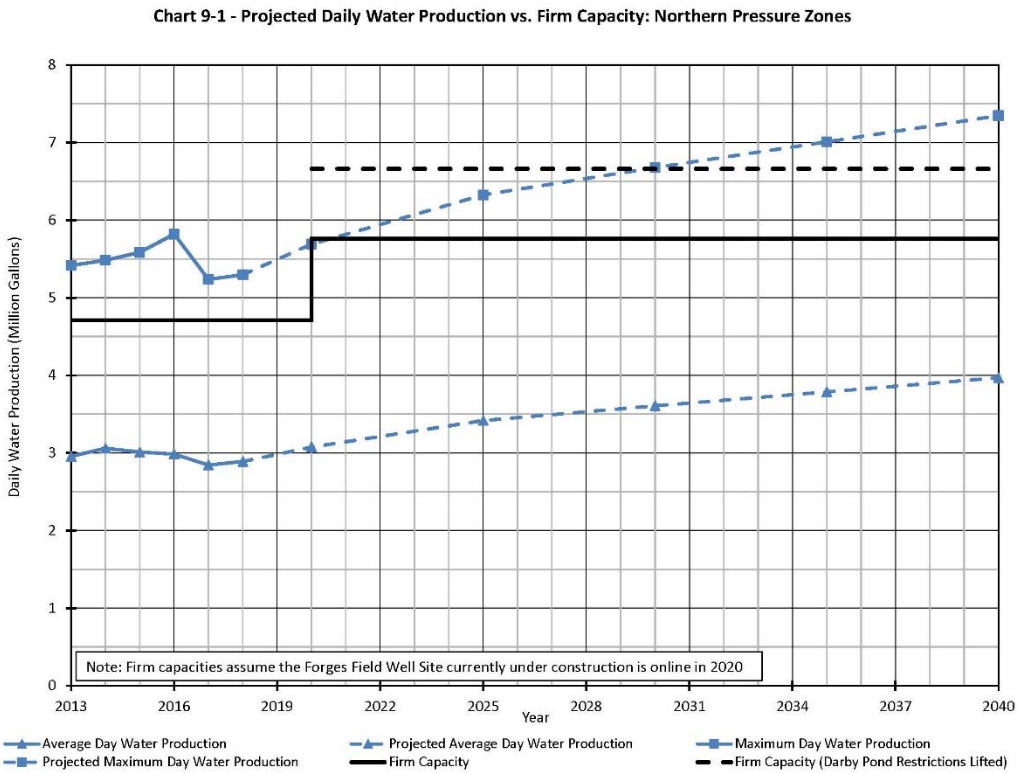
9.2.2 Lift Darby Pond Well Production Restrictions (Phase I)

Withdrawals from the Darby Pond Well are limited to maintain minimum pond levels in accordance with the WMA Permit. When the water level in Darby Pond falls below 121.5 feet (NGVD29), pumping from the well is limited to 4 hours per day. During 2016, which was considered a drought year, the pond level remained below 121.5 feet for 6 months in a row. Since cranberry operations on neighboring properties withdraw water from Darby Pond for irrigation and flooding, it is recommended the Division continue to pursue acquisition of these properties in order to alleviate pumping limitations on the Darby Pond Well.

The Division has projected an operational capacity of 1.1 MGD if the source were available year round without permit restrictions. The current WMA Permit restricts withdrawals from Darby Pond to an annual average of 0.8 MGD. EP recommends petitioning to remove the WMA Permit water level restrictions and increasing the annual average withdrawal from the Darby Pond Well (while maintaining the Buzzard Bay Basin withdrawal limit of 1.59 MGD). In order to lift the water level restrictions, the Division should meet with the MassDEP WMA Program to discuss the project. A WMA Permit Amendment application would be required to remove the water level restrictions and increase the annual average withdrawal from Darby Pond.

By lifting the Darby Pond Well production restrictions, the Division could reliably withdraw 0.8 MGD from Darby Pond. Thus, the firm capacity in the Northern Pressure Zones increases and the maximum day production is not projected to exceed the Division's firm capacity until approximately 2029 as shown on Chart 9-1. After 2029, a new source of approximately 0.7 MGD for the Northern Zones would be needed to meet 2040 demands.

Chart 9-1 – Projected Daily Water Production vs Firm Capacity: Northern Pressure Zones



Additionally, the increased withdrawal from the Darby Pond Well could allow for an amended controls strategy that reduces operations of the Federal Furnace Well, which has elevated levels of manganese, and the Deep Water Booster Pumps, which further stress the Plymouth Center Pressure Zone when operating.

9.2.3 Manomet Pressure Zone Pipe Upgrades (Phase I & III)

A portion of Division customers in the Manomet Pressure Zone experience low pressures, which are mainly due to frictional losses and can be improved upon by upgrading water mains. It should be noted that based on recent fire flow testing and discussions with the Division, the condition of the State Road water main is not certain, with a potential C-factor (a factor representing the friction losses in the pipe) ranging between 60 and 100. EP recommends a pipe conditions test be performed to confirm the hydraulic capacity of the State Road water main as shown on Figure 9-2. The results of this pipe conditions test will help confirm the overall extent of the project described below.

As discussed in Chapter 7, the primary cause of high pressures in the Manomet Pressure Zone is an over-pressurization near the main water sources due to insufficient carrying capacity in the distribution system. More specifically, the high head losses between the southern sources and the South Pine Hills Tank force the pumps to produce extra pressure in order to fill the South Pine Hills Tank. In addition, available fire flow is primarily restricted by limited capacity of water mains, which can be mitigated by upgrading water mains. To alleviate these deficiencies, water main upgrades in the Manomet Pressure Zone are recommended as shown in Table 9-5 and Figure 9-3.

Table 9-5 – Manomet Pressure Zone Pipe Upgrades

Location	Length (ft)	Existing Size and Material	Proposed Size and Material
Priscilla Beach Road and Robbins Hill Road	1,700	6"/10" Cast Iron	12" Ductile Iron
Rocky Hill Road at White Horse Road	900	6" Cast Iron	8" Ductile Iron
White Horse Road from Robbins Hill Road to State Road	3,700	10" Cast Iron	12" Ductile Iron
Brook Road	4,450	6"/8" Cast Iron	8" Ductile Iron
Bartlett Road from State Road to Ray Road	4,100	6" Cast Iron	12" Ductile Iron
Manomet Point Road from State Road to Kevin Avenue	4,350	10" Cast Iron	12" Ductile Iron
Beaver Dam Road from State road to #96 Beaver Dam Road[1]	3,900	8" Cast Iron	12" Ductile Iron
Manomet Elementary School Loop[1]	900	6"/8" Cast Iron	12" Ductile Iron

1. Phase III water main project.

By completing the above water main upgrades in the northern portion of the Manomet Pressure Zone, the hydraulic connectivity between the controlling South Pine Hills Tank and the water sources can be improved significantly, which greatly reduces the extent of high pressure surges. Under average day and maximum day demand conditions, using the proposed controls strategy, the water main upgrades proposed eliminate all pressures above 80 psi in the Manomet Pressure Zone except for a low-lying area between the Ship Pond Well and the Ellisville Well, as shown in Figure 9-4.

While it is possible to reduce all of the pressures above 80 psi during periods of maximum day demand, the amount of water main upgrades required would cease to be cost effective, such as increasing the State Road water main to 16-inch diameter all the way to the Cedarville Booster Pumping Station. One alternative that could further reduce high pressures in the Manomet Pressure Zone is cleaning and lining the existing 10-inch water main along State Road. However, as discussed above, the condition of the State Road water main is not certain, and a pipe conditions test should be performed to confirm the hydraulic capacity of the State Road water main.

Completing the upgrades addresses all ISO fire flow deficiencies in the Manomet Pressure Zone except for ISO Test Site 15. As discussed in Chapter 7, the average available pressure at ISO Test Site 15 is less than 20 psi, and therefore the available fire flow is considered 0 gpm, even though considerable fire flow is available below 20 psi due to the proximity of the site to the Indian Hill Tank.

It should be noted that ISO Test Site 14 is at the Indian Brook Elementary School. As shown in Table 9-5 above, the Division would need to upgrade the service line to a 12-inch diameter main to meet the required ISO flow of 3,000 gpm. This would more than double the volume of the service line, increasing water age. EP recommends the Division coordinate the funding, construction, and maintenance of this service line with Plymouth Public Schools.

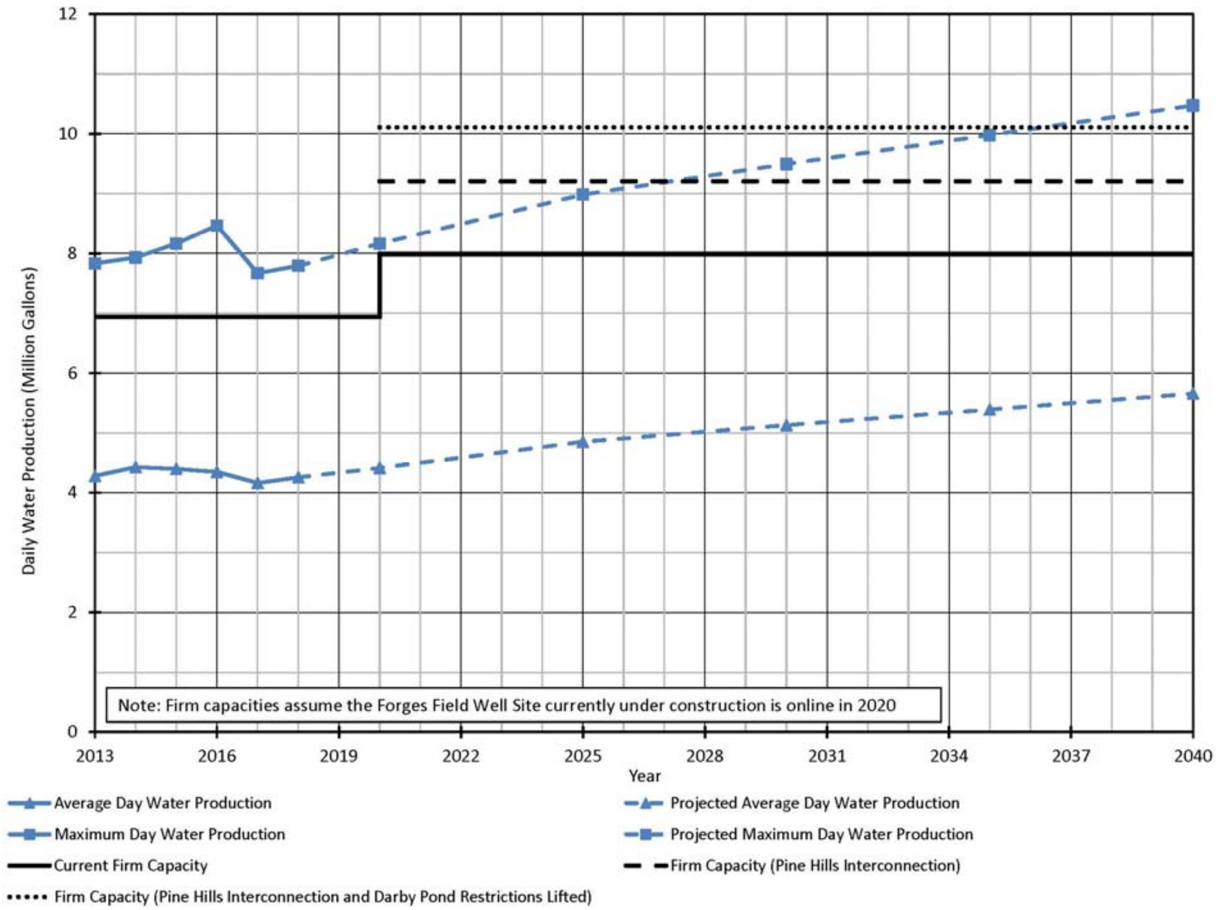
Due to limited hydraulic capacity in the northern Manomet Pressure Zone, the Manomet Pressure Zone Pipe Upgrade project should be prioritized in order to improve fire flow deficiencies, maintain adequate system pressures throughout the pressure zone, provide redundancy if the Wannos Pond WPS is unavailable, and improve the effectiveness of the future Pine Hills Interconnection project (discussed below).

9.2.4 Pine Hills Pressure Zone Interconnection (Phase I)

As discussed in Chapter 4, there is a current firm capacity deficit in each independent region of the distribution system. If the Northern Pressure Zones could be connected to the Eastern Pressure Zones, water could be delivered to where it is needed in the event there is an isolated water supply deficit (i.e. multiple sources offline). This could provide an additional level of redundancy and reduce the risk of declining tank levels. Therefore, EP recommends performing a series of upgrades in the vicinity of the Pine Hills Pressure Zone to provide a reliable interconnection between the Northern and Eastern Pressure Zones.

Infrastructure improvements to the Pine Hills Pressure Zone would include construction of one new combined flow control valve and pumping station, upgrades to one booster pumping station to include a flow control valve, and the installation of approximately 13,200 linear feet of 12-inch water main as shown on Figure 9-5. The water main upgrades will provide the additional capacity necessary to transfer water between the Northern and Eastern Pressure Zones. (The extent of required water main upgrades may reduce, pending the results of the pipe conditions assessment in the Manomet Pressure Zone and design conditions.) These upgrades will allow operators to remotely monitor and control the bidirectional flow of water through the Pine Hills Pressure Zone and potentially alleviate the Division's firm capacity deficit to approximately 2027 as shown in Chart 9-2 below.

Chart 9-2 – Projected Daily Water Production vs Firm Capacity: System-Wide



Should the Pine Hills Interconnection be constructed, the maximum day production is not anticipated to exceed the system's firm capacity until approximately 2027. Additionally, by constructing the Pine Hills Interconnection in conjunction with lifting the Darby Pond Well production restrictions, maximum day production is not expected to exceed the system's firm capacity until approximately 2036 when a new source of approximately 0.4 MGD would be needed to meet 2040 demands.

The Pine Hills Pressure Zone Interconnection should be designed to convey the largest projected deficit of the two regions. Additionally, preliminary analysis indicates the Manomet Pressure Zone is incapable of conveying the required amount of water to the Northern Pressure Zones without incurring negative pressures in northern Manomet. Therefore, the Manomet Pressure Zone Pipe Upgrades project should be completed prior to the Pine Hills Pressure Zone Interconnection to ensure adequate carrying capacity is available for the Pine Hills Interconnection to serve its intended purpose.

9.2.5 Water Supply and Management (Phase I)

Per the analysis provided in Chapter 4, the Division does not have enough supply to continuously meet future demands and remain within the WMA Permit withdrawal limits as early as 2023. Additionally, the Division currently has a firm capacity deficit. Consequently, the Division will need to take steps to increase the available supply and reduce usage as outlined below. A net 2.9 MGD of water supply gain and/or demand reduction is required to meet projected 2040 requirements assuming no improvements are made.

9.2.5.1 New Source (Phase I)

The requirements (size and location) of a new source depend heavily on which recommended improvements the Division executes and when they are completed. The recommended improvements listed above, if done in conjunction, may alleviate the Division's firm capacity deficit. In the Northern Pressure Zones, a new source of approximately 1.6 MGD would be needed to meet 2040 demands, which may be reduced to approximately 0.7 MGD if the Darby Pond Well production restrictions are lifted.

Should the Division move forward with lifting the Darby Pond Well production restrictions and not the Pine Hills Pressure Zone Interconnection, a new source for the Eastern Pressure Zones is necessary in the immediate future. In the Eastern Pressure Zones, the maximum day production is shown to have exceeded the firm capacity since 2013, which will worsen with continued growth. A new source of approximately 1.3 MGD will be needed to meet 2040 demands in the Eastern Zones.

Even if the Division could meet future demands with existing sources, several of those sources have declining water quality. As discussed in Chapter 1, Federal Furnace Well, Ship Pond Well, and Lout Pond Well have elevated levels of iron and manganese, which can lead to aesthetic issues (e.g. staining) and customer complaints, even though the water remains potable. In addition, these metals can clog well screens and impair other treatment plant components, leading to increased maintenance requirements. Therefore, a new source with improved water quality could be a significant benefit for the Division.

EP recommends that the Division continue to strategically pursue new sources through well site exploration as discussed in Chapter 5 as well as completing a feasibility study on the Great South and Little South Pond (discussed below). It is recommended to continue new source development in order to ensure future demands are met in 2040 and to provide system redundancy should existing water supplies continue to decline.

The New Source work is broken up into the following tasks:

- New Source Groundwater Exploration: This includes a combination of continued desktop studies for non-Town owned properties as well as exploratory drilling at additional sites outlined in Chapter 5.
- New Source Permitting: Upon identifying a suitable site from exploratory drilling, this task includes the submission of a request for site examination and pumping test proposal to MassDEP. Once approved by MassDEP, a prolonged 5-day pumping test is necessary to the Zone II and safe yield of the source. Following the pump test, a pump test approval report is submitted to MassDEP.
- New Source Design: Following the new source pump test permitting, the design of the pump station and connection of the new source to the water system should commence. During this phase additional design-related permitting efforts should be completed including WMA Permit Amendment, MEPA ENF or EIR, Approval to Construct, Notice of Intent, and additional MassDEP permits.

- New Source Construction: Following design and permitting, the construction of the new source can begin.

The above new source tasks are each anticipated to take one year during Phase I.

9.2.5.2 Water Conservation (Phase I)

To continuously meet future demands and to remain within the WMA Permit withdrawals limits, the Division should further develop its existing water conservation program, as described in Chapter 4, to include a rebate program for low water use appliances; additional education and public outreach; and continue to discourage irrigation systems.

EP also recommends the Division develop a Water Balance/Banking Program. The program would require all new, large users above a certain demand threshold to submit development plans for engineering peer review, as well as implement water conservation practices to offset increased demands. The new large users would need to provide a net zero increase to the water system demands. An example Water Balance/Banking Program is included in Appendix F. Offset measures could include the following:

- Applicant provides funds to a Division-owned Water Bank. These funds would be used by the Division to help fund water conservation efforts.
- Applicant either identifies and develops, or finances the development of, a supplemental source of supply for the Division.
- Applicant can develop and submit their own water conservation program that demonstrates sufficient water savings.

As noted above, the Division should continue to perform leak detection throughout the water system to identify areas of water loss and minimize nonrevenue water. The purchase of correlators to data log and identify potential leakage would streamline this process. Additionally, the Division should require private developments to provide annual leak detection reports. EP recommends the Division continue to track and reduce nonrevenue water in accordance with the latest AWWA M36 standards.

9.2.6 Facility Upgrades (Phases I through III)

A number of facility upgrades were recommended in earlier chapters of the report. Upgrades to well stations, booster pump stations, and storage tanks are imperative to the resiliency of the Division's water system. The recommended upgrades are intended to maximize the readiness of facilities to provide high quality drinking water without interruption through preventative maintenance and compliance with latest drinking water codes and regulations. These recommendations have been divided into three groups, as described below.

9.2.6.1 Pump Facility Rehabilitation (Phases I and II)

Chapter 1 listed numerous important upgrades that are required at every major pumping facility. Previous investigations have identified many of these upgrades, but the Division has been unable to execute these projects due to a lack of funding. Therefore, EP recommends that the Division obtain funding to implement an annual pump facility upgrade plan, as outlined in Table 9-6 below, to ensure this work is finally completed.

Table 9-6 – Pump Facility Rehabilitation Schedule

Phase	Year	Upgrade Category
1	1	Electrical - Interior
	2	Mechanical
	3	Underground Electrical Upgrades
	4	Instrumentation
	5	Treatment
2	6	Site
	7	Architectural

The schedule begins with electrical upgrades at all facilities including replacing/upgrading motor control centers and VFDs. Then, mechanical upgrades across all facilities should be completed; these upgrades include replacing all Parco valves and upgrading all meters. Subsequent upgrades include converting all overhead electrical wiring to underground electrical service, as well as instrumentation, treatment, site and architectural upgrades. It is recommended that the Division continuously set aside funds to perform routine maintenance on their facilities.

9.2.6.2 Generators (Phases I and II)

As described in Chapter 1, there are several facilities that are without emergency power systems. This includes Darby Pond WPS, Cedarville BPS, and all ten (10) water storage tanks. EP recommends that each of these facilities be outfitted with a functional standby power generator, ATS, and appurtenances. For the tank sites, priority is given to the controlling tanks in each pressure zone, but it is recommended that standby power is provided at every tank. A generator installation schedule is provided in Table 9-7.

Table 9-7 – Generator Installation Schedule

Phase	Year	Facility
1	1	Darby Pond WPS
	2	Cedarville BPS
	3	Harrington Standpipe
	4	Lout Pond Tank
	5	Stafford Street Standpipe
	6	North Pine Hills Tank
	7	South Pine Hills Tank
	8	Cedarville Tank
2	9	North Plymouth Tank
	10	Samoset Street Standpipe
	11	Chiltonville Standpipe

Additionally, EP recommends the Division include an alarm in SCADA to notify operators when generators are exercising. This SCADA alarm should be added to all pump stations and tank sites.

9.2.7 Gate Valve and Flushing Plan (Phase I)

The Division has reported that they currently flush four of six pressure zones each year. Some valves and hydrants are operated during flushing, but the Division does not currently have valve or hydrant exercising programs and the flushing program should be updated. Additionally, the Division has noted that they do not know the locations of many of the valves, as records are either missing or outdated. EP recommends the Division do the following:

- Test and locate all valves and hydrants with a geographic position system (GPS);
- Develop valve and hydrant exercising plans that utilize a GIS-based asset management system;
- Purchase a skid motorized gate valve exerciser and vacuum to speed up valve exercising operations. This equipment will also improve both maintenance and repair procedures for the Division; and
- Update the existing flushing plan to be a unidirectional program utilizing the water system hydraulic model and increase annual flushing to include 100 percent of the water system. Additional labor force may be required to accomplish this recommendation.

9.2.8 Groundwater Protection District (Phase I)

The Division's existing sources will continue to be relied upon to meet demands in the coming decades. Extra precautions should be taken to prevent chemical or microbiological contamination of existing water supplies, which poses a risk to both public health and safety and the ability to meet demand. EP recommends the Division develop a groundwater protection district and a Wellhead Protection Plan to provide an additional level of protection against contamination of the groundwater supplies above and beyond the minimum requirements of the Massachusetts Drinking Water Regulations and the existing Aquifer Protection District. Additional hydrogeologic modeling is recommended to delineate the contributing area for each water supply based on average day demands rather than the 180-day drought condition with no groundwater recharge of which the Zone II area is based upon. By using average day demands to delineate the groundwater protection district, future land uses can be better managed to not cause water quality to be degraded. This is of particular concern for new development that could occur within these capture zones, and the effect that this development could have on water quality.

EP recommends incorporating the groundwater protection districts into a Wellhead Protection Plan which may also include wellhead management, public outreach, wastewater reuse, and stormwater runoff treatment/prevention including best management practices (BMPs).

9.2.9 Redevelop Well Sites (Phase I)

As discussed in Chapter 1, the specific capacity of four water supply wells have reduced more than 15 percent from the original specific capacity: Bradford Well #1, South Pond Well #1, South Pond Well #2, and Federal Furnace. These wells should be conditioned and redeveloped to recover lost specific capacity. Additionally, EP recommends the Division perform well performance tests at each well every one to two years to monitor specific capacity.

9.2.10 Great South and Little South Pond Feasibility Study (Phase I)

Due to regulatory changes, Great South and Little South Pond were abandoned as primary sources in 1992 but remain emergency sources for the Division. In order for Great South and Little South Ponds to be returned to active status, the Source Approval Process must be completed and improvements made to meet current treatment regulations.

A feasibility study is recommended to evaluate the potential of Great South and Little South Ponds as a water source. The study would include preliminary water quality testing to estimate initial treatability requirements. In the decades since the sources were abandoned, the EPA and MassDEP have promulgated significantly more stringent rules, regulations, and guidelines for surface water treatment. A feasibility study would also include a review of the existing piping and pumping infrastructure. According to the 2006 Plymouth Master Plan, the transmission main from Great South and Little South Ponds is the jacket type and in poor condition. A firm yield study of the source would be completed to estimate the sizing of the treatment process and may include a bathymetric study, analysis of the stage-storage relationship of the pond, and a review of land use in the watershed. Water withdrawal and treatment permitting requirements would be investigated through coordination with MassDEP. Preliminary planning for a treatment plant would be initiated which may include a cost estimate for full-scale pilot study, identification of potential treatment plant locations, and an order of magnitude cost estimate for full-scale treatment plant.

9.2.11 Staffing Evaluation (Phase I)

As the water system grows and expands, the Division should start ensuring they have the capacity to maintain and operate the existing and future water system infrastructure. The Division requires a comprehensive review of current operations and staffing levels, an update of employee positions, qualifications, and policies to reflect the Division's requirements and industry standards, and recommendations to meet staffing requirements. The Division should complete a staffing evaluation that includes the following:

- Review operator license and staffing requirements. Review and evaluate the Division management structure as well as employee roles, responsibilities, and qualifications. Review current employee workload against existing job descriptions.
- Review and evaluate the existing certifications, licensure and training of Department personnel. Compare the Department's certifications, licensure, and training to what is required by State regulations, recommended by industry, and consistent with similar surrounding communities. Recommend certifications, licenses, and training for current staff.
- Review Division staffing against the American Water Works Association Manual 5, Water Utility Management and Code of Massachusetts Regulations – Department of Environmental Protection (310 CMR).
- Identify and evaluate staffing alternatives for different functions of the Division and recommend specific tasks to be either completed in house or potentially outsourced.

9.2.12 Interconnection Standard Operating Procedures (Phase I)

The Division has two existing interconnections with the Town of Kingston, as described in Chapter 8. EP recommends that the Division develop a standard operating procedures for maintaining and exercising both interconnections. Additionally, the Division should prepare a formal agreement with the Town of Kingston for the operations and maintenance of the interconnections.

The Division should take advantage of any opportunities to establish interconnections with other water systems in the area if the possibility arises in the future.

9.2.12.1 Storage Tank Improvements (Phase I)

As previously mentioned in this Chapter, the Division currently inspects and cleans two storage tanks each year. It is recommended that the Division continue this maintenance program. Additionally, as discussed in Chapter 1, improvements to storage tank sites were recommended as summarized in Table 9-8.

Table 9-8 – Storage Tank Improvements Schedule

Phase	Tank	Improvements
1	Samoset Street Standpipe	Replace finial vent vacuum pallet and improve gravel access drive to prevent washout and improve access.
	Chiltonville Standpipe	Replace overflow box; install safety climbing system; and, improve/repair access drive.
	North Plymouth	Improve/repair access drive.
	Indian Hill Tank	Improve access around tank.

Additionally, EP recommends the Division upgrade the existing altitude valves to be remotely operable via the Water Division's SCADA system.

9.2.13 Water Distribution Upgrades (Phases I through III)

While there are some limitations on the water system due solely to topography, such as low pressures in close proximity to storage tanks and other high points throughout the system, there are many deficiencies which can be ameliorated by increasing hydraulic capacity. The primary metrics for assessing potential water main improvements within the scope of this analysis include the following:

- Reducing the number of pressures above 80 psi
- Reducing the number of pressures below 35 psi
- Meeting ISO fire flow requirements

The following sections detail water main upgrade recommendations that address the above deficiencies in each pressure zone. Water main upgrades for the Manomet Pressure Zone are prioritized and discussed above.

9.2.13.1 Plymouth Center Pressure Zone Distribution Upgrades (Phase II)

Several water main upgrades are recommended in the Plymouth Center Pressure Zone to meet fire flow requirements, as described in Table 9-9. These recommendations are meant to work in conjunction with the Bradford Pressure Zone Reconfiguration project. It should be noted that if the Bradford Pressure Zone

Reconfiguration is not completed, additional water main upgrades may be necessary to eliminate high pressure surges and meet fire flow requirements. An approximation of such additional upgrades is included in Table 9-9 below for reference.

Table 9-9 – Plymouth Center Pressure Zone Water Main Upgrades

Location	Length (ft)	Existing Size and Material	Proposed Size and Material
Sandwich Road from River Street to Hayden Hollow	3,500	8" Cast Iron	12" Ductile Iron
Coles Lane	800	6" Cast Iron	8" Ductile Iron
Doten Road	1,350	6" Cast Iron	8" Ductile Iron
Ropewalk Court Loop to Cordage Park	850	6" Cast Iron	12" Ductile Iron
Warren Road (Route 3A) west of Pine Hills BPS	700	8" Cast Iron	12" Ductile Iron
Margerie Street[1]	375	6" Cast Iron	8" Ductile Iron
Highland Place[1]	200	6" Cast Iron	8" Ductile Iron
Savory Lane[1]	625	6" Cast Iron	8" Ductile Iron
Main Street and Sandwich Street from Summer Street to Chiltonville Tank[1]	10,750	12" Cast Iron and Ductile Iron	16" Ductile Iron
Court Street from Brewster Street to Cordage Park[1]	10,000	12" Ductile Iron	16" Ductile Iron

1. Approximation of water main upgrades required if the BPZ Reconfiguration project is forgone.

With the above water main improvements, in conjunction with the Bradford and Plymouth Center Pressure Zone Reconfiguration project, all fire flow deficiencies discussed in Chapter 7 can be addressed, except at Saw Mill Drive, Sever Street, and Braley Road. All three of these residential locations feature high elevations, and no reasonable amount of water main upgrades will allow for sufficient fire flow availability due to limited residual pressures.

Importantly, the above improvements increase hydraulic capacity in low-pressure areas, as well as between the Chiltonville Tank and the current Plymouth Center Pressure Zone water sources. This results in a drastic reduction in the number of high-pressure areas and slightly reduces the number of low-pressure areas in the Plymouth Center Pressure Zone.

9.2.13.2 West Plymouth Pressure Zone Distribution Upgrades (Phase I and III)

As discussed in Chapter 7, several areas in the West Plymouth Pressure Zone have insufficient fire flow availability, including Megansett Drive and the Plymouth Mobile Estates, as well as ISO Test Sites 18, 19, and 22.

Tables 9-10 and 9-11 summarizes the recommended water main improvements in the West Plymouth Pressure Zone. Smaller projects are prioritized (Table 9-10) as they can provide an immediate benefit for a relatively low cost.

Table 9-10 – West Plymouth Pressure Zone Water Main Upgrades Group 1

Location	Length (ft)	Existing Size and Material	Proposed Size and Material
Plymouth Mobile Estates	800	6” PVC	12” & 8” Ductile Iron
West Elementary School Service Line	800	8” Ductile Iron	12” Ductile Iron

Table 9-11 – West Plymouth Pressure Zone Water Main Upgrades Group 2

Location	Length (ft)	Existing Size and Material	Proposed Size and Material
Megansett Drive	700	4” AC	8” Ductile Iron
Plymouth Municipal Airport Loop to Federal Furnace Road	3,250	none	12” Ductile Iron
Armstrong Road	2,000	8” Ductile Iron	12” Ductile Iron
Westerly Road from Deep Water BPS to Summer Street	2,150	12” Cast Iron	12” CIP Liner

With the above improvements, the high pressures in the West Plymouth Pressure Zone are reduced as much as is practically possible. The exceptions are the areas just downstream of the Darby Pond Well and Deep Water Booster Station Pumps, where pressures are necessarily boosted during operations.

Additionally, ISO Test Site 19 is located at the end of a long, dead-end water main near the airport on South Meadow Road. This ISO Test Site and Test Site 18 at the Federal Furnace School both experience a fire flow deficiency. The Division has indicated the presence of a 12-inch fire suppression line in the airport property extending more than halfway to South Meadow Road. EP Recommends the Division explore the possibility of completing this loop, as it has the potential to bring Test Site 19 into compliance.

While this loop would improve the available fire flow at the Federal Furnace School (Test Site 18), it would still experience a slight deficiency. Only by upgrading the entirety of the water main between the school and Carver Road to 16-inch, totaling roughly 19,700 feet, could this ISO Test Site be brought into compliance. Increasing the diameter of such a long dead end would further reduce water velocities, thereby increasing water age and likely decreasing water quality considerably in the vicinity of a source with elevated levels of iron and manganese. Therefore, EP recommends providing an enhanced fire suppression system for the elementary school, if one does not already exist, rather than undertaking this significant water main project.

ISO Test Site 14 is at West Elementary School. As shown in Table 9-10 above, the Division would need to upgrade the service line to a 12-inch diameter main to meet the required ISO flow of 3,000 gpm. It should be noted that this would more than double the volume of the service line, increasing water age. EP Recommends the Division coordinate the funding, construction, and maintenance of this service line with Plymouth Public Schools.

9.2.13.3 Cedarville Pressure Zone Distribution Upgrades (Phase III)

The typical static pressures in the Cedarville Pressure Zone range from approximately 21 to 107 psi, primarily due to topography.

Fire flow availability appears to meet ISO standards throughout the Cedarville Pressure Zone, with the exception of Test Site 17 on State Road at the Cedarville Village Fire Station. To meet the required 3,500 gpm requirement, it is recommended that the Division extend the 16" ductile iron water main on State Road an additional 5,000 feet, to the location of the Cedarville Village Fire Station.

9.2.14 Ongoing Pipe Replacement (Phases I through III)

As discussed in Chapter 1, approximately 25 percent of the Division's water distribution system piping is constructed of asbestos cement piping. The Division has been working to replace asbestos cement and jacket piping throughout the water system and has reduced the percentage of jacket piping in the distribution system down to 0.1 percent. EP recommends that the Division continues to set aside funding to replace asbestos cement piping based on size and location within the distribution system.

9.2.15 PFAS Preparedness (Phase I)

In preparation for the anticipated Massachusetts drinking water MCL for PFAS, EP recommends the Division complete a desktop study to determine the susceptibility of the water system to PFAS contamination. The desktop study should include a review of land use data and environmental databases to identify potential sources of PFAS within the established water supply protection areas of the Division's groundwater supplies. As a part of the desktop study, potential contaminant sources can be identified, as well as the overall system resiliency to a potential PFAS contamination. Secondly, a feasibility study should be completed to identify potential PFAS treatment alternatives (e.g. GAC, Ion Exchange, Membranes) and to assess the design, permitting, and construction constraints for each of the Division's water supply sources.

9.2.16 Bradford and Plymouth Center Pressure Zone Boundary Reconfiguration (Phase II)

The geography and topography of the Plymouth Center Pressure Zone are at the root of its high and low pressures and resulting fire flow deficiencies. By reconfiguring the pressure zone boundaries between the Bradford and Plymouth Center Pressure Zones, over-pressurization within the Plymouth Center Pressure Zone can be minimized. More importantly, the reconfiguration is expected to minimize low pressures (less than 20 psi) within the Plymouth Center Pressure Zone in accordance with 310 CMR 22.19 (1) which requires residual water pressure at street level of at least 20 psi.

The proposed reconfiguration, as shown on Figure 9-6, would adjust the pressure zone boundaries to incorporate higher elevation customers into the higher pressure zone, improving pressure profiles and fire flow availability within the current Plymouth Center Pressure Zone. EP recommends that the Division complete an alternatives analysis that incorporates a review of existing topography, sources, and infrastructure necessary to reconfigure pressure zone boundaries and the effects of various pressure zone configurations on system pressures.

One alternative to accomplish this reconfiguration involves closing existing valves or installing new isolation valves (or cutting and capping water mains), as necessary, on Oak Street, Allerton Street, Vernon Street, Clyfton Street, Russell Street, Newfield Street, and Summer Street in the Plymouth Center Pressure Zone. In addition, a new water main connection would need to be established on Newfield Street at the location of the decommissioned Newfield Street PRV. This isolates the high elevation areas near Oak Street, but does not transition them to the Bradford Pressure Zone.

Under this reconfiguration, a portion of the Plymouth Center Pressure Zone, including the Lout Pond Tank, Lout Pond Well, and South Pond Wells, would be connected to the Bradford Pressure Zone either via Braley Lane at South Street, via an extension to the proposed Home Depot Drive development, or both.

Additionally, the Lout Pond Tank, once situated in the Bradford Pressure Zone, will need to be upgraded to an elevated storage tank with an overflow elevation to match the Stafford Street Tank and a diameter at least as large as the Stafford Street Tank (50 feet). A detailed analysis of sources and control set points, including the Nook Road Actuator Valve would need to be completed as a part of the design project. It is possible the capacity of the Nook Road Actuator Valve may need to be increased, or else a new interconnection be established in the southeastern extents of the Plymouth Center Pressure Zone, such as between Russell Mills Road and East Russell Mills Road.

Preliminary hydraulic modeling results generally suggest massive improvements in typical service pressures and available fire flow are possible in and around the area to be converted to the Bradford Pressure Zone. With the above changes, significant reductions in the number of high and low pressures in the Bradford and Plymouth Center Pressure Zones can be achieved as follows:

- 80% reduction in pressures between 80-100 psi
- 35% reduction in pressures between 20-35 psi
- 80% reduction in pressures below 20 psi

Future design efforts should evaluate options for maintaining available fire flow in downtown Plymouth where elevated existing working pressures are expected to decrease to normal levels as part of this upgrade.

Additionally, the available fire flow storage in the Plymouth Center Pressure Zone is insufficient, as outlined in Table 6-11. By transitioning the highest customers out of the Plymouth Center Pressure Zone, it appears the usable fire flow storage in the adjusted Plymouth Center Pressure Zone would become positive. However, the loss of the Lout Pond Tank to the Bradford Pressure Zone would result in large pressure swings in the remaining Chiltonville Tank. Further, a side effect of reducing the high pressure surges in Downtown Plymouth is reduced available fire flow in this region. Future design efforts should evaluate options for maintaining available fire flow in Downtown Plymouth and stabilizing the tank levels in the adjusted Plymouth Center Pressure Zone, such as by constructing a new storage tank as discussed below.

9.2.16.1 New Tank in Plymouth Center Pressure Zone (Phase II)

The Bradford and Plymouth Center Pressure Zone reconfiguration described above would leave the Chiltonville Tank as the sole storage tank in the Plymouth Center Pressure Zone. It is recommended that a new storage tank be constructed to reduce the severity of pressure swings in the zone in conjunction with the pressure zone reconfiguration. If possible, the new storage tank should be located at the northern extent of the Plymouth Center Pressure Zone to allow for fire flows to be met in several deficient areas.

The addition of a new water storage tank near downtown Plymouth likely necessitates additional water main upgrades to improve the hydraulic capacity between the new tank and the Chiltonville Tank, as well as fire flow deficient areas in Downtown Plymouth.

9.2.17 Drought Management Plan (Phase II)

During the drought conditions in 2016, the Division was faced with increased summer demands, mechanical failure at one well supply, and limited use of water supplies due to the WMA restrictions. A water ban was necessary to maintain storage capacity and meet demands for water use and firefighting. In preparation for future spells of extended dry weather, it is recommended that the Division prepare and regularly update the Drought Management Plan of the Division's Emergency Response Plan.

The Drought Management Plan should be developed in accordance with the American Water Works Association drought preparedness and response planning guidance (AWWA 2019 or latest version) and the 2019 Massachusetts Drought Management Plan. The Division should develop strategies appropriate to the system to reduce daily and seasonal peak demands and develop contingency plans to ameliorate the impacts of drought, seasonal shortages, and other non-emergency water supply shortfalls. The Drought Management Plan should be incorporated into the Division's Emergency Response Plan.

9.2.18 Route Lout Pond Well to Bradford WTP (Phase II)

The Division continues to experience iron/manganese water quality challenges at the Lout Pond Well which has drastically limited the operational capacity of the well. In order to gain capacity back from the Lout Pond Well it is possible to route the raw water transmission main to the Bradford WTP where raw water can be treated for iron and manganese. The raw water transmission main may be connected to the Bradford WTP via Braley Road, Home Depot Drive, or Billington Street. This recommendation is currently under review as part of an ongoing water quality study, where the feasibility is being determined. For the purpose this master plan, it is anticipated that the project would require approximately 9,000 feet of transmission main, a review of Bradford WTP hydraulics, a new filter, and additional plant upgrades. However, given the potential costs of this transmission main and treatment plant upgrades, the water quality study includes an on-going preliminary evaluation of an alternative, lower cost treatment strategy at the Lout Pond Well.

9.2.19 SCADA Review (Phase III)

A reliable SCADA system provides important monitoring and controls capabilities allowing operators to efficiently oversee the water system. If the SCADA system provides confusing/inaccurate information, it limits operator's ability to perform their work. It is understood that the Division is currently updating their

SCADA system. EP recommends the Division conduct another holistic SCADA and communications system audit to identify areas of need every 10 years. It is recommended that the Division fund the overhaul of the SCADA system based on the results of the investigation. The cost to overhaul the SCADA system will depend on the outcome of the investigation.

9.2.20 Replace Critical Pressure Reducing Valves (Phase III)

As discussed in Chapter 1, the Division has four PRVs that are currently inactive. The Rocky Hill Road PRV would be replaced as part of the Pine Hills Interconnection Project. The PRV on Summer Street will likely become obsolete should the above recommended improvements be completed in their entirety.

The final extent and nature of the Bradford Pressure Zone Reconfiguration project may warrant reactivation of the Hall Street PRV, particularly if a tank cannot be situated in the northern extent of the Plymouth Center Pressure Zone. In that case, the Hall Street PRV could help maintain a minimum pressure in this region and improve fire flow availability. The Obery Street PRV could provide an important conduit for delivering water to the Plymouth Center Zone under this reconfiguration project if the output of the nearby Nook Road Actuator Valve cannot be significantly increased.

Since the existing PRVs are below-grade structures and considered confined spaces, EP recommends replacing them with above ground structures, similar to the new Jordan Road/Forges Field Road valve control station. EP recommends identifying suitable land for an above ground structure in the vicinity of each below grade PRV and securing access to the land through easements or direct purchases.

9.3 CAPITAL IMPROVEMENTS PLAN

As discussed in Section 9.2, a phasing plan was developed to prioritize capital projects as shown in Table 9-2 through 9-4 and Figures 9-1 and 9-2. EP recommends implementing the control strategy adjustments as soon as possible to improve system hydraulics. Next, the Division should move forward with lifting the Darby Pond Well production restrictions. Lifting the Darby Pond Well Production restrictions will alleviate the firm capacity deficit in the Northern Pressure Zones. Additionally, the Division should continue to prioritize New Source Exploration with the goal to bring a new source online in the next five years in order to achieve system redundancy and operational flexibility should a high-yield source become available. The new source process is long and onerous, so it is imperative the Division begin to investigate and develop new sources several years before they are required.

Then, the Manomet Pressure Zone Pipe Upgrade project should be prioritized to maintain adequate system pressures throughout the zone and to improve the effectiveness of the future Pine Hills Interconnection project as discussed in the alternatives analysis below. Following the Manomet Pressure Zone Pipe Upgrades, the Division should move forward with the Pine Hills Pressure Zone Interconnection and new source exploration to address the firm capacity deficit in the Northern Pressure Zones. Subsequent recommendations should be implemented in accordance with Tables 9-2 through 9-4, and Figures 9-1 and 9-2. Costs associated with each recommendation are included in Section 9.4 below.

9.3.1 Capital Improvements Plan Alternatives Analysis

An alternatives analysis was completed to determine whether the Division should prioritize the Manomet Pipe Upgrades or the Pine Hills Interconnection. EP evaluated the two projects on the basis of firm capacity, operational capacity, and the resulting system performance.

As discussed in Chapter 4, both the Northern and Eastern Pressure Zones currently exhibit a supply deficit in a firm capacity scenario. As noted above, lifting the restrictions on withdrawals at the Darby Pond Well can eliminate the deficit in the Northern Pressure Zones until approximately 2027. However, should these efforts prove unsuccessful, hydraulic modeling efforts indicate that a supply of at least 300 gpm is needed through the proposed Pine Hills Interconnection project to stabilize the pressures and tank levels in the Northern Pressure Zones.

In the Eastern Pressure Zones, the firm capacity is currently limited by the reported operational capacity of the Ship Pond and Ellisville Wells, resulting in a firm capacity output of approximately 2.23 MGD (Table 4-14). However, hydraulic modeling efforts indicate that achieving the safe yield of 2.92 MGD from the Manomet Pressure Zone sources is possible in a reduced pressure environment. For example, when Savery Pond Well, the largest source in the Eastern Pressure Zones, goes offline, the Cedarville Booster Pumps kick on. This creates a drop in pressures near the Ship Pond and Ellisville Wells and subsequent increase in their operational capacity, with their output increasing sufficiently to meet demands. While the South Pine Hills Tank levels do drop, they ultimately stabilize.

Therefore, while there is a reported firm capacity deficit in the Eastern Pressure Zones, hydraulic modeling results indicate this is due to hydraulic constraints on the Ship Pond and Ellisville Wells that are removed in a firm capacity scenario. Thus, the firm capacity deficit in the Eastern Pressure Zones does not represent a true supply deficit, but rather a lack of sufficient hydraulic capacity to meet the required demands with an adequate pressure profile.

This analysis shows that the immediate, primary value of the Pine Hills Interconnection project is its potential to supply the Northern Pressure Zones, where there is little ability to increase yields in a firm capacity scenario.

To further evaluate the Pine Hills Interconnection and Manomet Pipe Upgrades projects, EP simulated a firm capacity scenario in the Northern Pressure Zones by applying a constant demand at the intersection of the Manomet and Pine Hills Pressure Zones. This demand was then increased under various combinations of system improvements to identify an approximate maximum withdrawal rate from the Manomet Pressure Zones, as well as the anticipated minimum pressure in the Manomet Pressure Zone at the required 300 gpm withdrawal rate. This analysis was used to evaluate the effect of the two proposed capital improvement project and their ability to supply water under a firm capacity scenario in the Northern Pressure Zones. Table 9-12 below shows the results of this alternatives analysis.

Table 9-12 – Maximum Withdrawal from the Manomet Pressure Zone

Scenario[1]	Max BPS Flow[2] (gpm)	Max BPS Flow (MGD)	Suction Pressure at 300 gpm (psi)
No Upgrades	245	0.353	-4.5
Pine Hills Interconnection Only, including Rocky Hill Road Water Main Upgrades	400	0.576	5.3
Manomet Pipe Upgrades Only	420	0.605	7.5
Pine Hills Interconnection Upgrades and Manomet Pipe Upgrades	670	0.965	15.5

1. Scenarios were modeled using the proposed controls strategy outlined in Chapter 7.
2. The maximum allowable withdrawal was taken as the flow which produced a residual pressure of 0 psi on the suction side of the proposed booster pumping station.

As stated above, the required flow rate to stabilize the Northern Pressure Zones is approximately 300 gpm. As shown in Table 9-12, while the required flow is possible without the Manomet Pipe Upgrades, the resulting residual pressure of 5 psi could result in unsafe operating conditions. Therefore, EP recommends the Division prioritize the Manomet Water Main Upgrades over the Pine Hills Interconnection project to ensure the interconnection can be operated in as safe a manner as possible.

It should be noted that at the request of the Division, EP drafted a preliminary layout of the Pine Hills Interconnection project in December 2018, which included the identification of two alternate locations for the East Pine Hills Booster Pumping Station. Both of these locations are at lower elevations than the existing Rocky Hill Road PRV. Therefore, anticipated suction pressures for the above alternatives would likely improve if one of the alternate sites is selected. Preliminary analysis indicates that suction pressures at the required 300 gpm could be increased to above 20 psi if both upgrades are completed and one of the alternate booster pumping sites is selected.

In summary, the primary benefit of the Pine Hills Interconnection project is its potential to supply water to the Northern Pressure Zones during the loss of the its largest source (South Pond Well No. 2); supplying water to the Eastern Pressure Zones is of less concern, as the Ship Pond and Ellisville Wells have considerable remaining capacity that will become available following the loss of a large water source. Hydraulic modeling efforts indicate that the Pine Hills Interconnection project will have insufficient capacity to safely supply the required 300 gpm to the Northern Pressure Zones unless the Manomet Water Main Upgrades are completed. Therefore, EP recommends the Manomet Pipe Upgrades be prioritized ahead of the Pine Hills Interconnection project such that sufficient capacity is available for the Pine Hills Interconnection to serve its intended purpose.

9.4 CAPITAL COSTS

Opinions of probable project costs (OPPC) are presented for all of the previously recommended water system improvements. The OPPC estimates in this chapter are assumed to be Class 5 estimates, per the American Association of Cost Engineers (AACE) International Recommended Practice No. 18R-97. This corresponds with a project definition maturity of 0 to 2 percent, which is an estimate used for concept screening. Unless otherwise noted, a contingency of 25 percent was applied to each of the estimates. All of these costs are based on recent bid results for similar work in southeast Massachusetts and projected to 2020 dollars. The future use of this cost data must be adjusted accordingly.

The OPPC presented in this section represent all the costs for the study, design, and construction, including contingencies and engineering assistance for bidding, construction administration, and resident engineering services for construction projects. Police details are included in the OPPC but should be revisited prior to budgeting the capital project for a funding request. Capital costs for ongoing maintenance programs discussed in Section 9.1 are not included. Prior to a capital project being undertaken, a detailed cost estimate should be performed in order to finance the capital project. A full summary of the recommended capital improvements OPPC by phase is provided in Tables 9-13 through 9-15.

Table 9-13 – Capital Improvements Summary, Phase I (Years 2020 to 2025)

Priority No.	Recommendation	Opinion of Probable Cost
1	Operational Controls Strategy Adjustments	No Cost
2	Lift Darby Pond Well Production Restrictions	$53,000[1]
3	Water Supply and Management - New Source Exploration	$200,000
4	Manomet Pipe Upgrades and Pipe Conditions Testing	$5,100,000
5	Emergency Power Upgrades - Darby Pond WPS and Cedarville BPS	$401,000
6	Ongoing Facility Upgrades - Electrical	$750,000
7	Pine Hills Pressure Zone Interconnection	$6,400,000
8	Water Supply and Management - New Source Permitting	$300,000
9	Emergency Power Upgrades - Controlling Tank Sites	$546,000
10	Ongoing Facility Upgrades - Mechanical	$500,000
11	Ongoing Facility Upgrades - Underground Electrical Upgrades	$575,000
12	Valve and Flushing Plan	$109,000
13	Groundwater Protection District	$80,000
14	Water Supply and Management - Water Conservation Measures	$18,000
15	Water Supply and Management - New Source Design	$350,000
16	Ongoing Facility Upgrades - Instrumentation	$500,000
17	Redevelop Well Supplies	$150,000
18	Great South and Little South Pond Feasibility Study	$110,000
19	Staffing Evaluation	$33,000
20	Standard Operating Procedure for Interconnections	$9,000
21	Storage Tank Improvements	$240,000
22	Water Supply and Management - New Source Construction	$3,500,000
23	Ongoing Facility Upgrades - Treatment	$500,000
24	Water Main Upgrades - West Plymouth Pressure Zone Group I	$420,000
25	Ongoing Pipe Replacement	$500,000
26	PFAS Preparedness	$22,000
	Phase I Improvements Total	**$21,229,000**

1. The cost does not include the cost to acquire the cranberry bogs located within the Zone II.

Table 9-14 – Capital Improvements Summary, Phase II (Years 2026 to 2030)

Priority No.	Recommendation	Opinion of Probable Cost
1	Bradford and Plymouth Center Pressure Zone Boundary Reconfiguration	$14,900,000
2	Ongoing Facility Upgrades - Site	$500,000
3	Ongoing Facility Upgrades - Architectural	$500,000
4	Water Main Upgrades - Plymouth Center Pressure Zone	$2,200,000
5	Lout Pond Raw Water Transmission Main to Bradford (or treatment)	$5,206,000
6	Emergency Power Upgrades - Non-Controlling Tank Sites	$364,000
7	Ongoing Pipe Replacement	$2,500,000
8	Drought Management Plan	$14,000
	Phase II Improvements Total	**$26,184,000**

Table 9-15 – Capital Improvements Summary, Phase III (Years 2031 to 2035)

Priority No.	Recommendation	Opinion of Probable Cost
1	Water Main Upgrades - Manomet Pressure Zone	$1,200,000
2	Water Main Upgrades - Cedarville Pressure Zone	$2,550,000
3	Water Main Upgrades - West Plymouth Pressure Zone Group II	$2,210,000
4	Ongoing Pipe Replacement	$2,500,000
5	SCADA Review	$58,000
6	Replace critical PRVs	$2,738,000
	Phase III Improvements Total	**$10,911,000**

References

Adams Fire Protection, Inc. March 2019. *Waterflow Test, 949 State Road, Plymouth, MA.*

Amory Engineers, P.C. January 2019. *Hydrant Flow Test – 70 Armstrong Road, Plymouth, MA.*

Amory Engineers, P.C. May 2019. *Hydrant Flow Test – 575 State Road (Route 3A).*

Environmental Partners Group, Inc. February 2018. *Forges Field New Water Supply Source, DEP Pumping Test Report BRP WS 19.*

Federal Emergency Management Agency. *FEMA Flood Map Service Center.* https://msc.fema.gov/portal/search

G&G Fire Protection Incorporated. May 2018. *Hydrant Flow Info for: 11 Resnik Road.*

GIO Group. January 2018. *Cordage Park Hydrant Flow Test.*

Haley and Ward, Inc. September 2012. *Report on Evaluation of Plymouth Water Supply Facilities.*

Haley and Ward, Inc. October 2015. *Water Storage Tank 2015 Annual Inspection Report, Lout Pond Reservoir.*

Haley and Ward, Inc. December 2018. *2018 Annual Sanitary and Security Water Storage Tank Inspection Report, Cedarville Reservoir, Chiltonville Standpipe, Harrington Standpipe, North Plymouth Concrete Reservoir, South Pine Hills Concrete Reservoir, Stafford Street Standpipe.*

Haley and Ward, Inc. June 2019. *Water Storage Tank Asset Management Schedule.*

Horsely Witten Group. March 2009. *Lout Pond Replacement Well Source Final Report.*

Insurance Services Office, Inc. 2019. *Public Protection Classification Summary Report.*

Maher Services, Inc. January 2015. *Plymouth Flow Tests.*

Massachusetts Department of Environmental Protection. July 31, 2003. *Source Water Assessment and Protection (SWAP) Report for Plymouth Water Division.*

Massachusetts Department of Environmental Protection. Multiple Dates. *Public Water System Annual Statistical Report: 2013, 2014, 2015, 2016, 2017.*

Massachusetts Department of Environmental Protection. July 3, 2018. *Public Water System Sanitary Survey.*

Massachusetts Department of Environmental Protection. March 1, 2019. *Findings of Fact in Support of FINAL Permit Issuance, Water Management Permit #9P42123901.*

Nitsch Engineering. April 2018. *Hydrant Flow Test Summary Sheet.*

South Shore Pipeline Services, Inc. March 2019. *Fire Flow Test No. 1.*

Sprink Design Inc. April 2018. *Hydrant Flow Test Report.*

Underwater Solutions, Inc. November 2013. *Inspection and Cleaning of the Lout Pond 1-Million Gallon Welded Steel Water Storage Tank.*

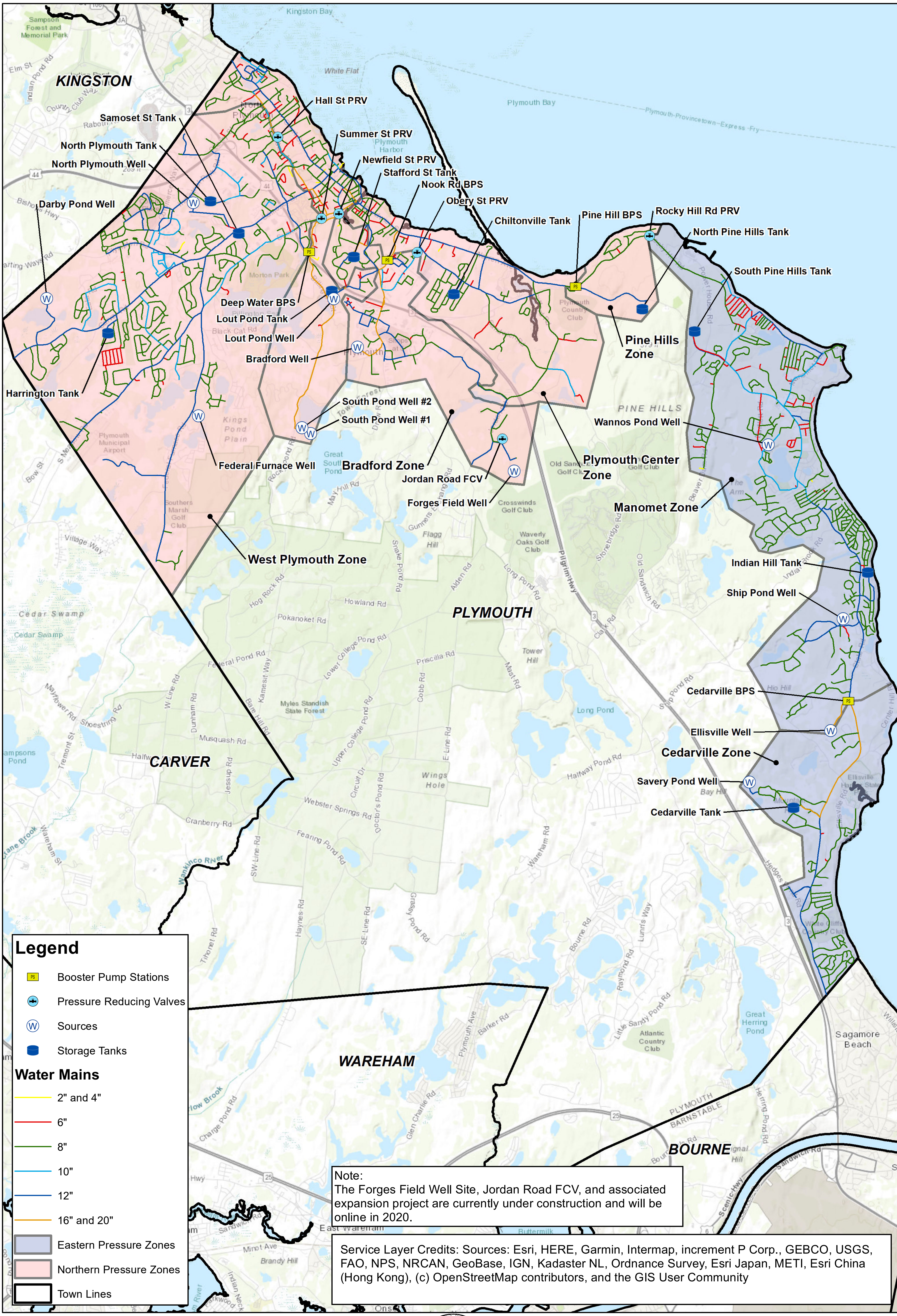
Underwater Solutions, Inc. September 2015. *Inspection and Cleaning (Sediment Removal) of the Indian Hill 1-Million Gallon Welded Steel Water Storage Tank.*

Utility Service Group. April 2014. *The North Pine Hills 1.0 Million Gallons CST Anniversary Inspection Report.*

Utility Service Group. November 2016. *Samoset St 520,000 Gallons Standpipe Condition Assessment Report.*

Wright-Pierce. April 2006. *Master Plan for the Plymouth, Massachusetts Water System.*

Figures



0 3,000 6,000 12,000 Feet

1 in = 6,000 feet

Environmental Partners GROUP
A partnership for engineering solutions.

Figure 1-1: Plymouth Water Department Water System Map
November 2019

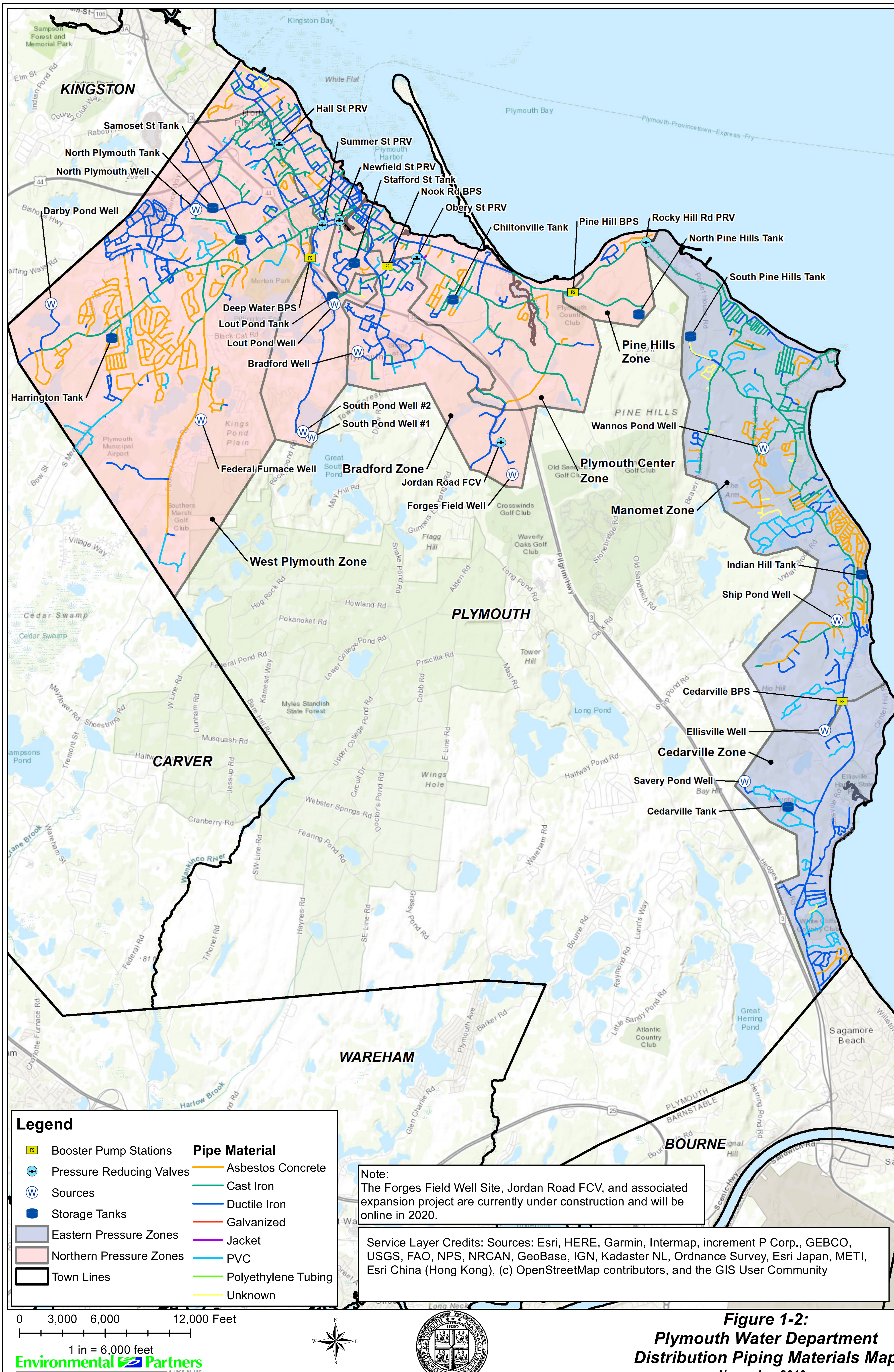
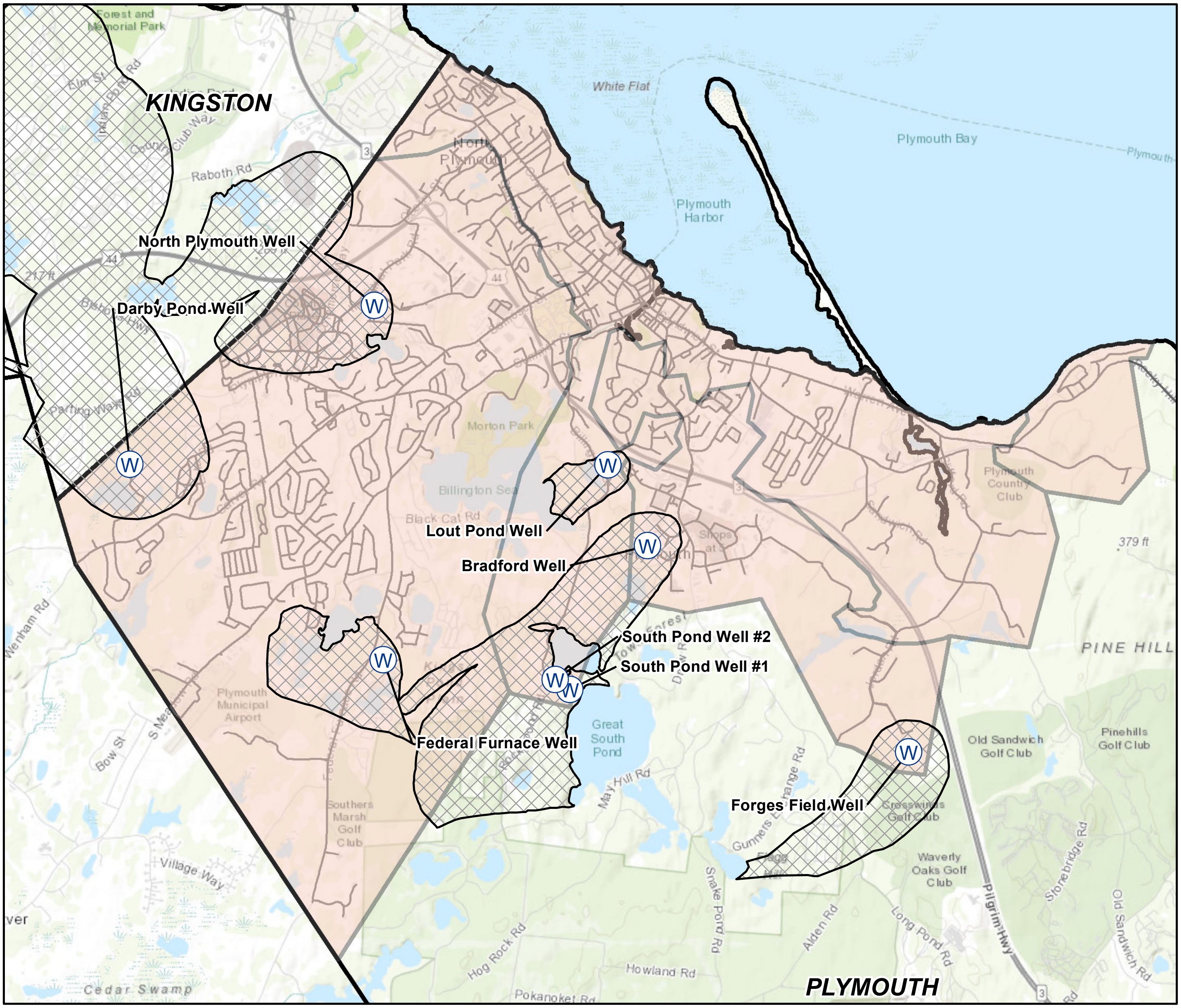


Figure 1-2:
Plymouth Water Department
Distribution Piping Materials Map
November 2019



Legend

- Sources
- Zone II Areas
- Northern Plymouth Pressure Zone

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

0 3,250 6,500 13,000 Feet

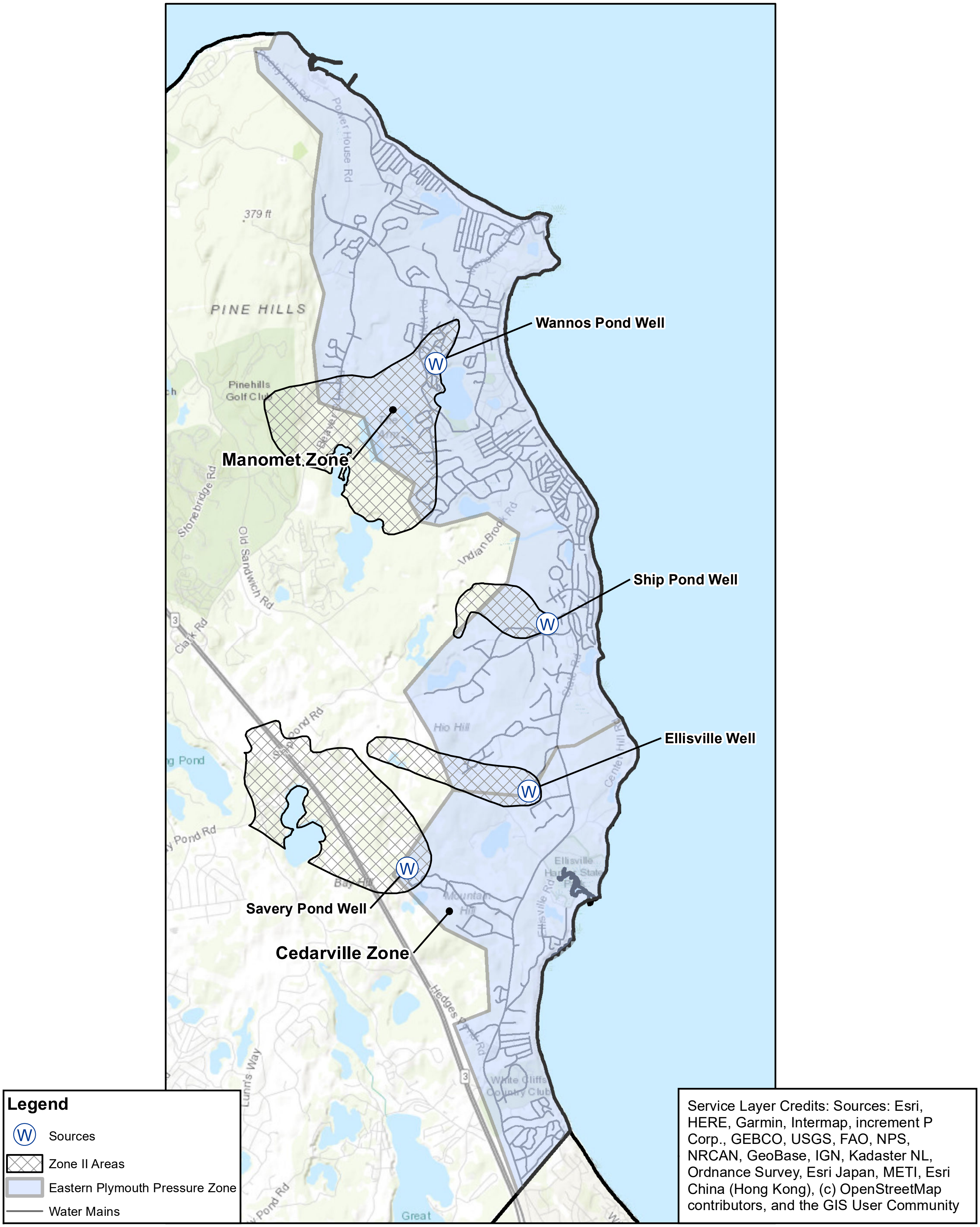
1 in = 6,500 feet

Environmental Partners GROUP

A partnership for engineering solutions.

Figure 2-1: Northern Pressure Zones Zone II Areas

November 2019



0 3,000 6,000 12,000 Feet

1 in = 6,000 feet

Environmental Partners GROUP
A partnership for engineering solutions.

Figure 2-2:
Eastern Pressure Zones
Zone II Areas
November 2019

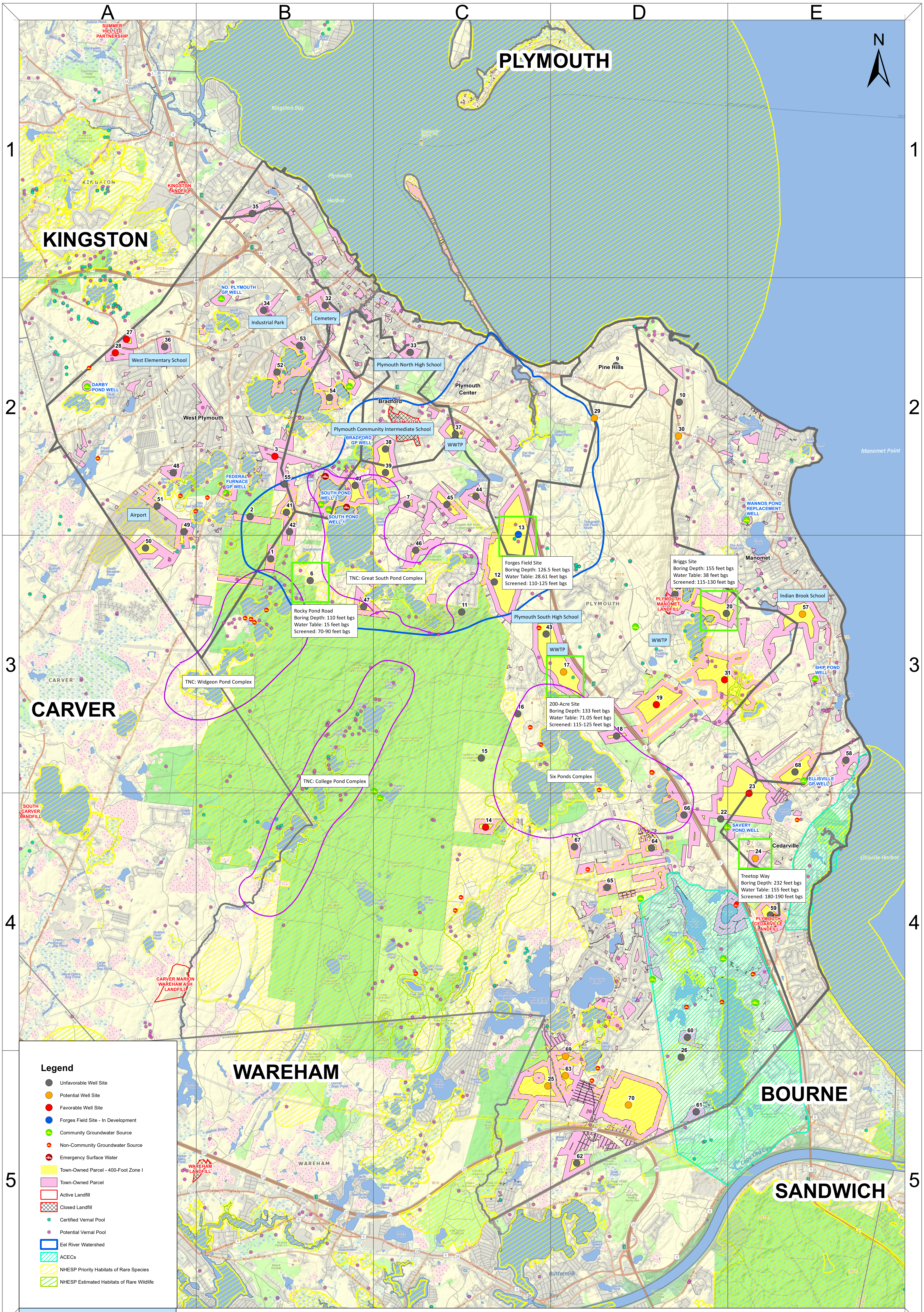


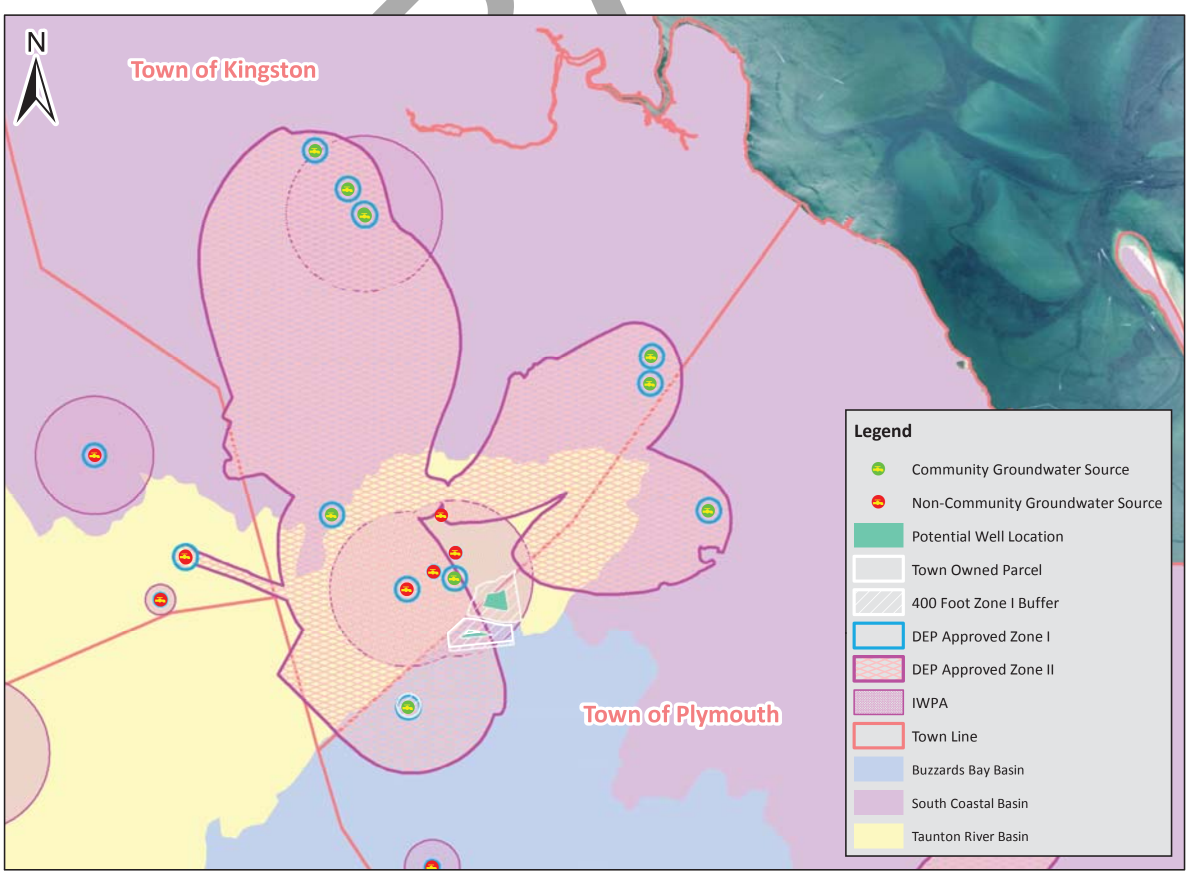
Figure 5-1 - New Source Site Screening
Plymouth, Massachusetts

Environmental Partners

Figure 5-2 - Potential New Source Sites
Plymouth, Massachusetts

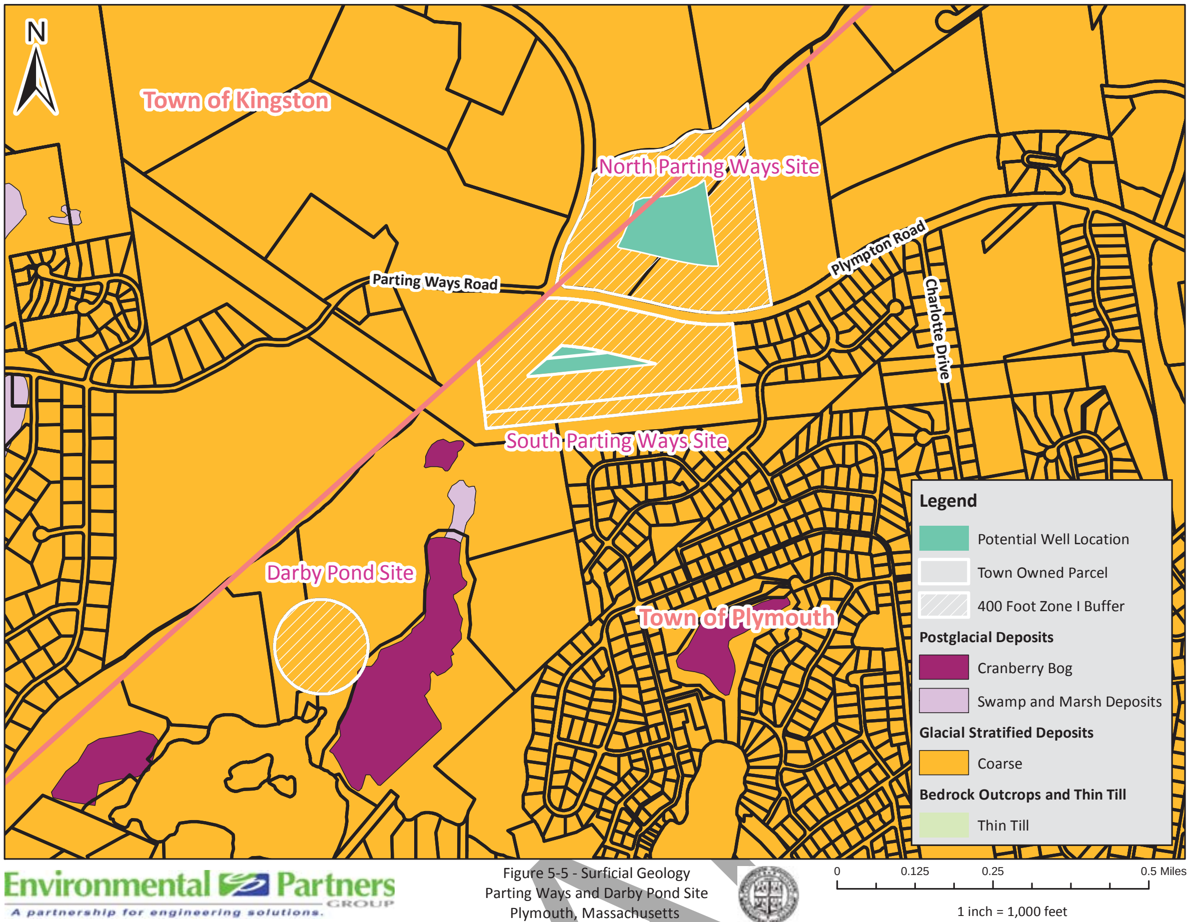
Environmental Partners Group
A partnership for engineering solutions.

Figure 5-3: Site Locus
Parting Ways and Darby Pond Site
Plymouth, Massachusetts



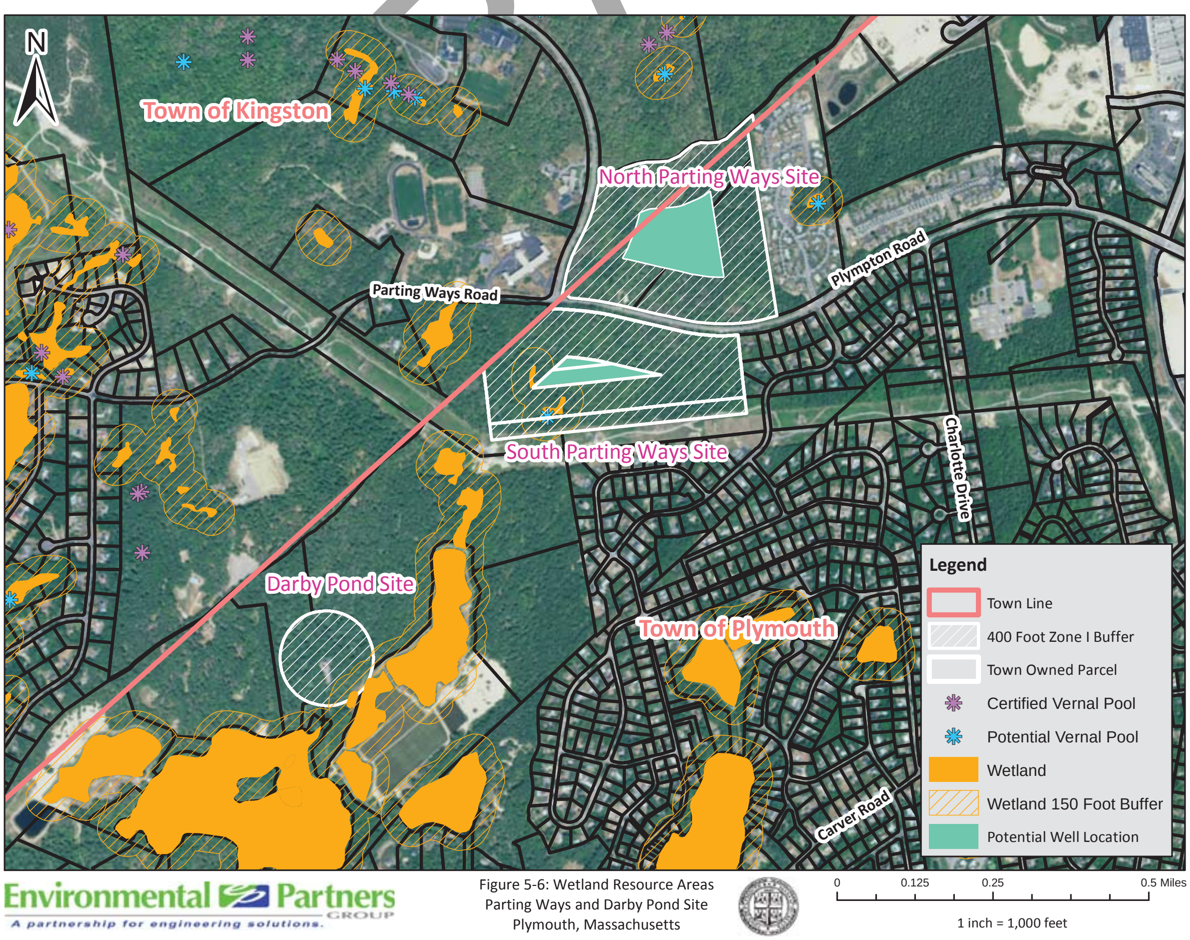
Environmental Partners Group
A partnership for engineering solutions.

Figure 5-4: Sub-Basins
Parting Ways and Darby Pond Site
Plymouth, Massachusetts



Environmental Partners Group
A partnership for engineering solutions.

Figure 5-5 - Surficial Geology
Parting Ways and Darby Pond Site
Plymouth, Massachusetts

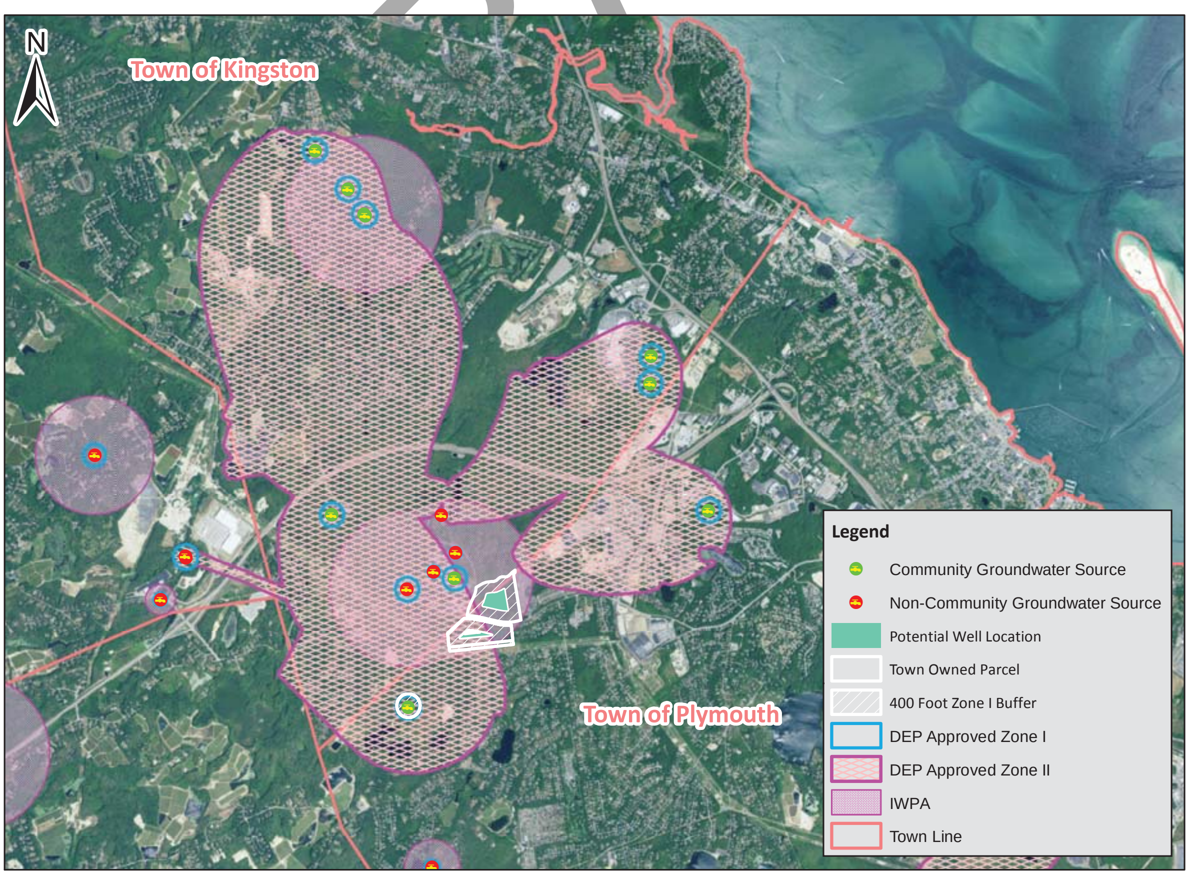


Environmental Partners Group
A partnership for engineering solutions.

Figure 5-6: Wetland Resource Areas
Parting Ways and Darby Pond Site
Plymouth, Massachusetts

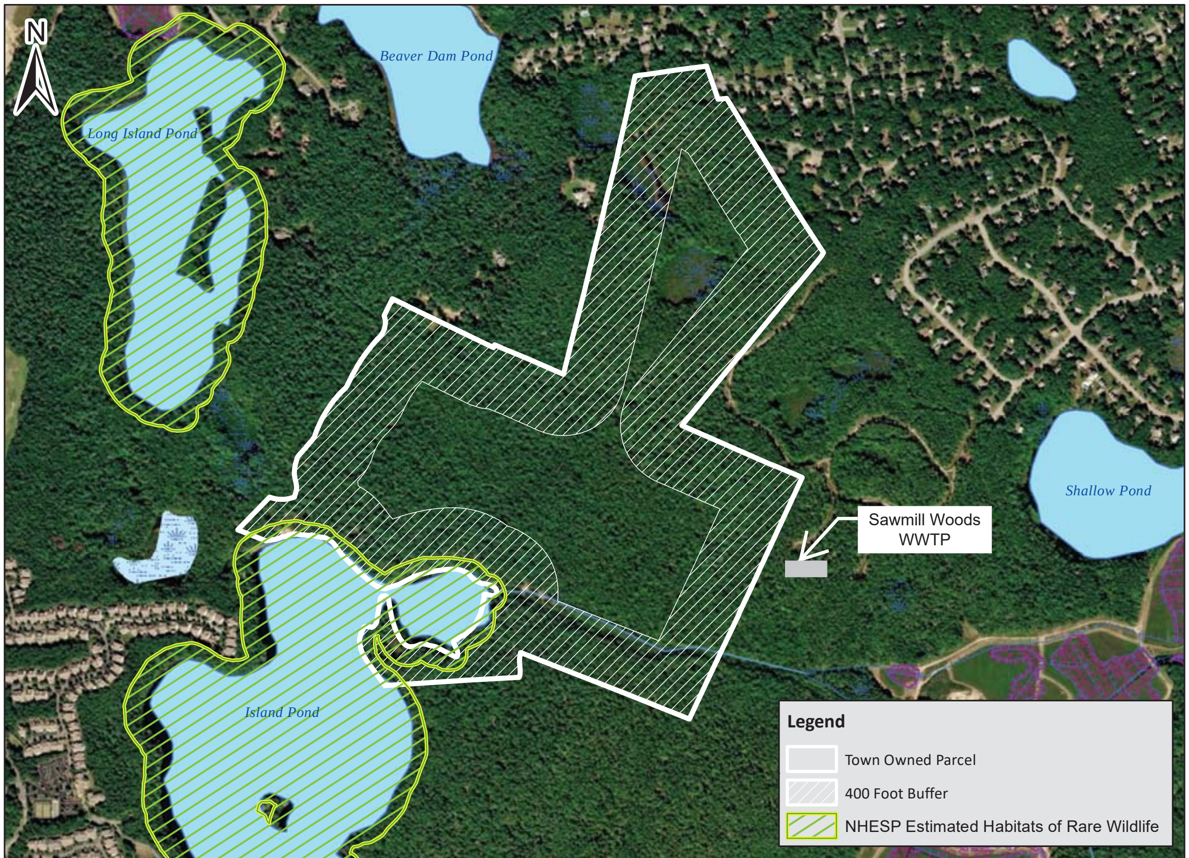
Environmental Partners Group — A partnership for engineering solutions.

Figure 5-7: Land Use
Parting Ways and Darby Pond Site
Plymouth, Massachusetts



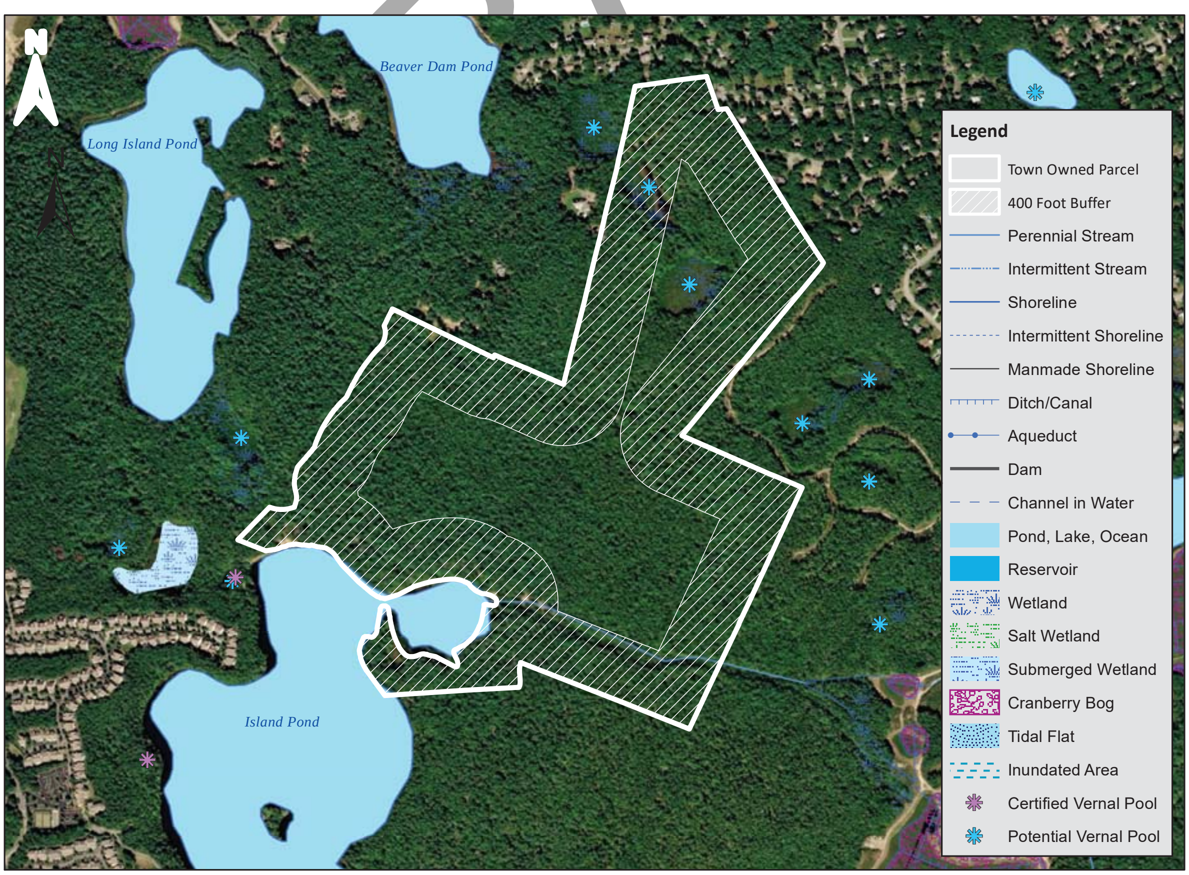
Environmental Partners Group — A partnership for engineering solutions.

Figure 5-8: Wellhead Protection Areas
Parting Ways and Darby Pond Site
Plymouth, Massachusetts



Environmental Partners Group
A partnership for engineering solutions.

Figure 5-9: Site Map
#20 Briggs Site
Plymouth, Massachusetts



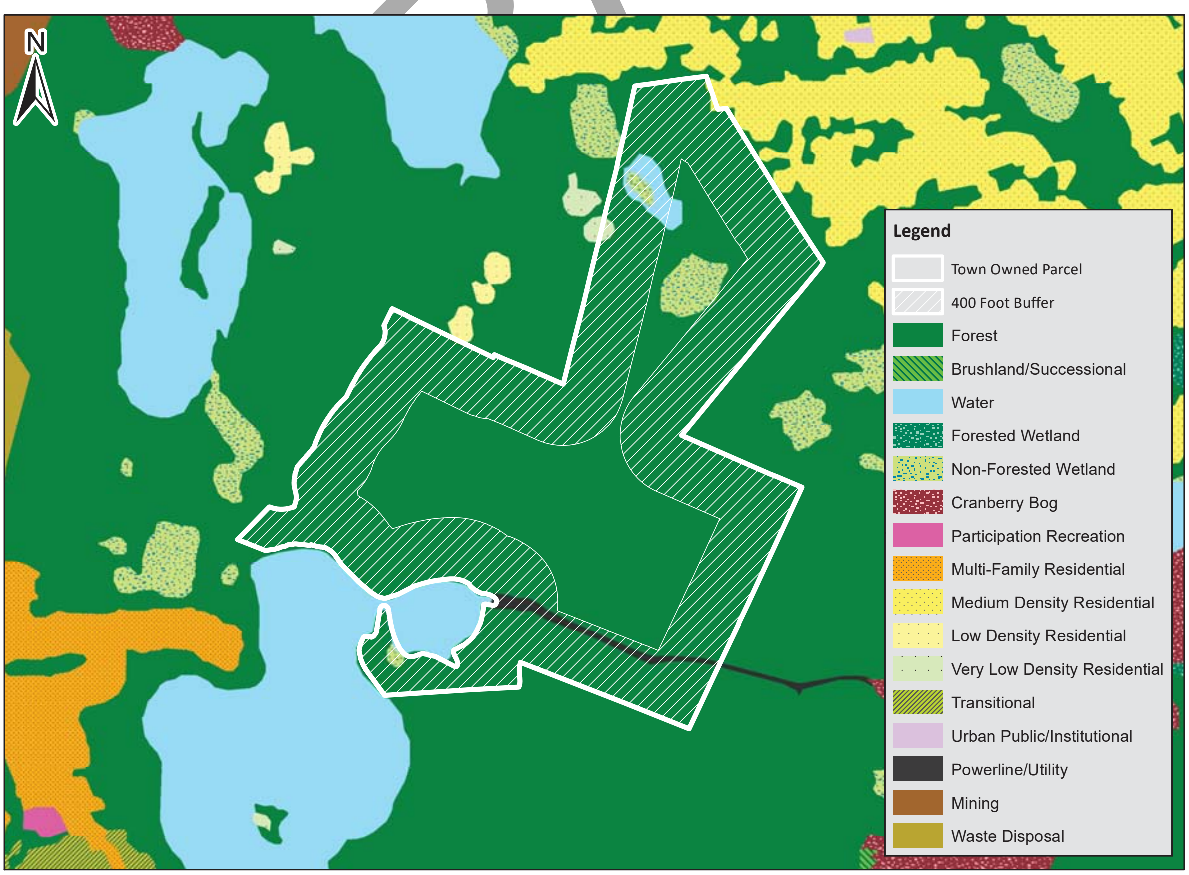
Environmental Partners Group
A partnership for engineering solutions.

Figure 5-10: Wetlands
#20 Briggs Site
Plymouth, Massachusetts

Environmental Partners GROUP
A partnership for engineering solutions.

Figure 5-11: Aquifer Zone & Surficial Geology #20 Briggs Site
Plymouth, Massachusetts

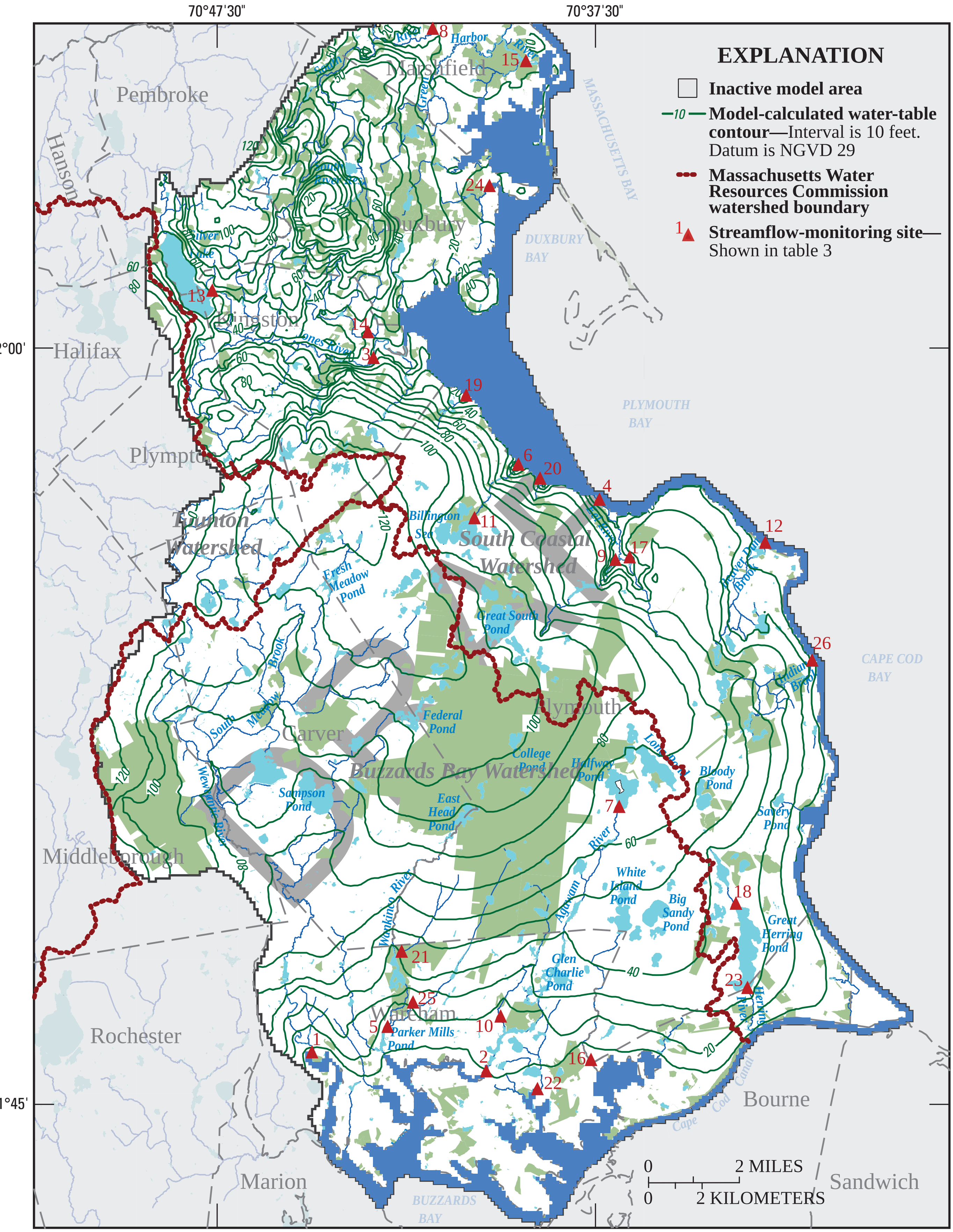
0 0.075 0.15 0.3 Miles
1 inch = 769 feet



Environmental Partners GROUP
A partnership for engineering solutions.

Figure 5-12: Aquifer Zone & Surficial Geology #20 Briggs Site
Plymouth, Massachusetts

0 0.075 0.15 0.3 Miles
1 inch = 769 feet



Base from U.S. Geological Survey and Massachusetts Geographic Information System data sources, Massachusetts State Plane Coordinate System, Mainland Zone

Figure 5-13 USGS 2009 Plymouth-Carver-Kingston-Duxbury Aquifer Model (Masterson et.al., 2009)

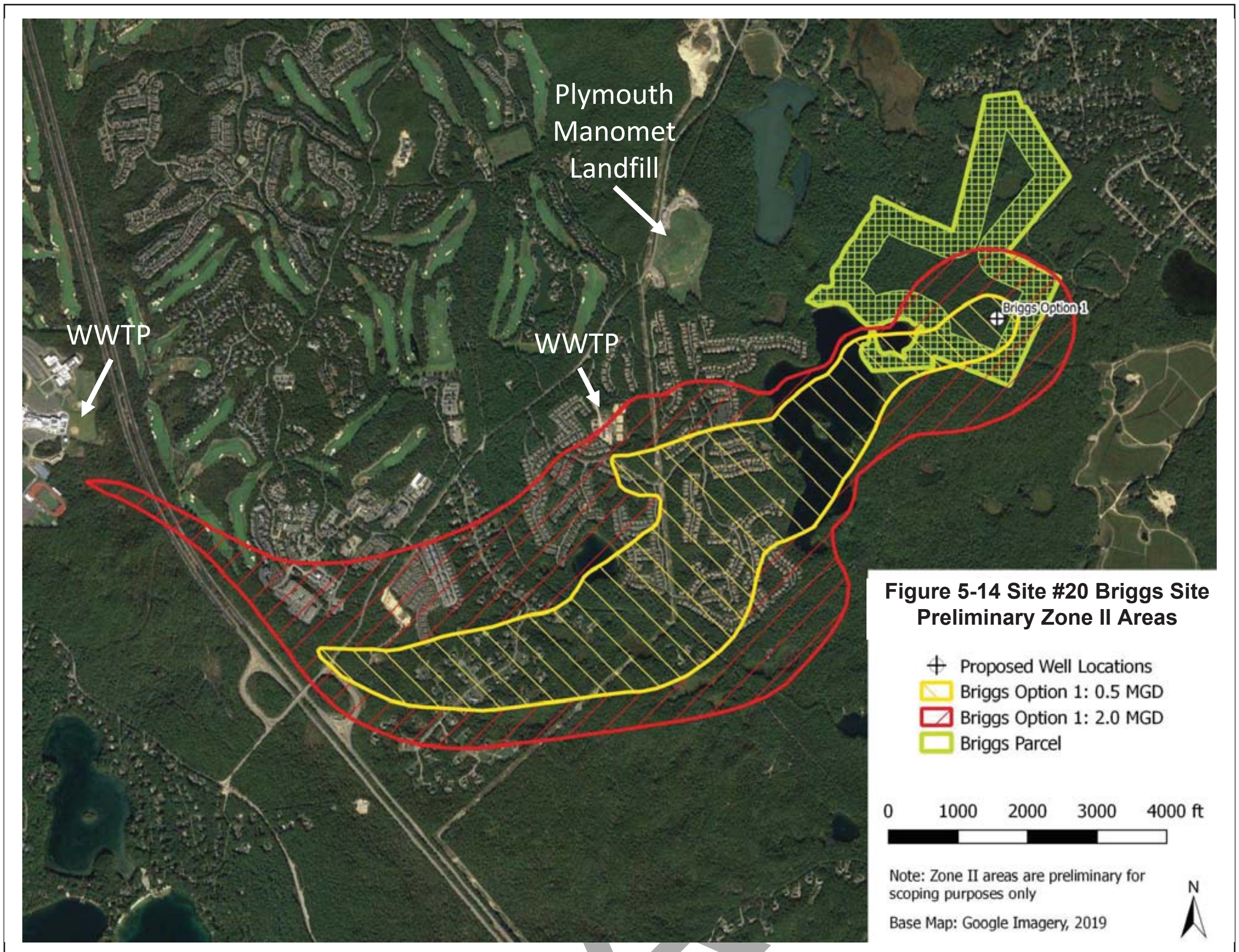
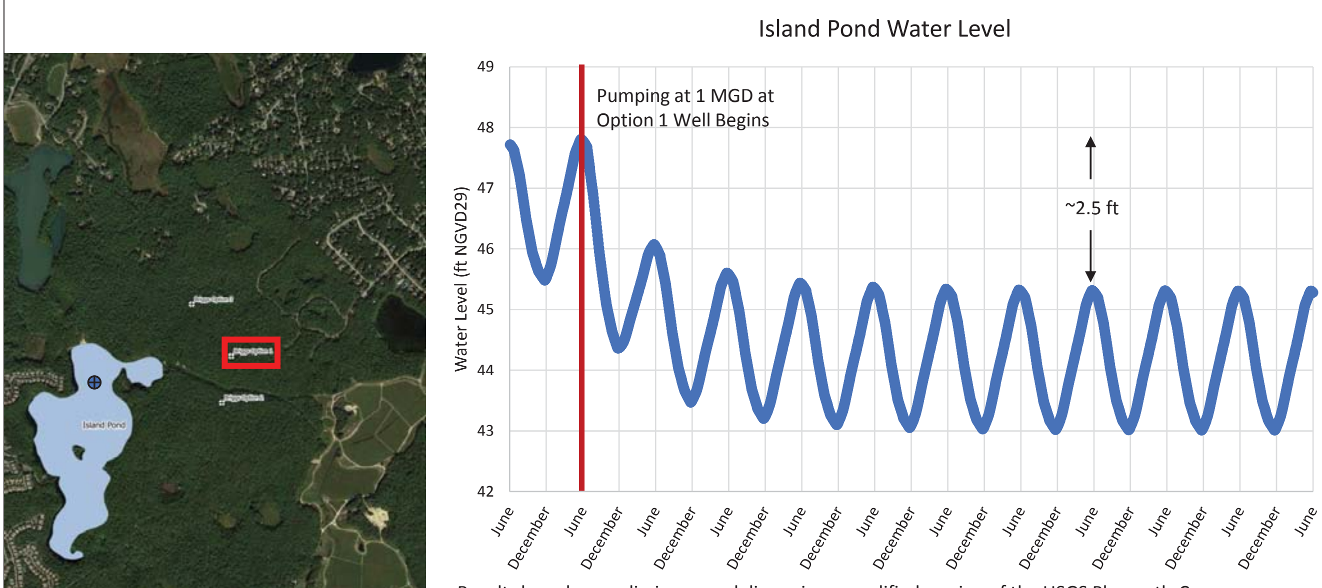


Figure 5-14 Site #20 Briggs Site Preliminary Zone II Areas

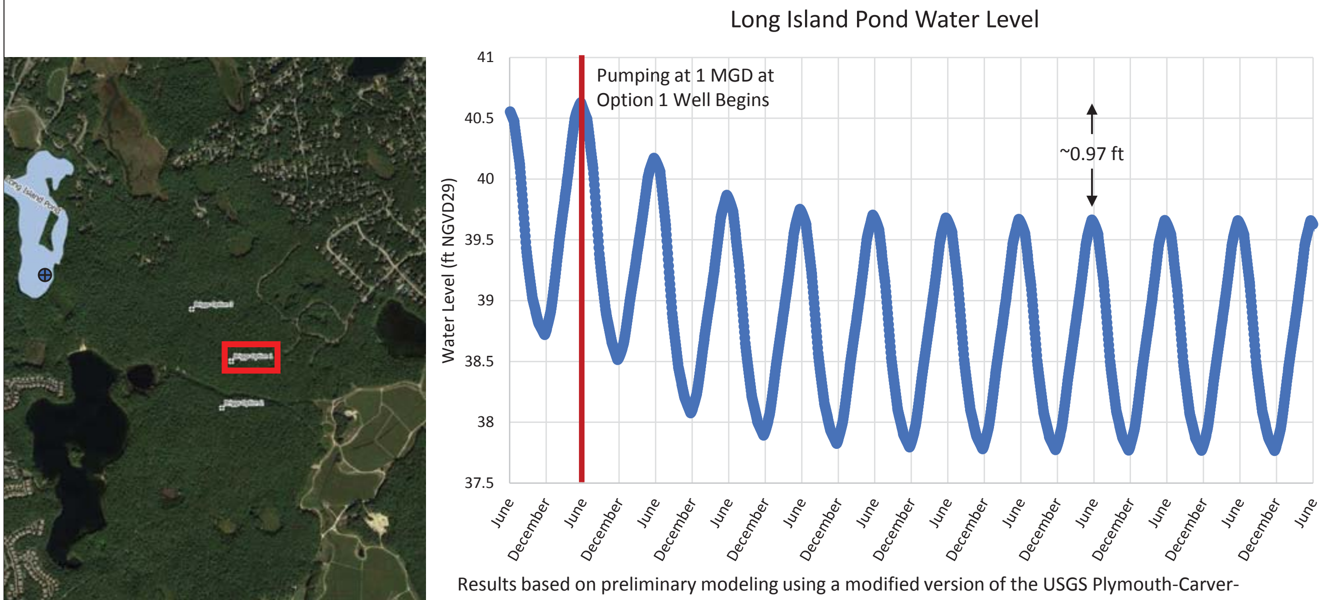
Figure 5-15: Site #20 Briggs Site
Preliminary Drawdown in Island Pond - Pumping Rate 1 MGD



Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.

⊕ - Approximate Model Monitoring Well Location

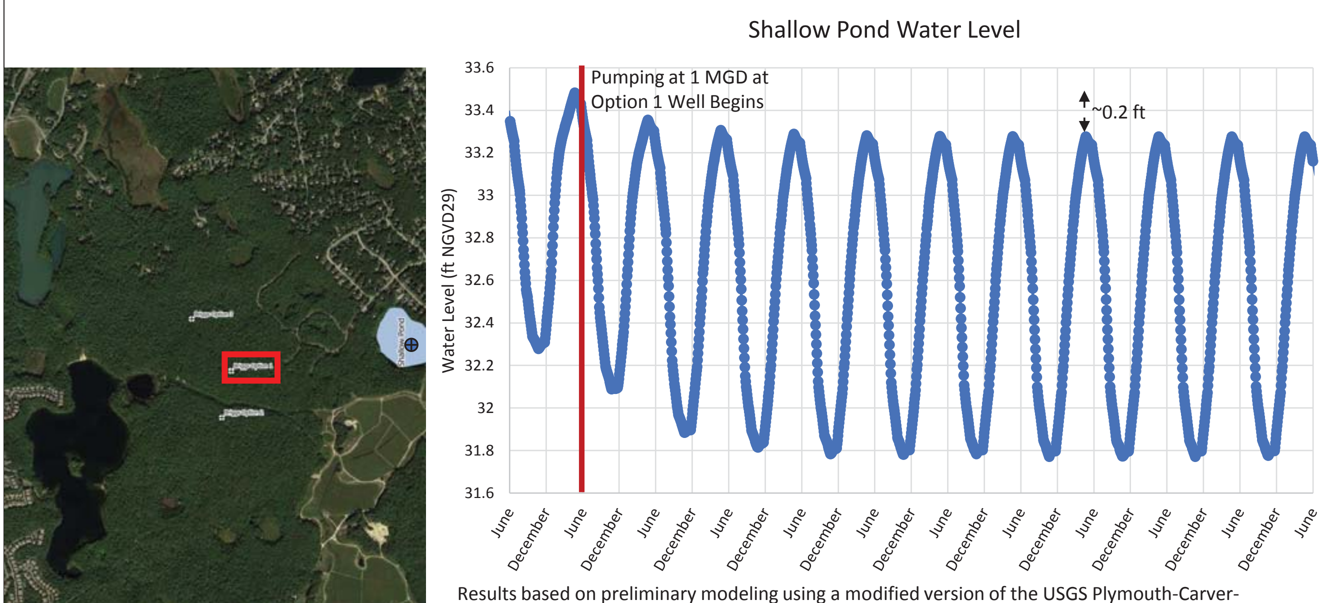
Figure 5-16: Site #20 Briggs Site
Preliminary Drawdown in Long Island Pond - Pumping Rate 1 MGD



Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.

⊕ - Approximate Model Monitoring Well Location

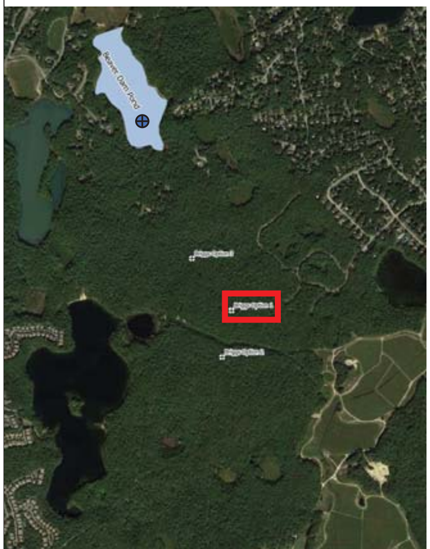
Figure 5-17: Site #20 Briggs Site
Preliminary Drawdown in Shallow Pond - Pumping Rate 1 MGD



Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.

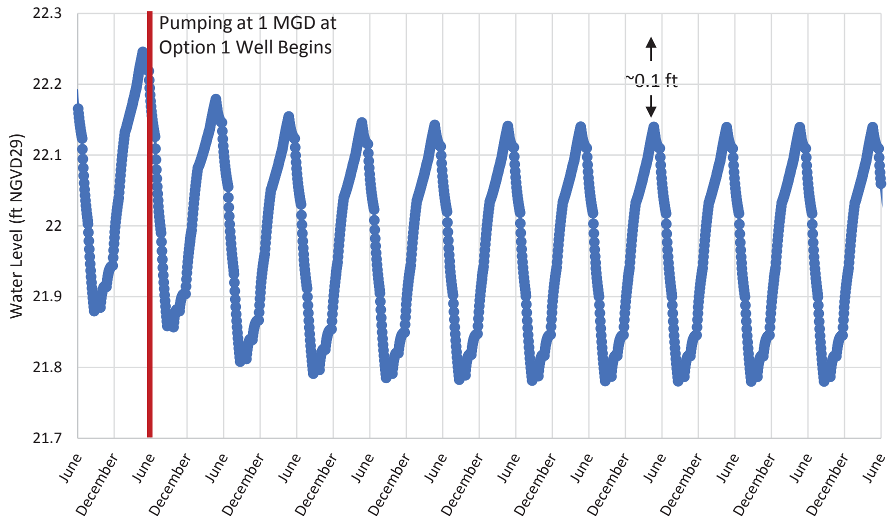
⊕ - Approximate Model Monitoring Well Location

Figure 5-18: Site #20 Briggs Site
Preliminary Drawdown in Beaver Dam Pond - Pumping Rate 1 MGD



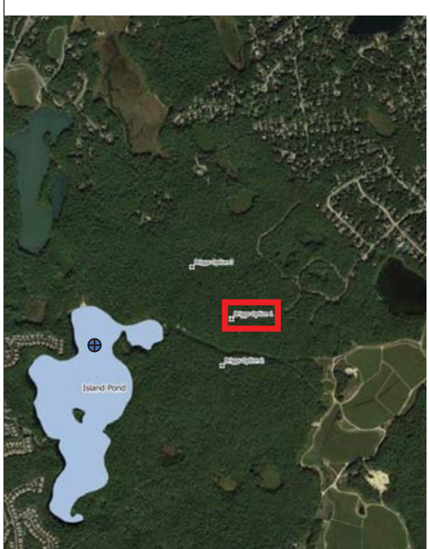
⊕ - Approximate Model Monitoring Well Location

Beaver Dam Pond Water Level



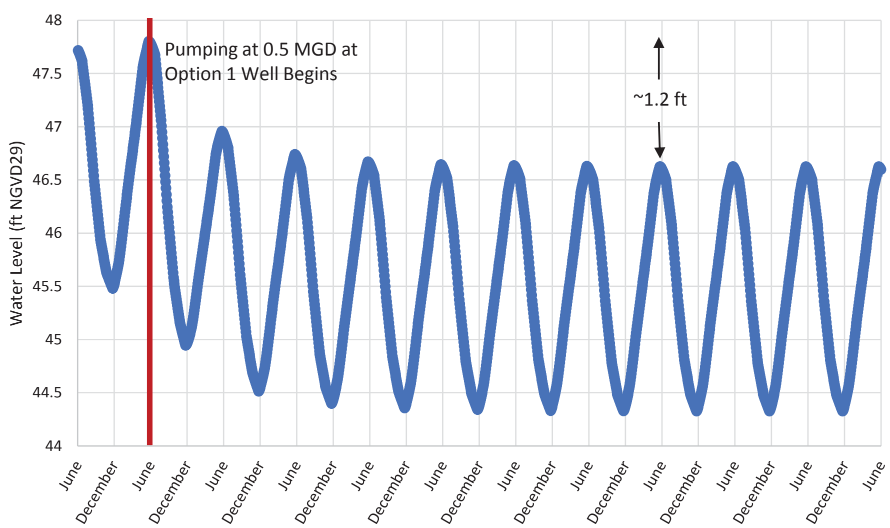
Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.

Figure 5-19: Site #20 Briggs Site
Preliminary Drawdown in Island Pond - Pumping Rate 0.5 MGD

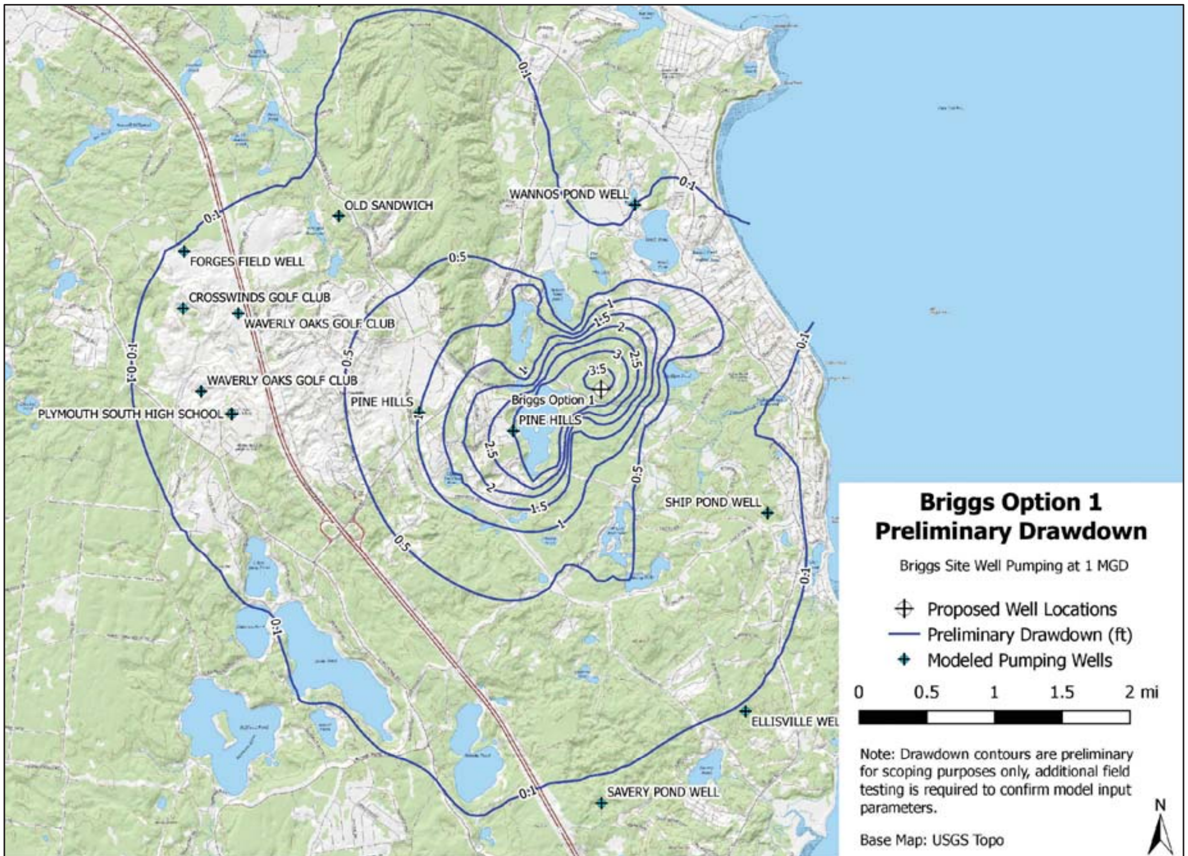


⊕ - Approximate Model Monitoring Well Location

Island Pond Water Level



Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.



Environmental Partners Group
A partnership for engineering solutions.

Figure 5-20: Site #20 Briggs Preliminary Drawdown Map
Plymouth, Massachusetts

Environmental Partners Group
A partnership for engineering solutions.

Figure 5-21: Site #23 Site Locus
Plymouth, Massachusetts

0 0.25 0.5 1 Miles
1 inch = 2,000 feet

Environmental Partners Group — A partnership for engineering solutions.

Figure 5-22: Site #23
Wetland Resource Areas
Plymouth, Massachusetts

0 0.25 0.5 1 Miles
1 inch = 2,000 feet

Environmental Partners Group — A partnership for engineering solutions.

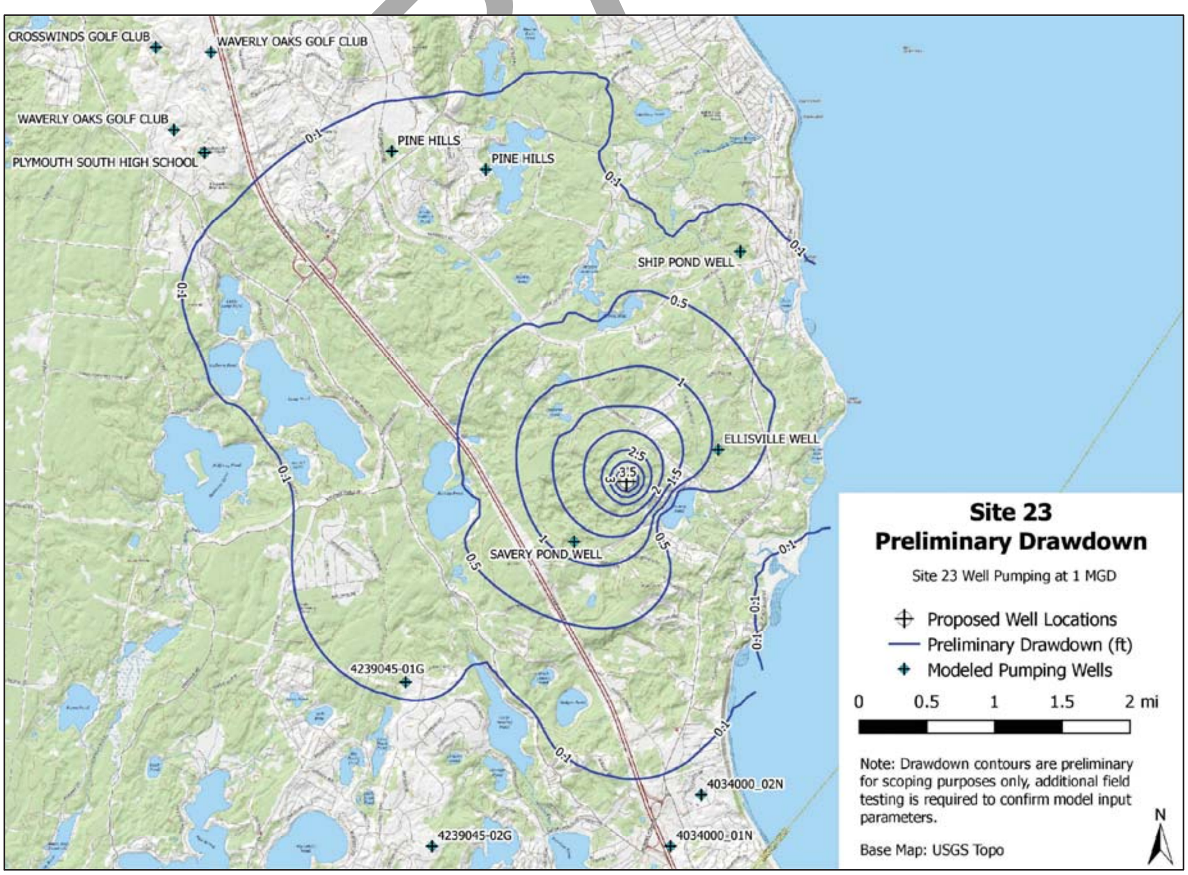
Figure 5-23: Site #23 Land Use
Plymouth, Massachusetts

0 0.25 0.5 1 Miles
1 inch = 2,000 feet

Environmental Partners GROUP
A partnership for engineering solutions.

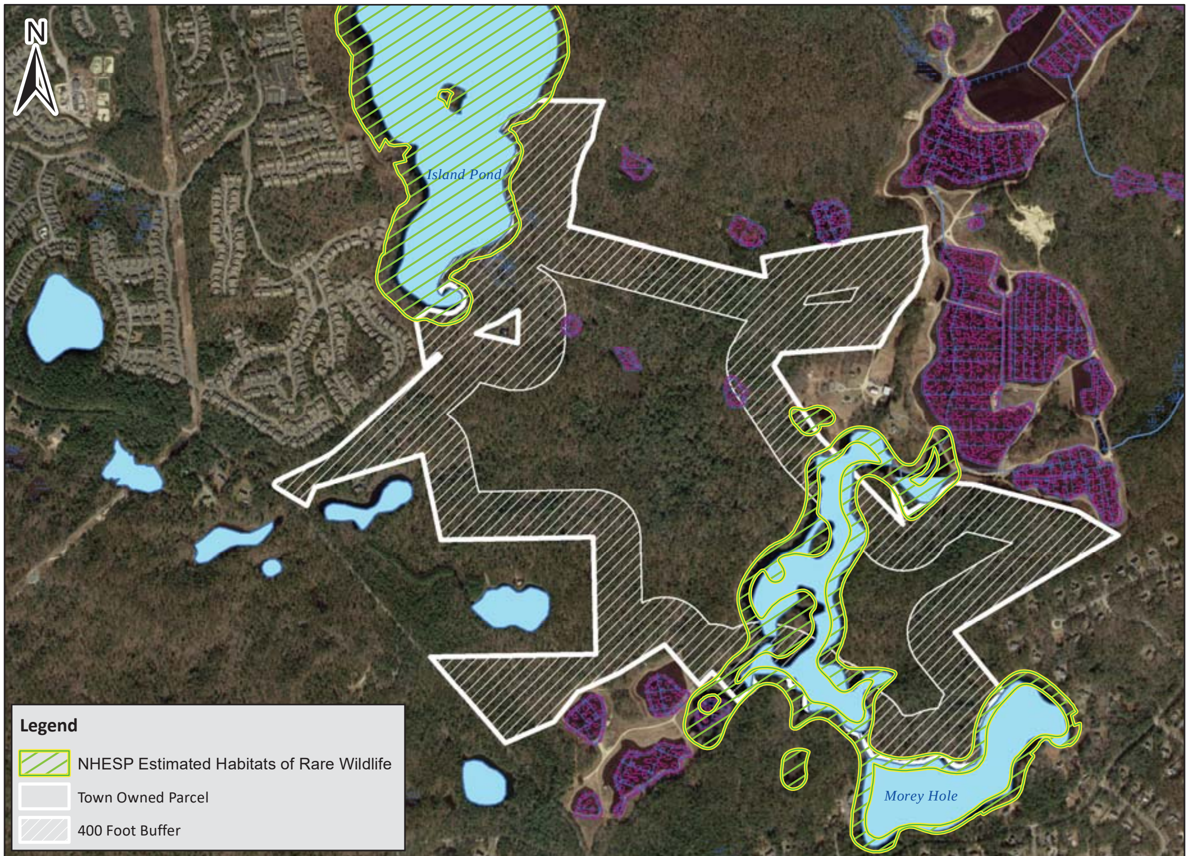
Figure 5-24: Site #23
Water Supply
Plymouth, Massachusetts

0 0.25 0.5 1 Miles
1 inch = 2,000 feet



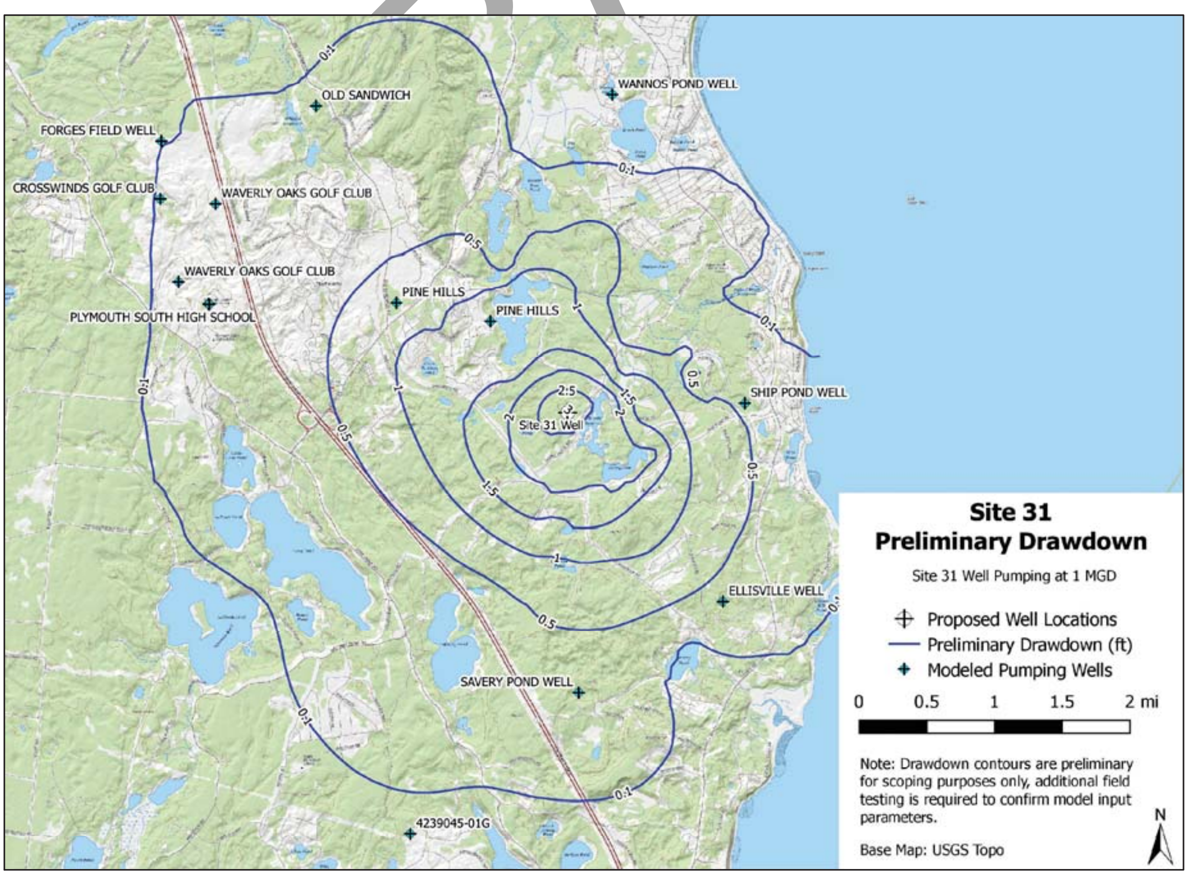
Environmental Partners GROUP
A partnership for engineering solutions.

Figure 5-25
Plymouth, Massachusetts



Environmental Partners GROUP
A partnership for engineering solutions.

Figure 5-26: Site Locus
Site #31
Plymouth, Massachusetts



Environmental Partners GROUP
A partnership for engineering solutions.

Figure 5-27
Plymouth, Massachusetts

Figure 5-28: Site Map Site
#57 Indian Brook Site
Plymouth, Massachusetts

0 0.125 0.25 0.5 Miles

1 inch = 1,000 feet

Figure 5-29 - Entergy Site Map
Plymouth, Massachusetts

1 in = 1,000 feet

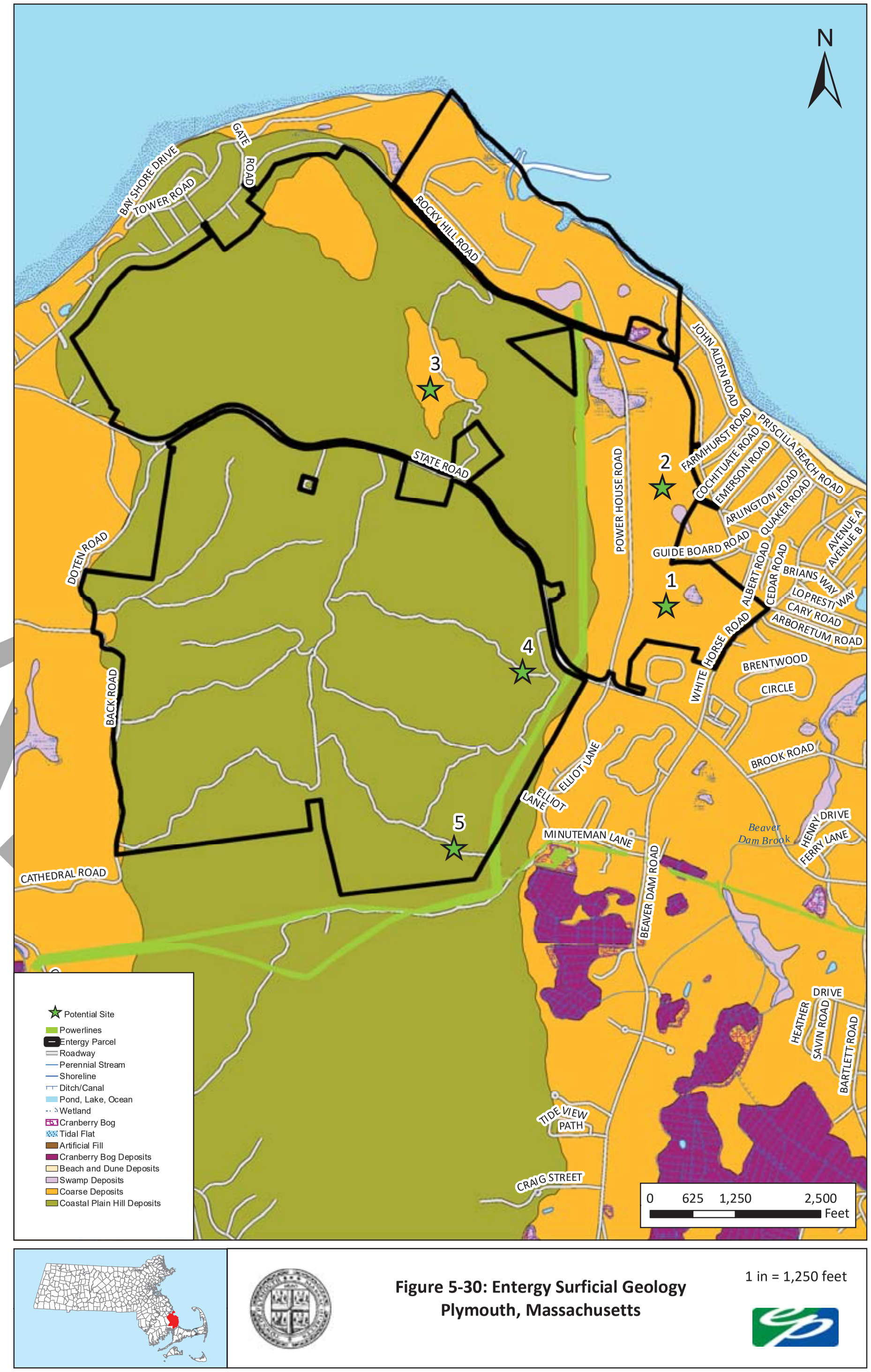


Figure 5-30: Entergy Surficial Geology
Plymouth, Massachusetts

1 in = 1,250 feet

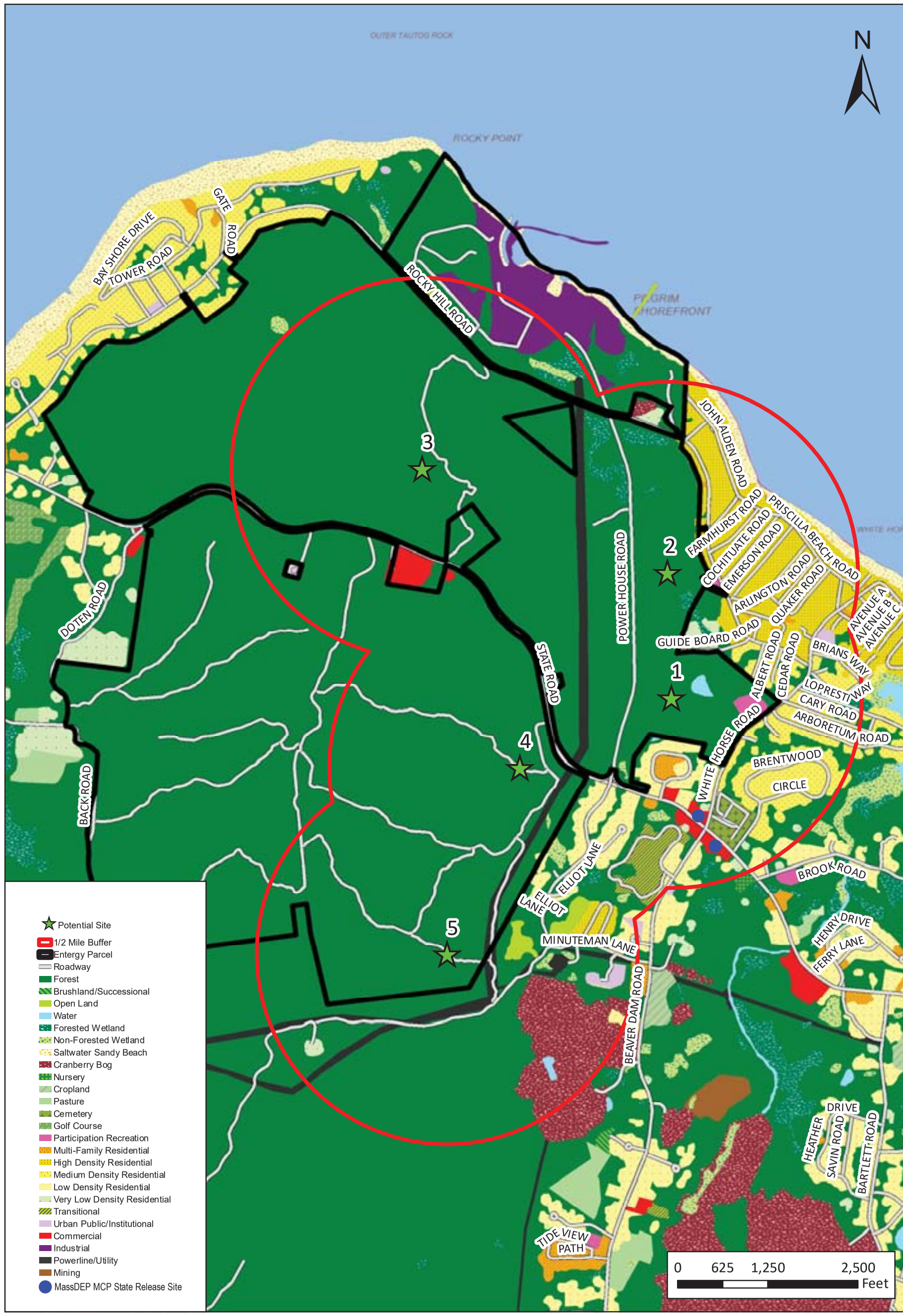


Figure 5-31: Entergy Land Use
Plymouth, Massachusetts

1 in = 1,250 feet

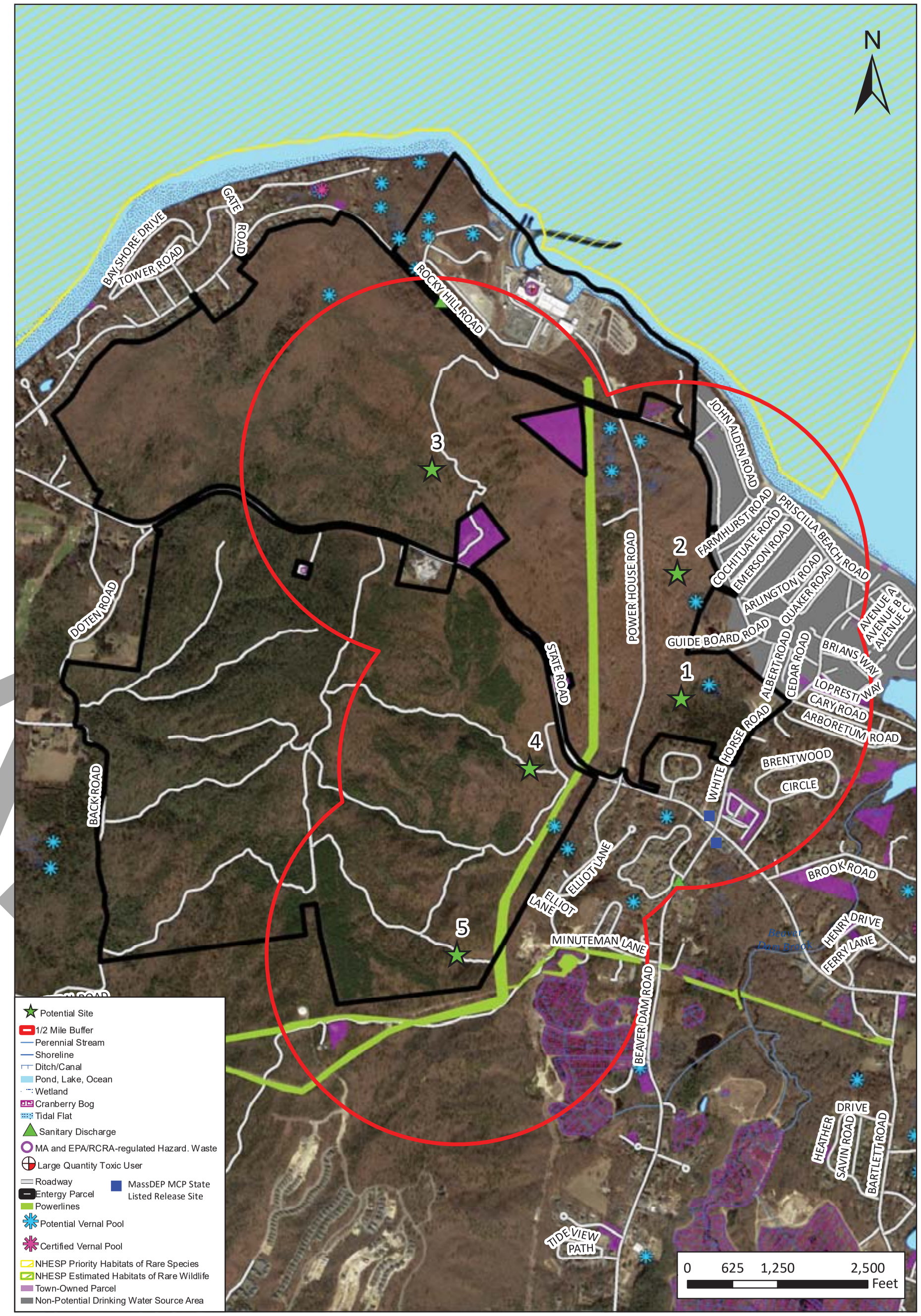


Figure 5-32 - Entergy Environmental Receptors
Plymouth, Massachusetts

1 in = 1,250 feet

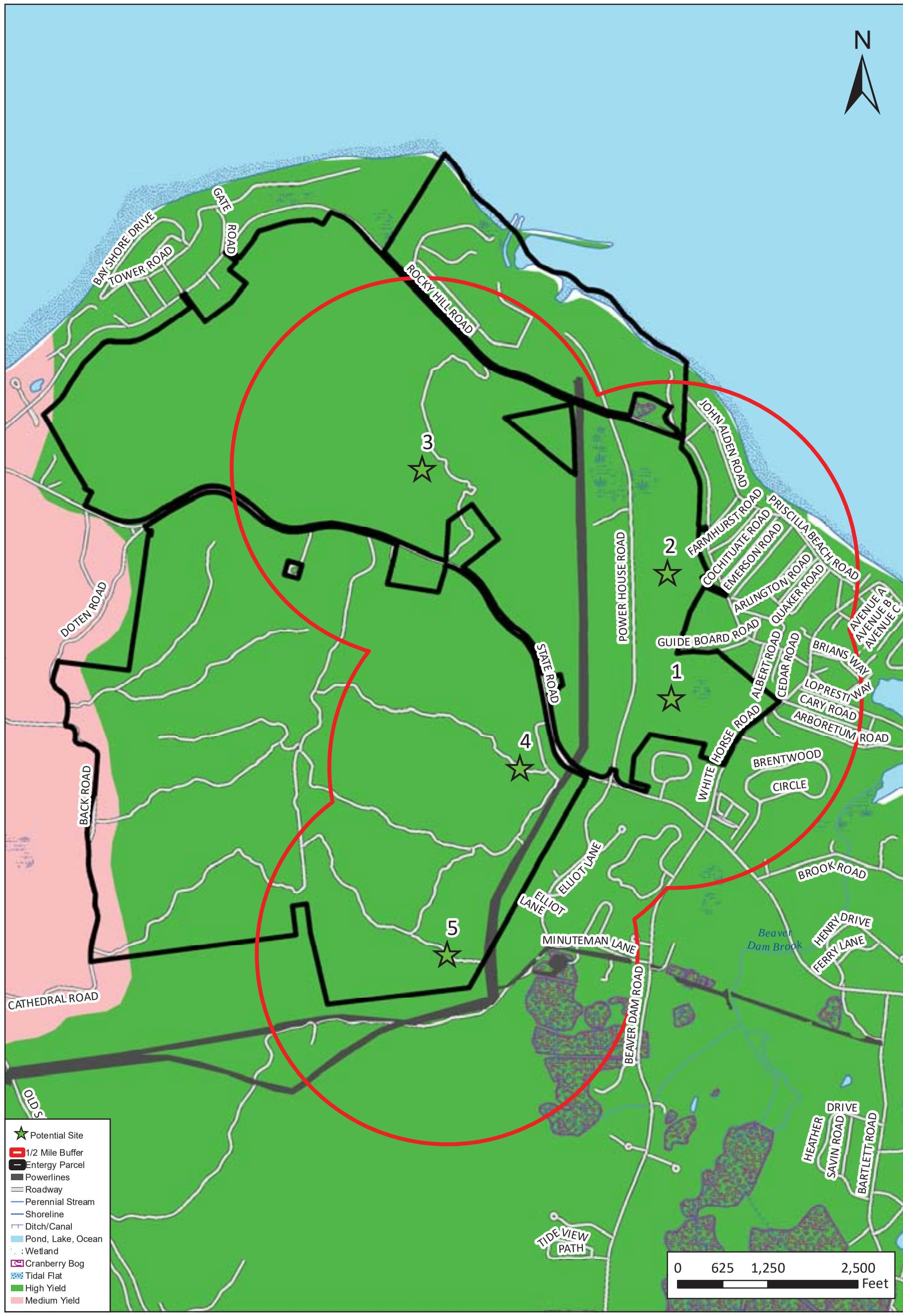


Figure 5-33: Entergy Aquifer Zones
Plymouth, Massachusetts

1 in = 1,250 feet

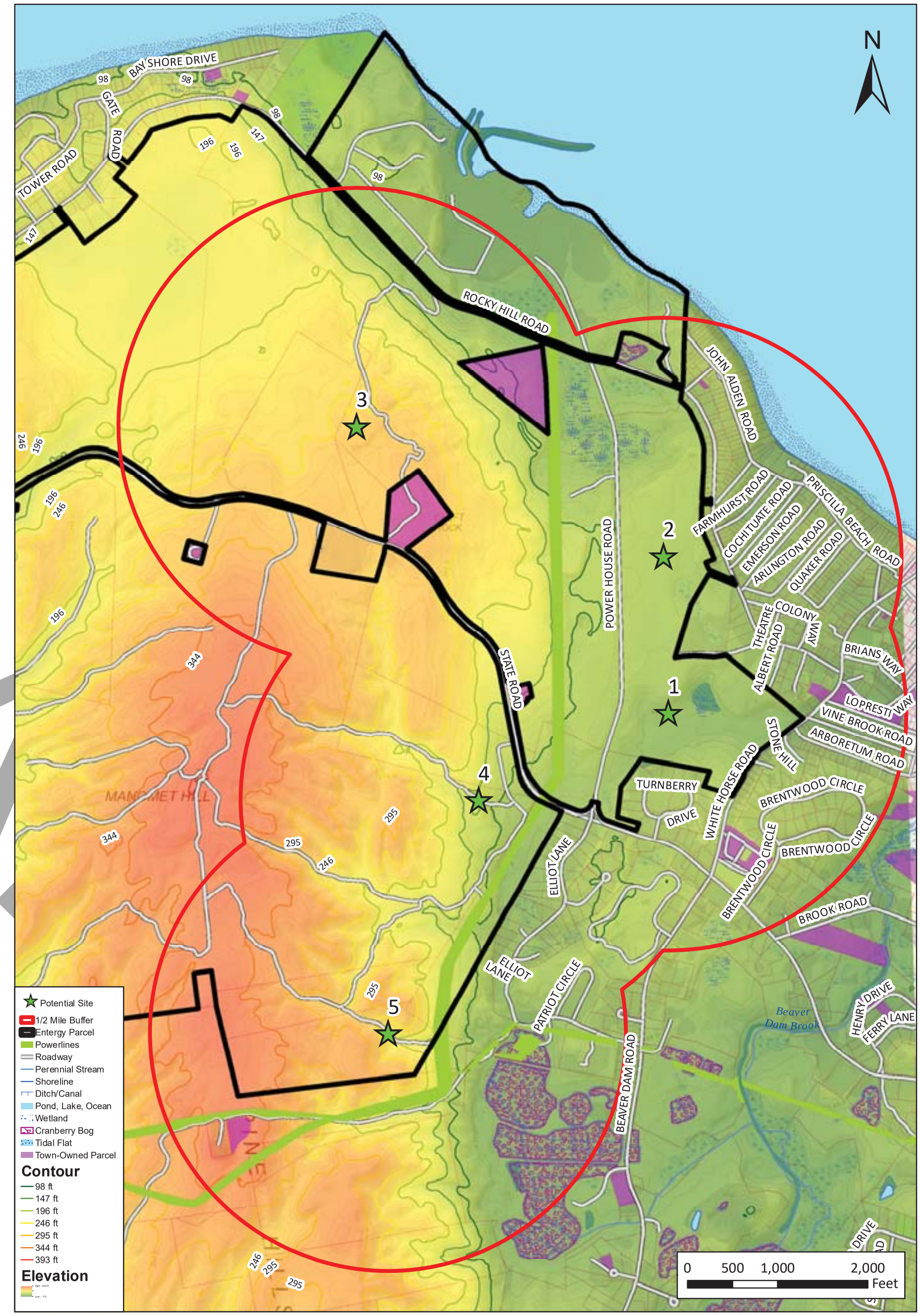
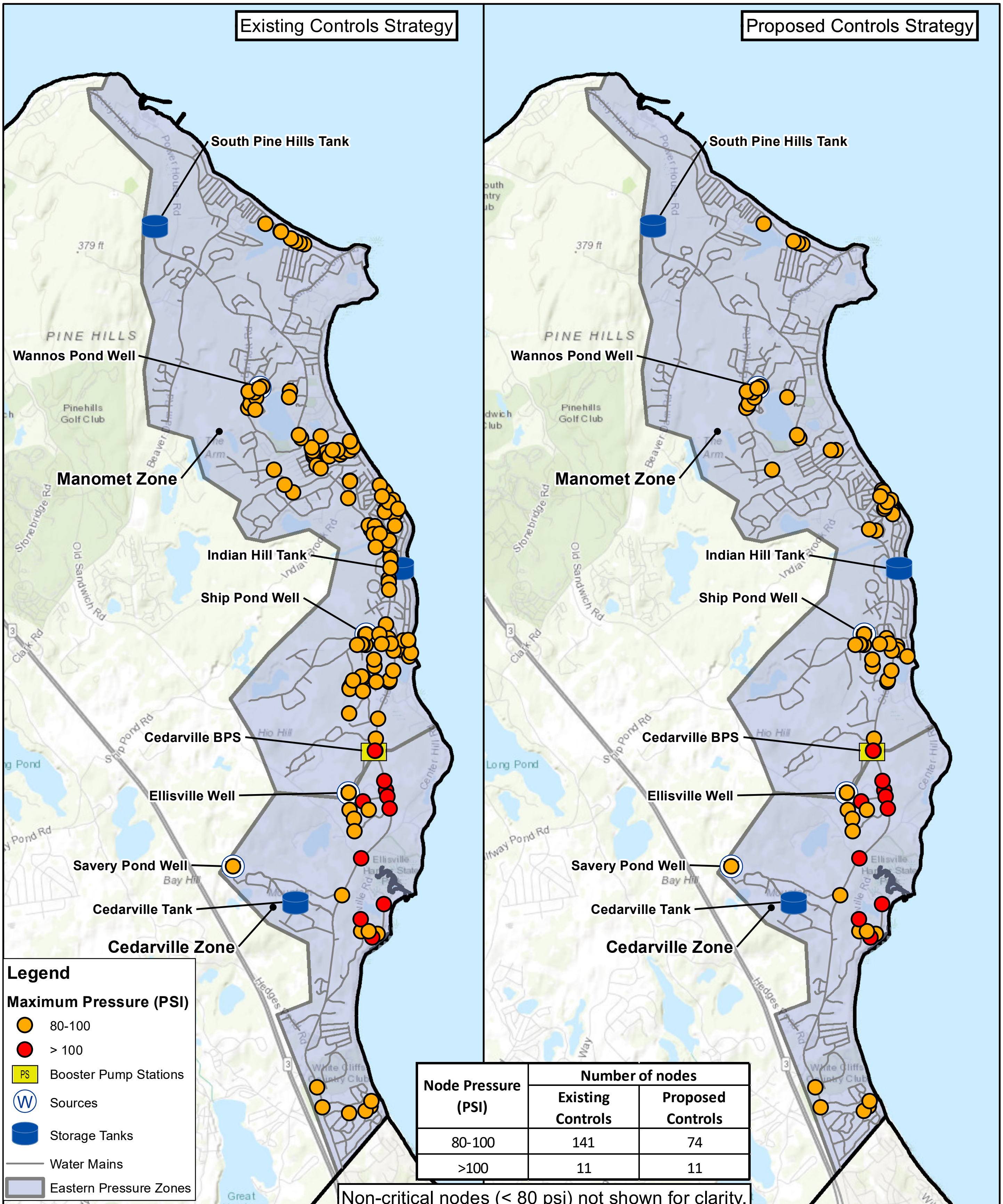


Figure 5-34 - Entergy Elevation Map
Plymouth, Massachusetts

1 in = 1,000 feet



Node Pressure (PSI)	Number of nodes	
	Existing Controls	Proposed Controls
80-100	141	74
>100	11	11

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

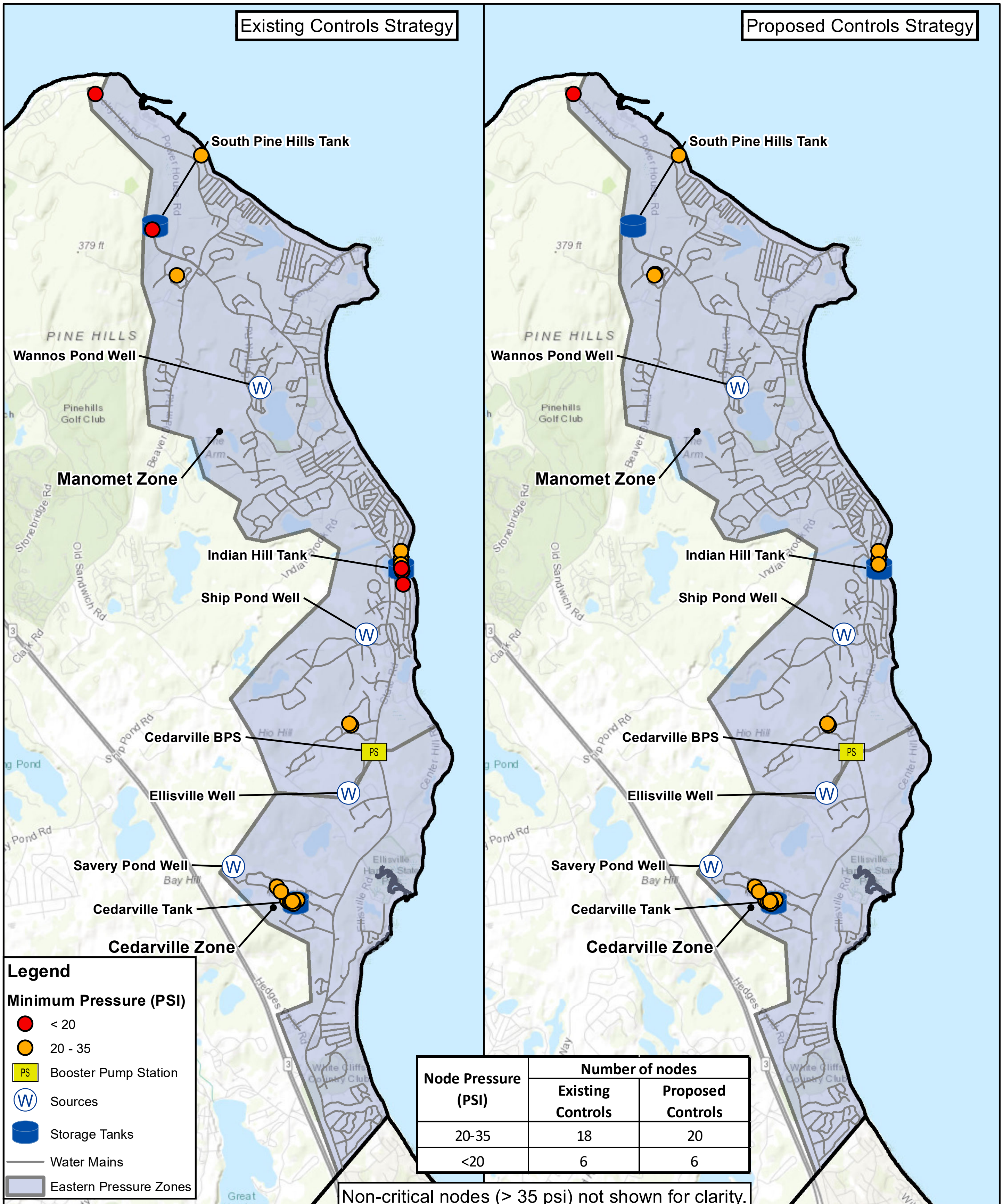
0 3,250 6,500 13,000 Feet

1 in = 6,500 feet

Environmental Partners GROUP
A partnership for engineering solutions.

Figure 7-1: Eastern Pressure Zones ADD Maximum Pressures

November 2019



Node Pressure (PSI)	Number of nodes	
	Existing Controls	Proposed Controls
20-35	18	20
<20	6	6

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

0 3,250 6,500 13,000 Feet

1 in = 6,500 feet

Environmental Partners GROUP
A partnership for engineering solutions.

Figure 7-2:
Eastern Pressure Zones
ADD Minimum Pressures
November 2019

Figure 7-3
ADD Hydraulic Performance Comparison
Manomet Pressure Zone

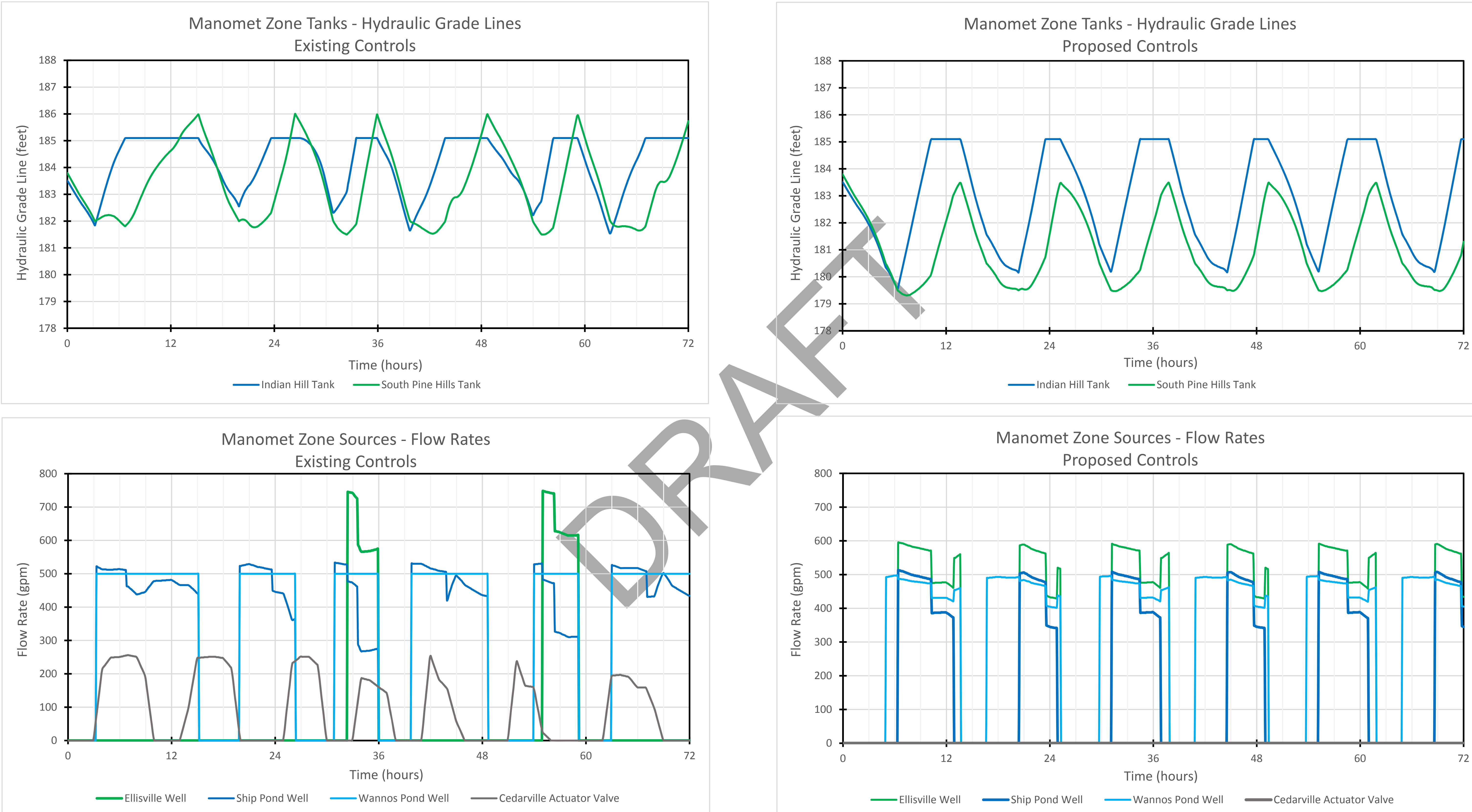
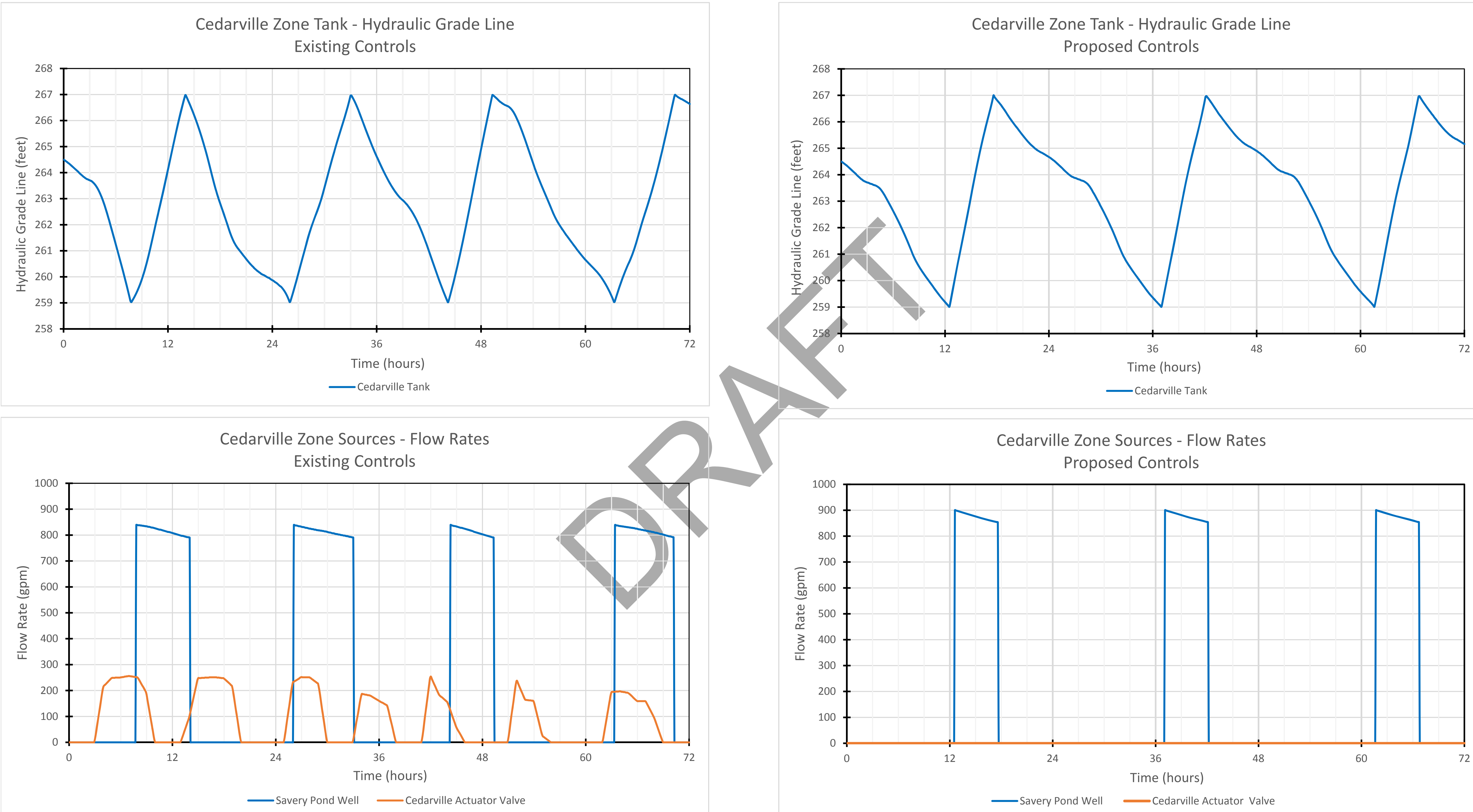
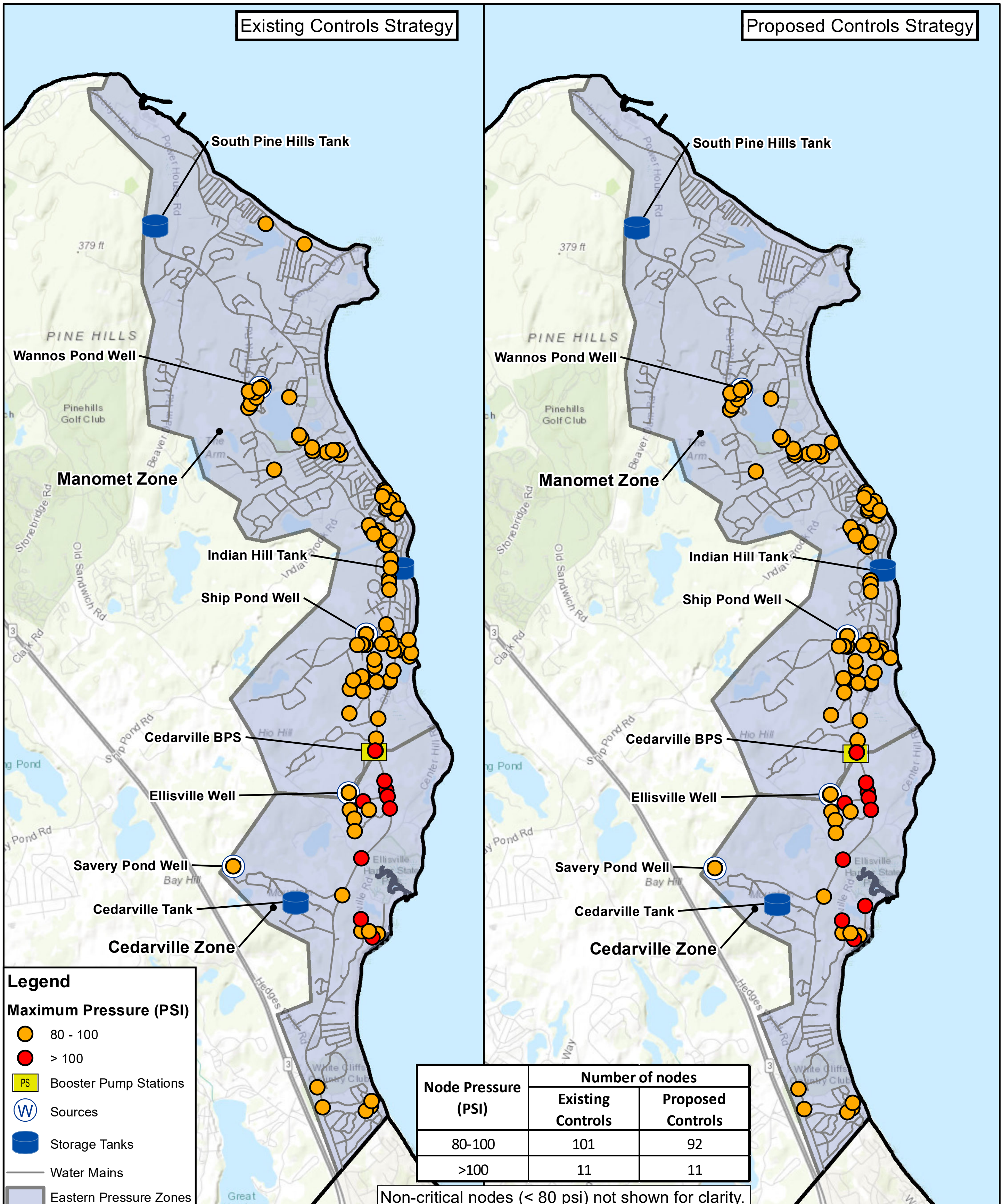


Figure 7-4
ADD Hydraulic Performance Comparison
Cedarville Pressure Zone





Node Pressure (PSI)	Number of nodes	
	Existing Controls	Proposed Controls
80-100	101	92
>100	11	11

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

0 3,250 6,500 13,000 Feet

1 in = 6,500 feet

Environmental Partners GROUP

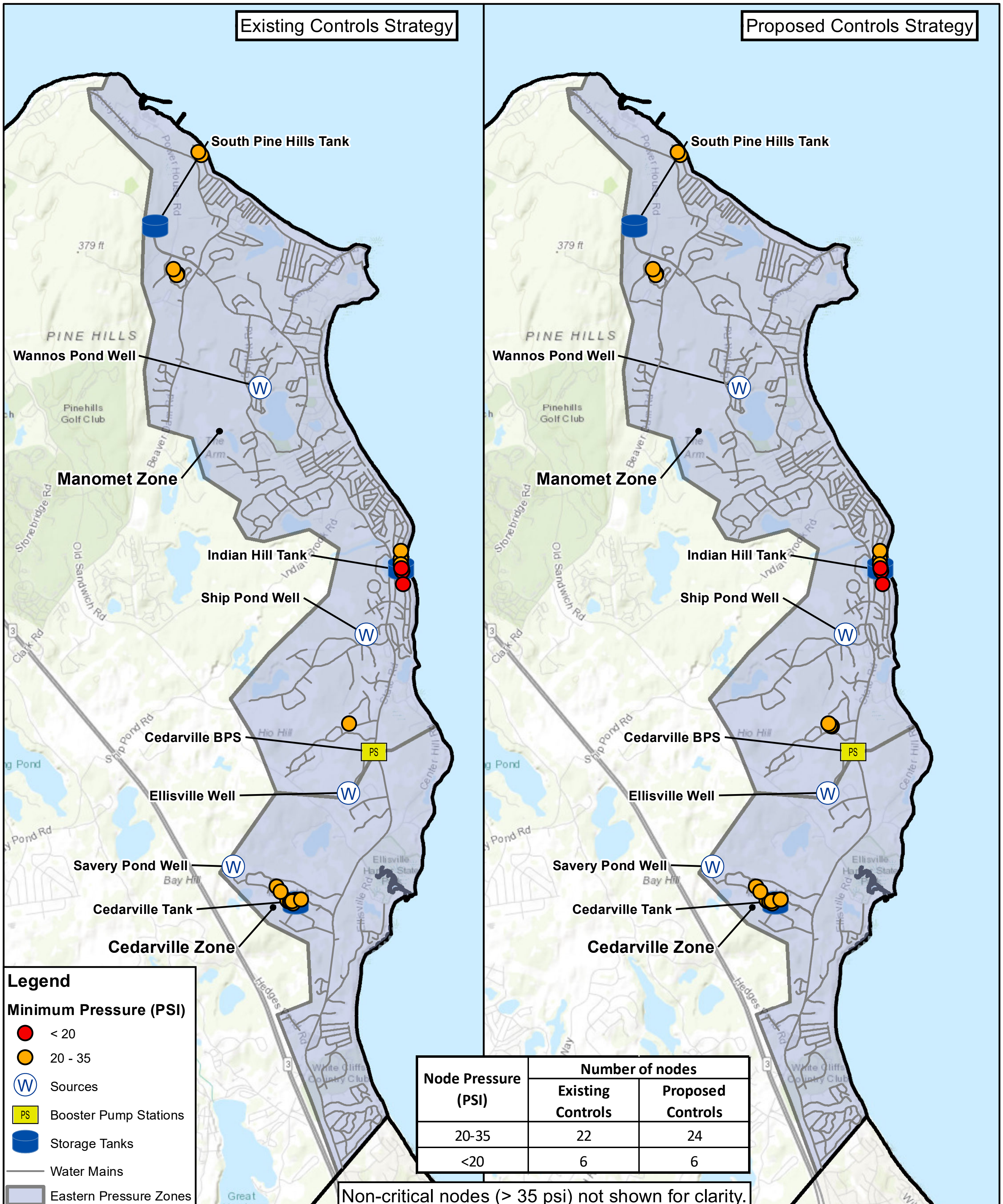
A partnership for engineering solutions.

Figure 7-5:

Eastern Pressure Zones

MDD Maximum Pressures

November 2019



Node Pressure (PSI)	Number of nodes	
	Existing Controls	Proposed Controls
20-35	22	24
<20	6	6

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

0 3,250 6,500 13,000 Feet

1 in = 6,500 feet

Environmental Partners GROUP
A partnership for engineering solutions.

Figure 7-6:
Eastern Pressure Zones MDD Minimum Pressures
November 2019

Figure 7-7
MDD Hydraulic Performance Comparison
Manomet Pressure Zone

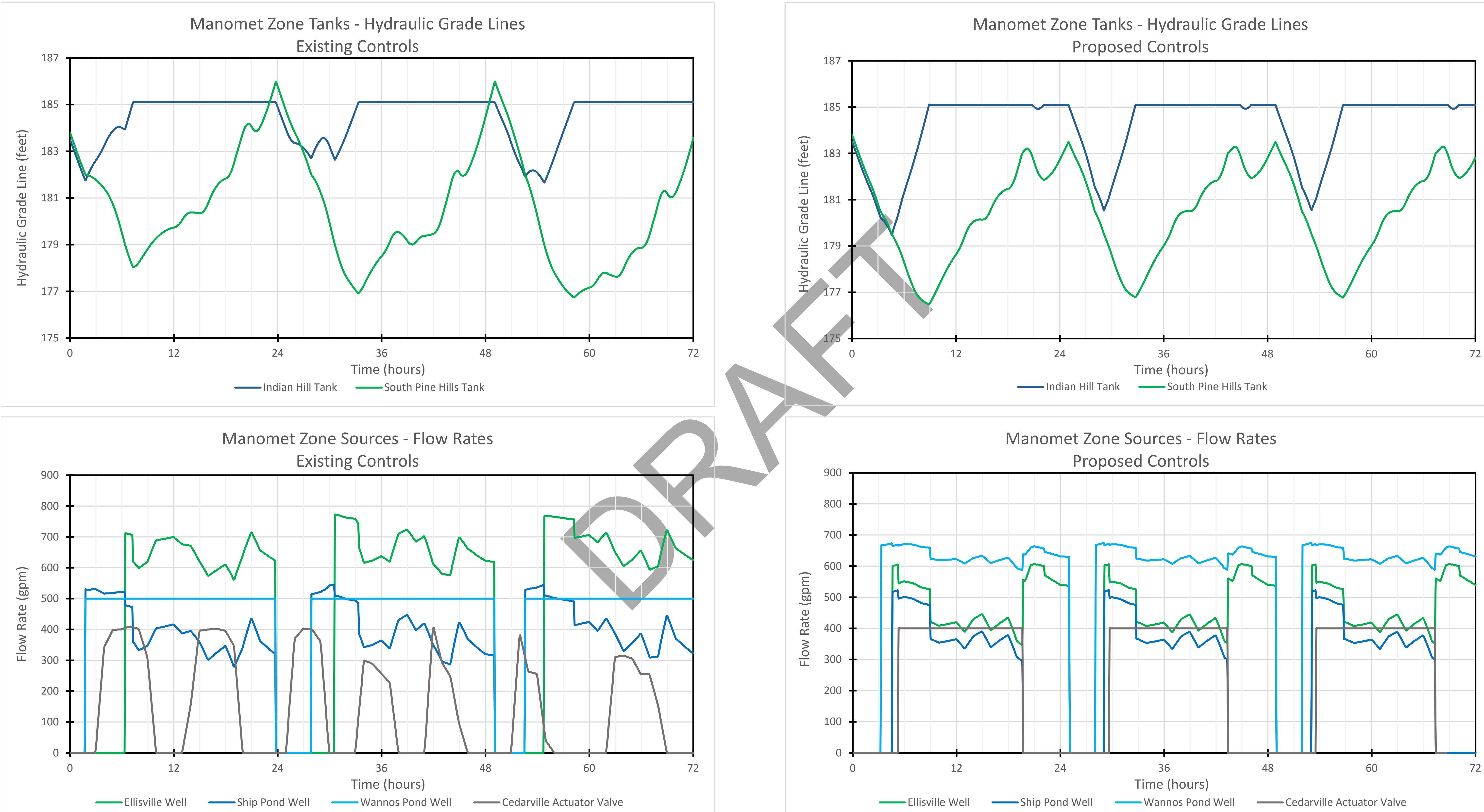
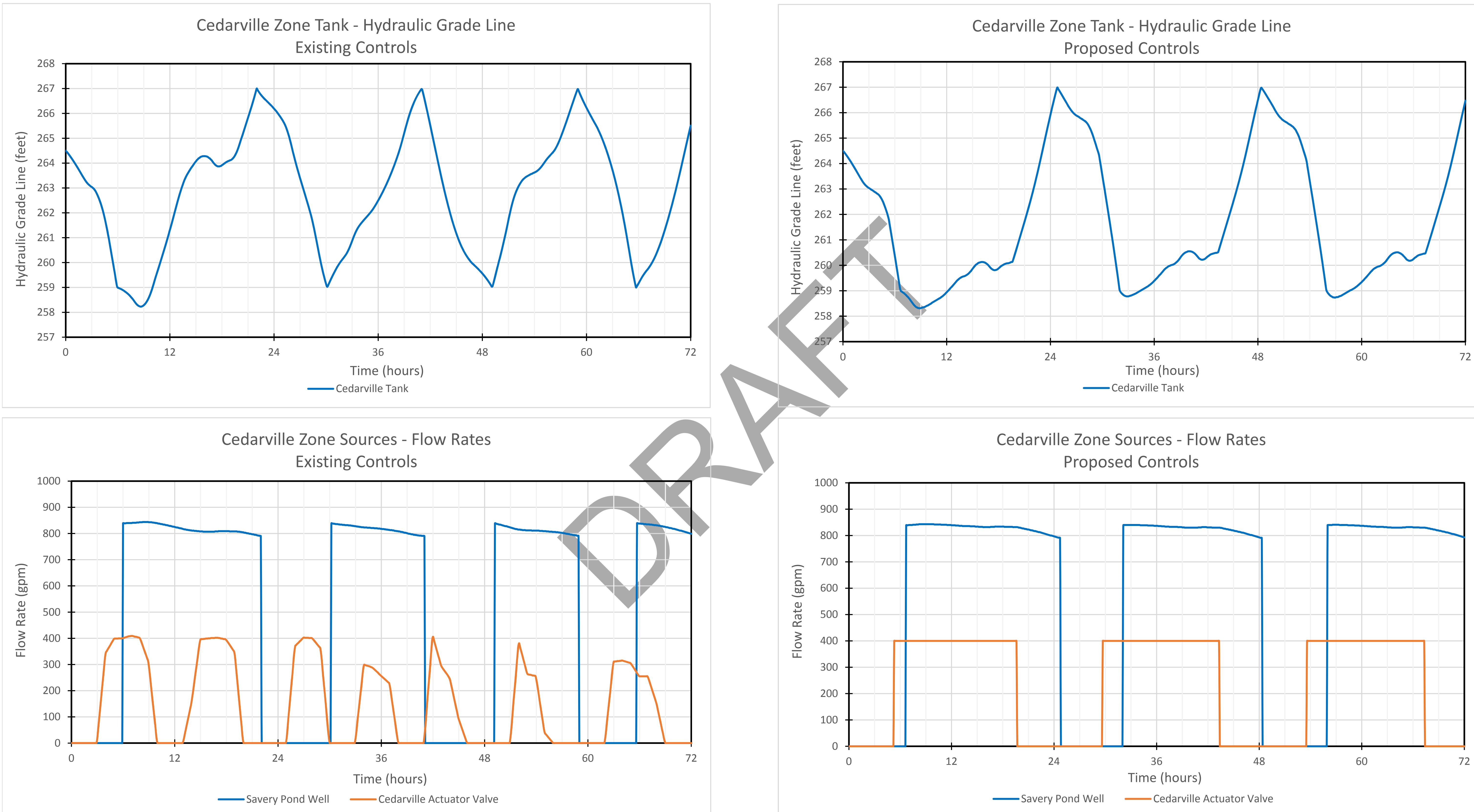
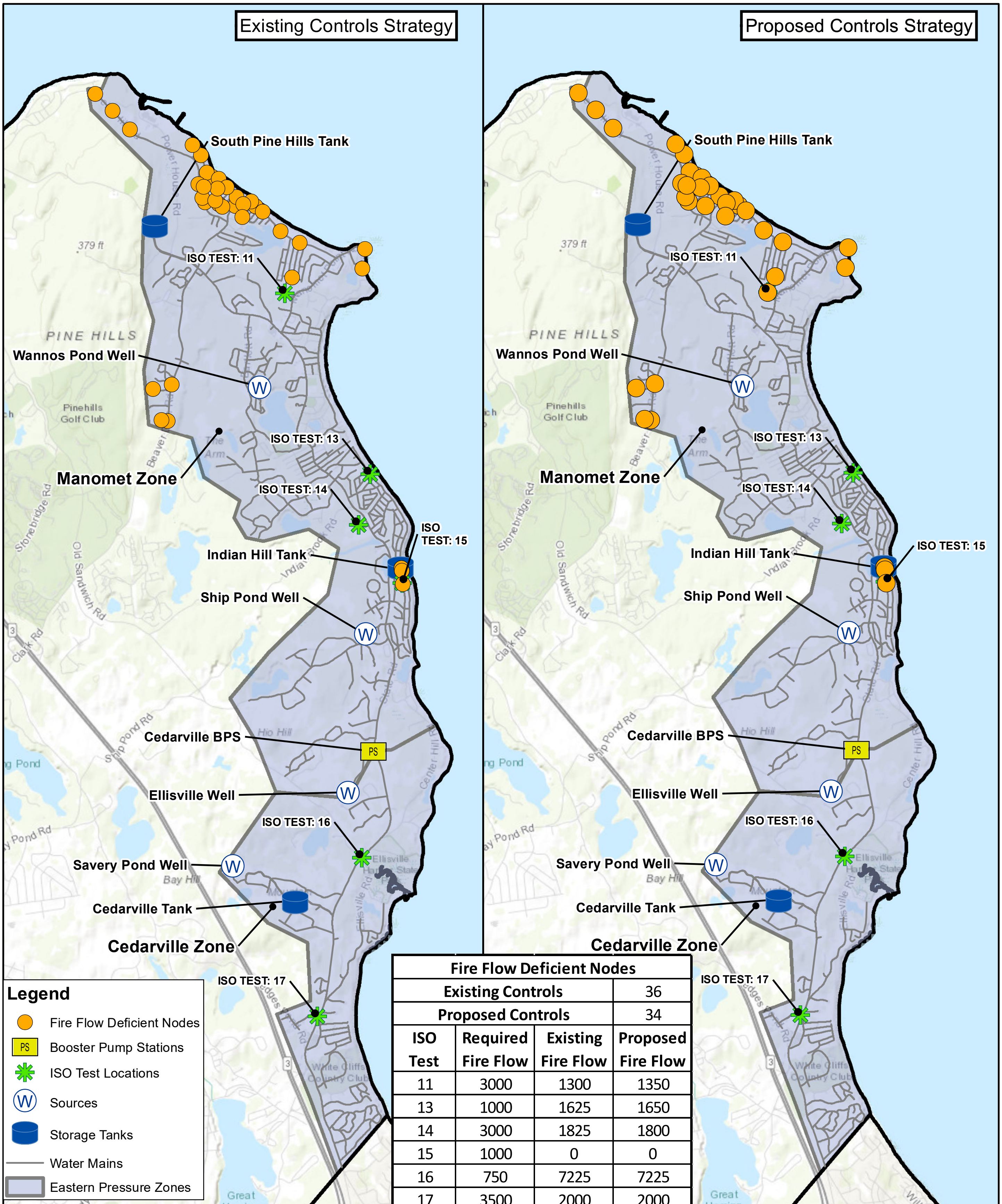


Figure 7-8
MDD Hydraulic Performance Comparison
Cedarville Pressure Zone





Fire Flow Deficient Nodes			
Existing Controls			36
Proposed Controls			34
ISO Test	Required Fire Flow	Existing Fire Flow	Proposed Fire Flow
11	3000	1300	1350
13	1000	1625	1650
14	3000	1825	1800
15	1000	0	0
16	750	7225	7225
17	3500	2000	2000

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

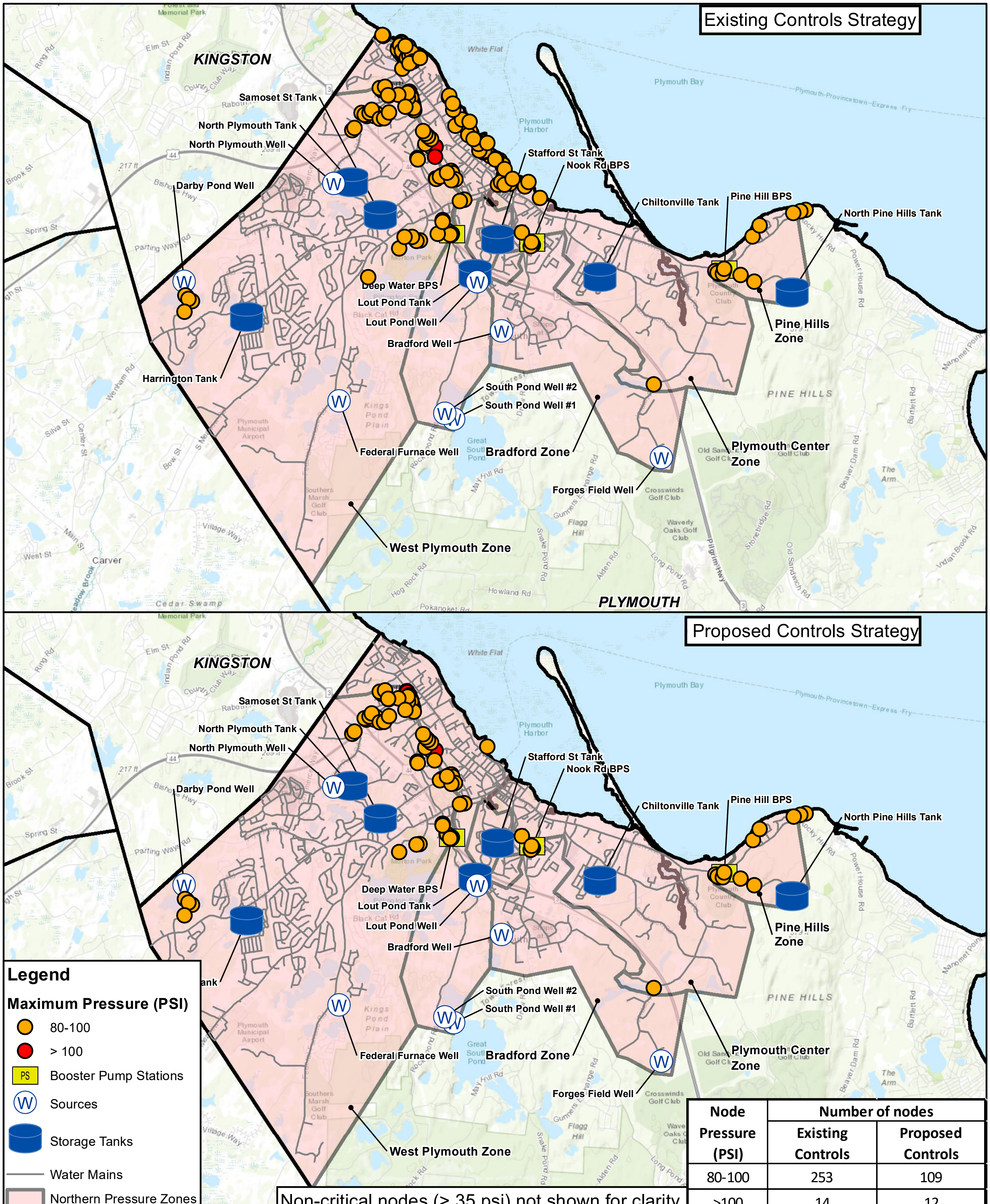
0 3,250 6,500 13,000 Feet

1 in = 6,500 feet

Environmental Partners GROUP

A partnership for engineering solutions.

Figure 7-9:
Eastern Pressure Zones Fire Flow Deficiencies
November 2019



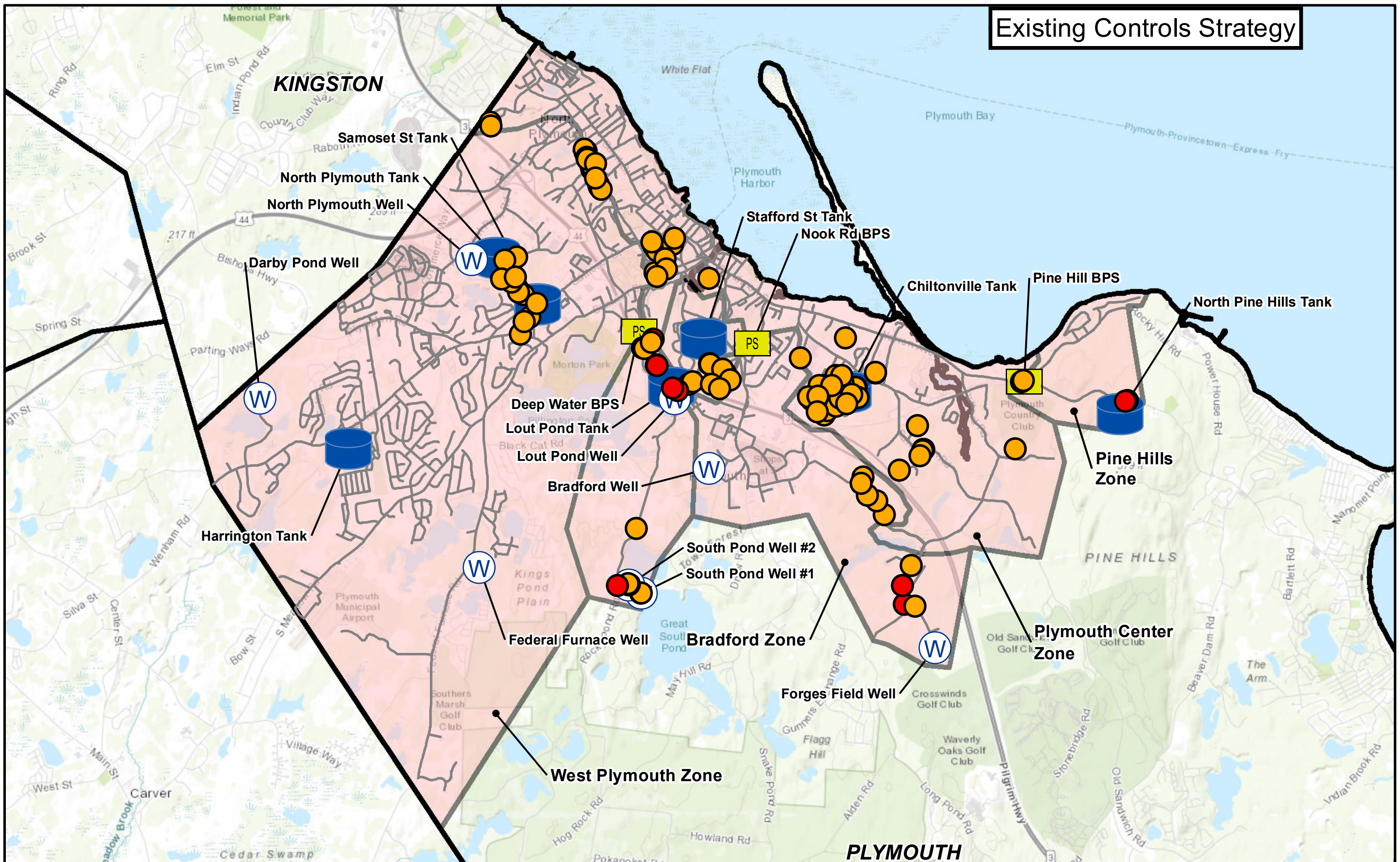
Node Pressure (PSI)	Number of nodes	
	Existing Controls	Proposed Controls
80-100	253	109
>100	14	12

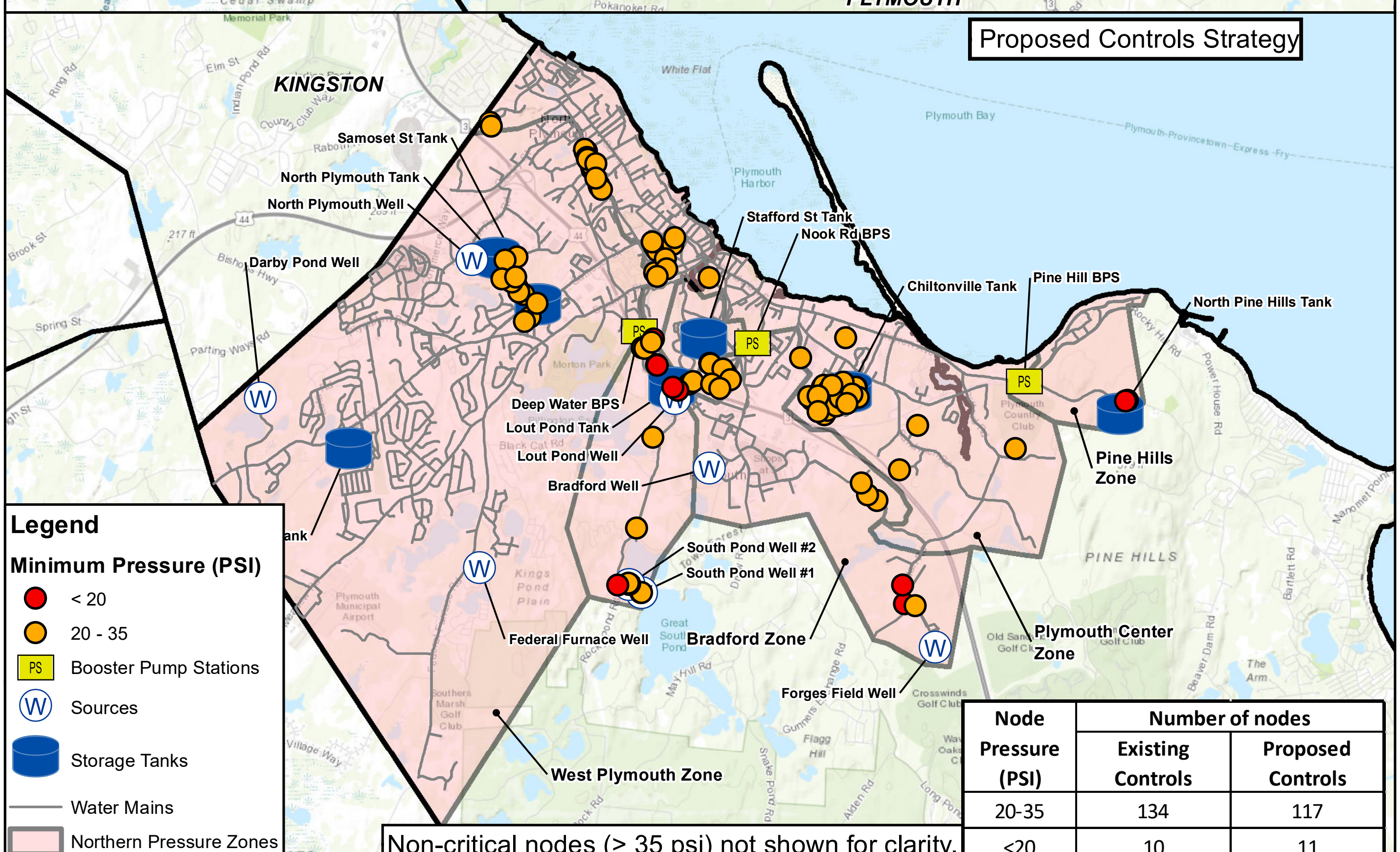
Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Environmental Partners GROUP
A partnership for engineering solutions.

Figure 7-10: Northern Pressure Zones ADD Maximum Pressures

November 2019





Node Pressure (PSI)	Number of nodes	
	Existing Controls	Proposed Controls
20-35	134	117
<20	10	11

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

0 4,500 9,000 18,000 Feet

1 in = 9,000 feet

Environmental Partners Group
A partnership for engineering solutions.

Figure 7-11:
Northern Pressure Zones ADD Minimum Pressures
November 2019

Figure 7-12
ADD Hydraulic Performance Comparison
Pine Hills Pressure Zone

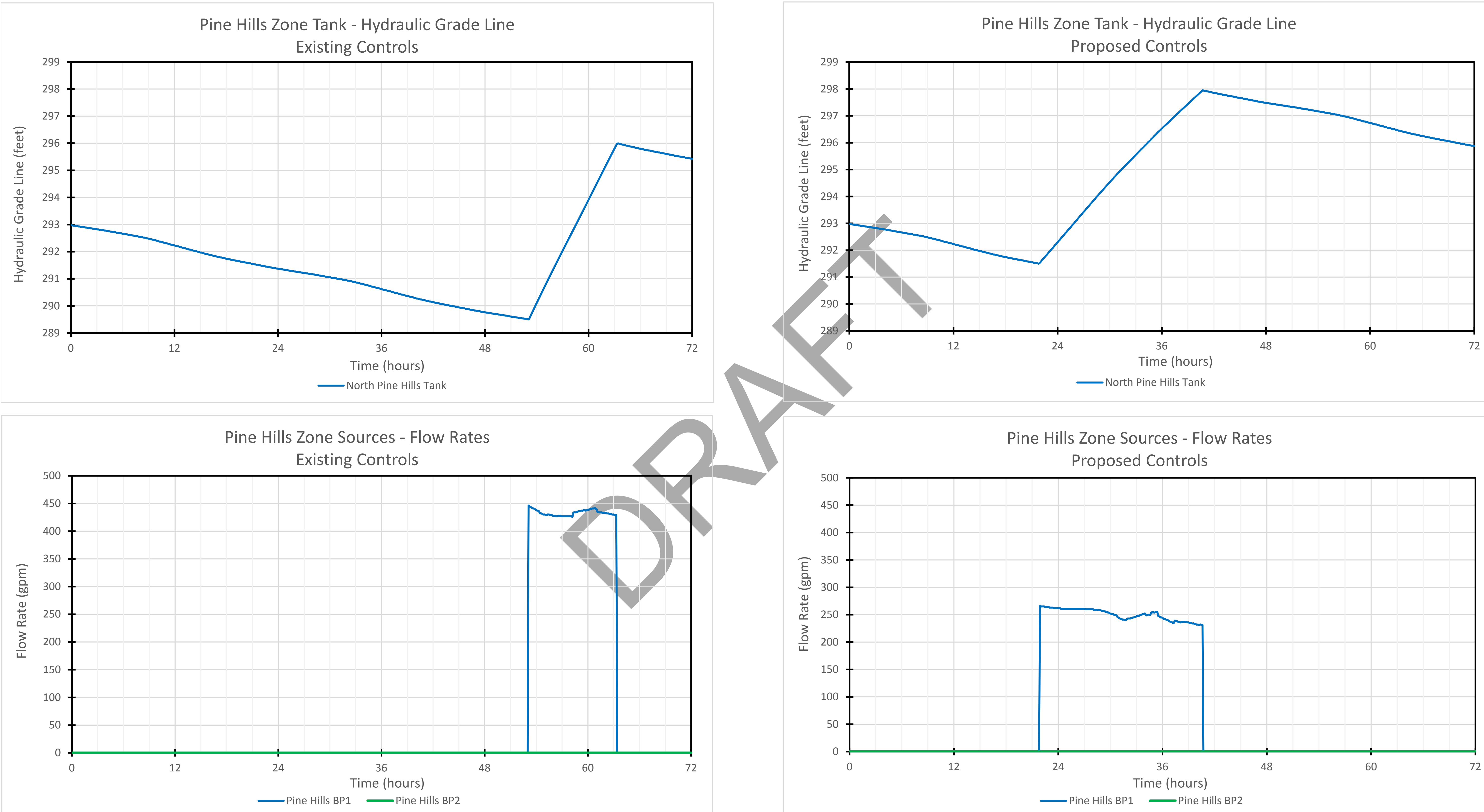


Figure 7-13
ADD Hydraulic Performance Comparison
Bradford Pressure Zone

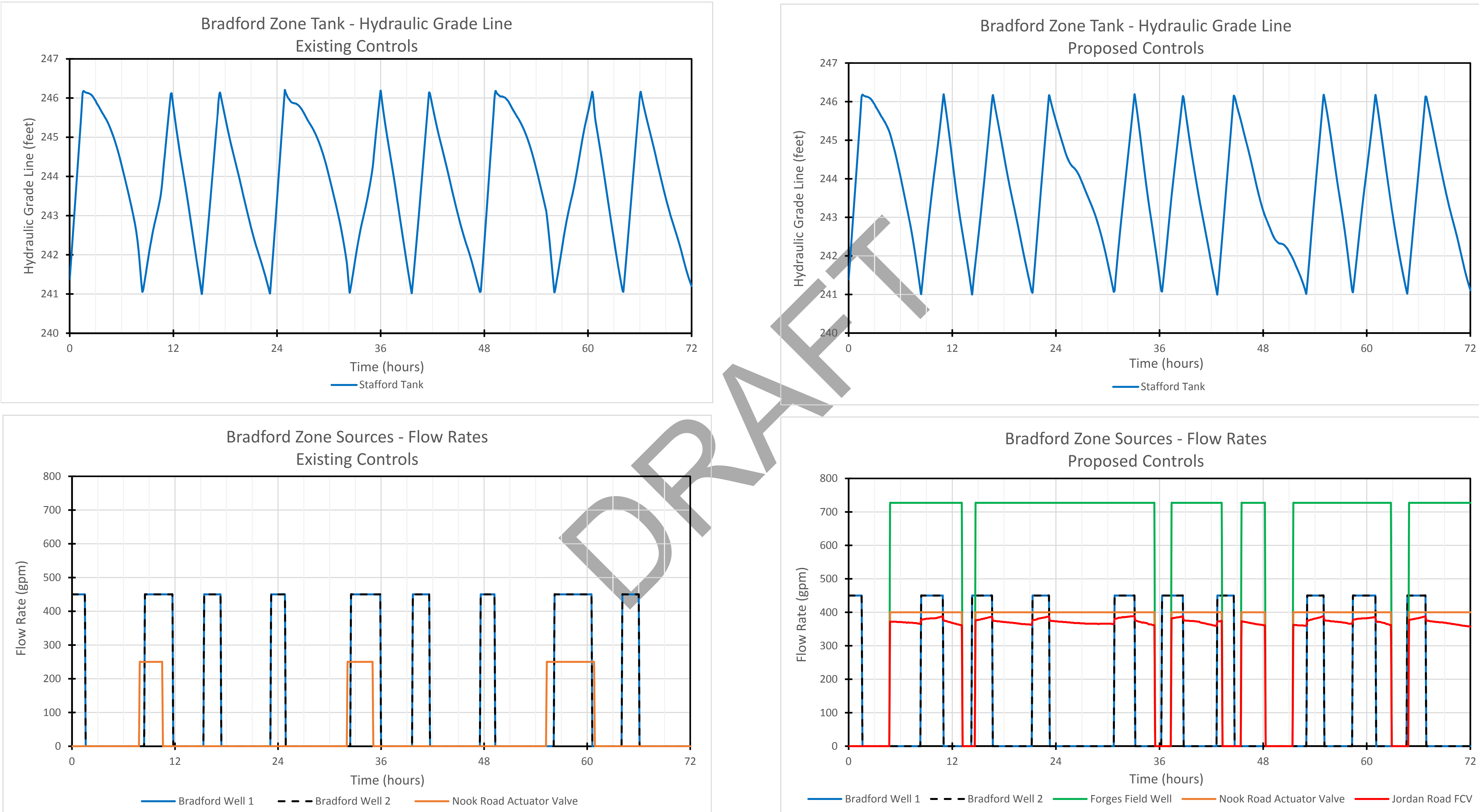


Figure 7-14
ADD Hydraulic Performance Comparison
West Plymouth Pressure Zone

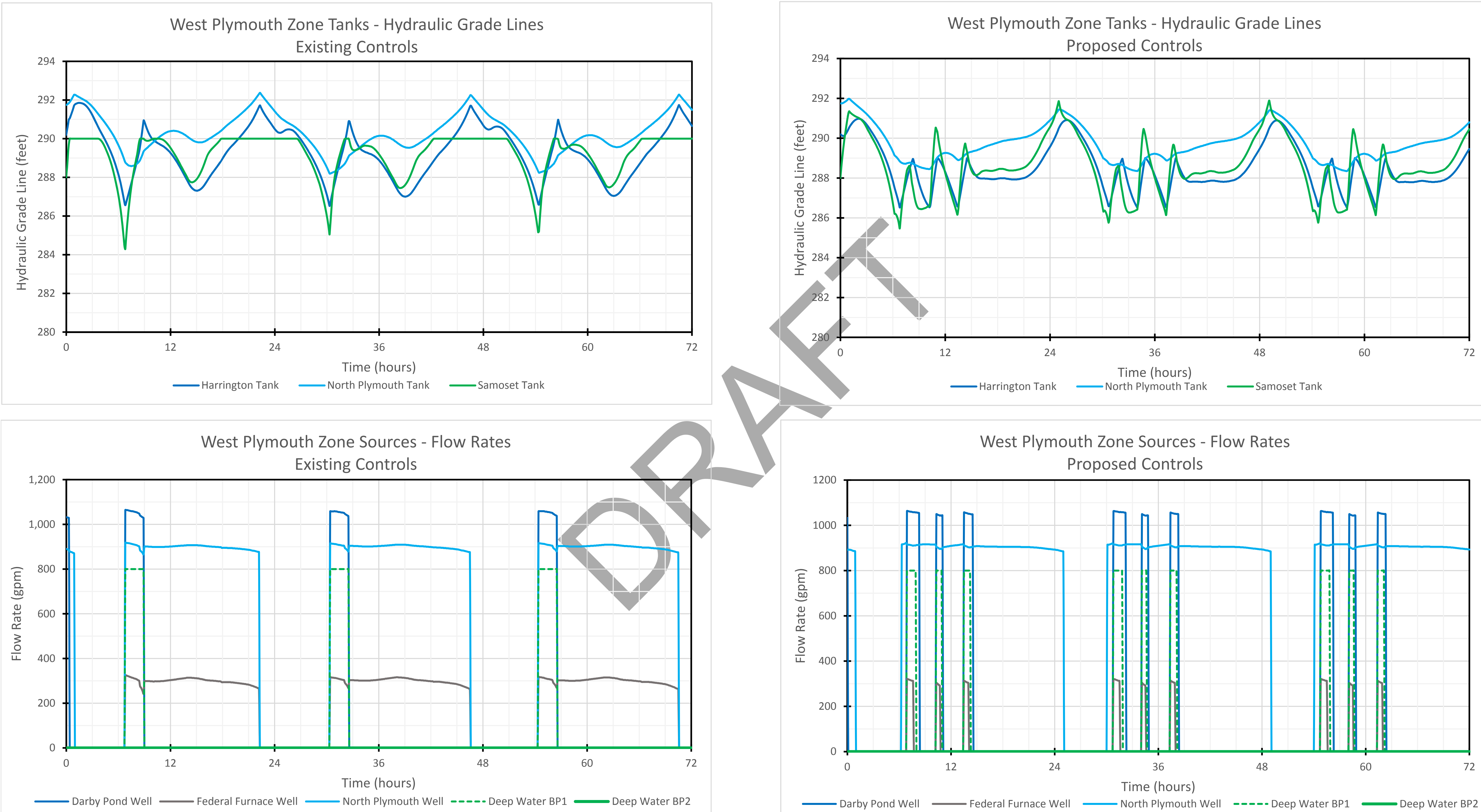
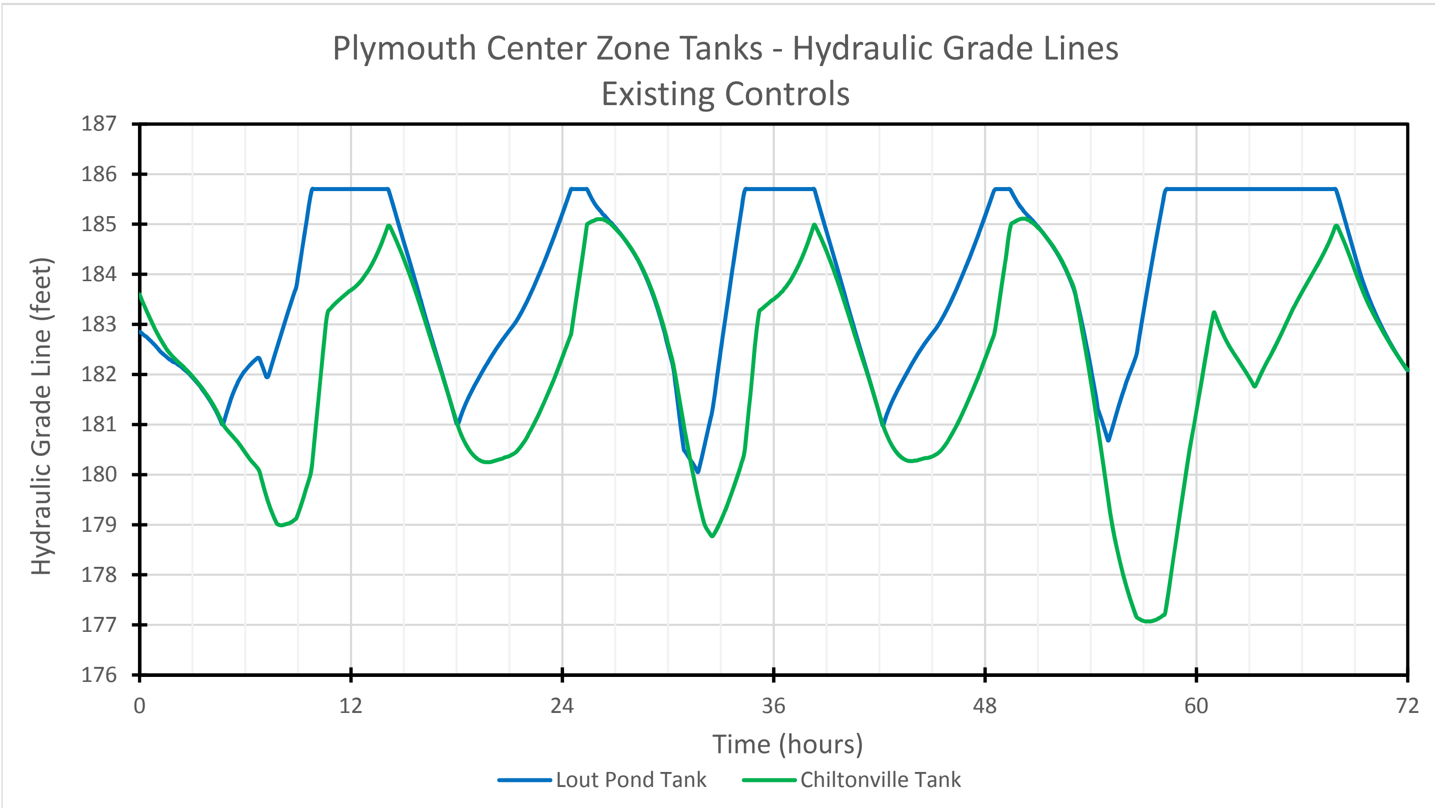
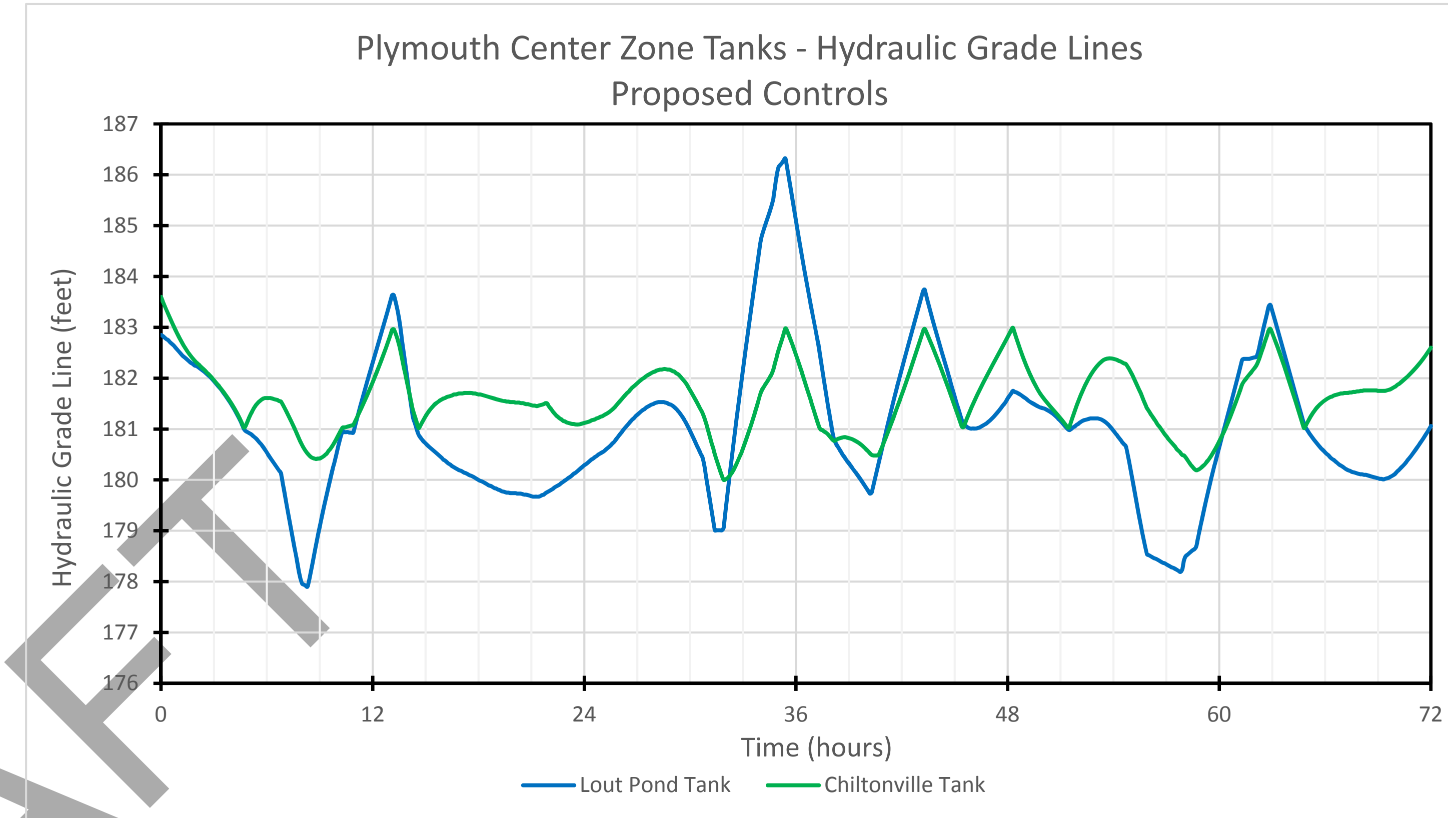
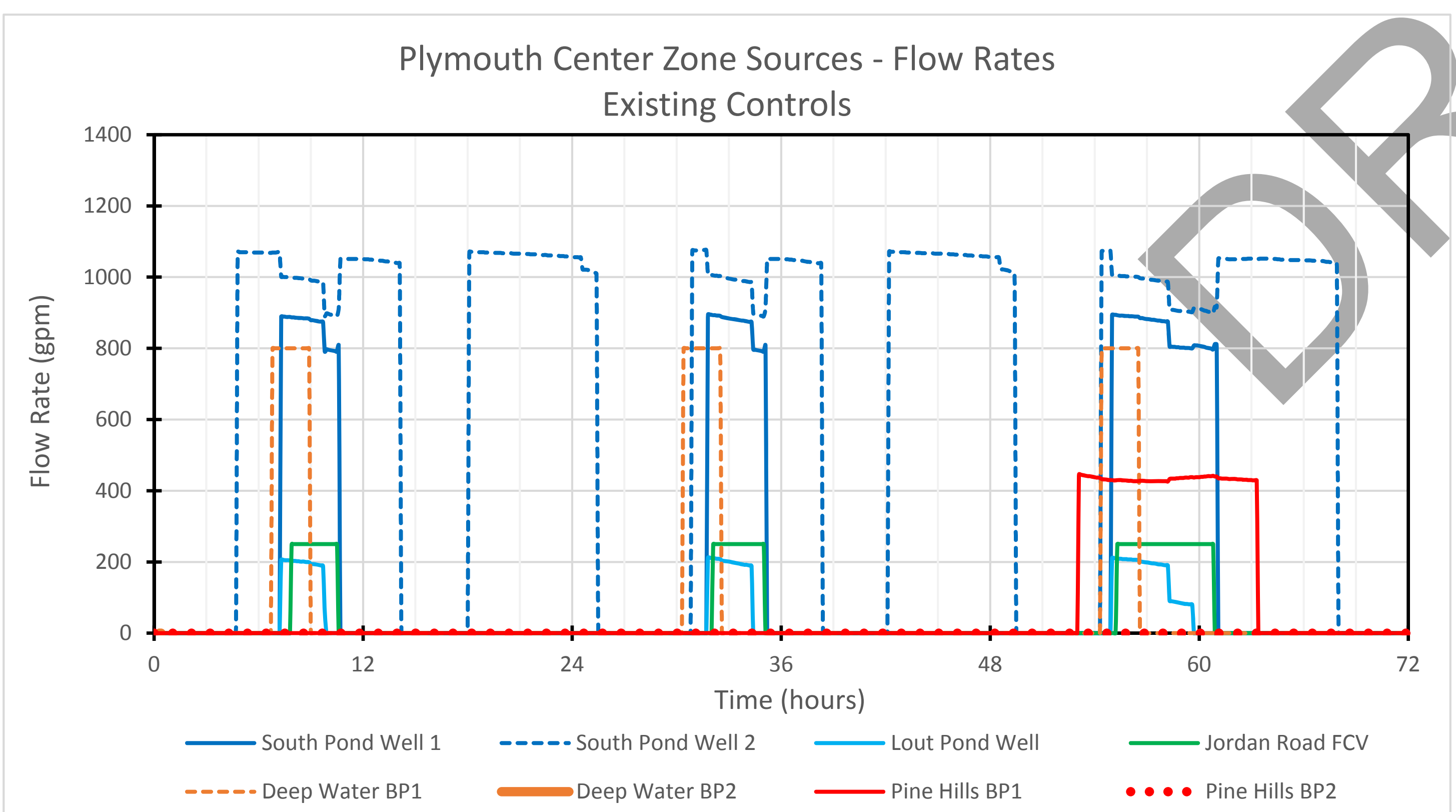
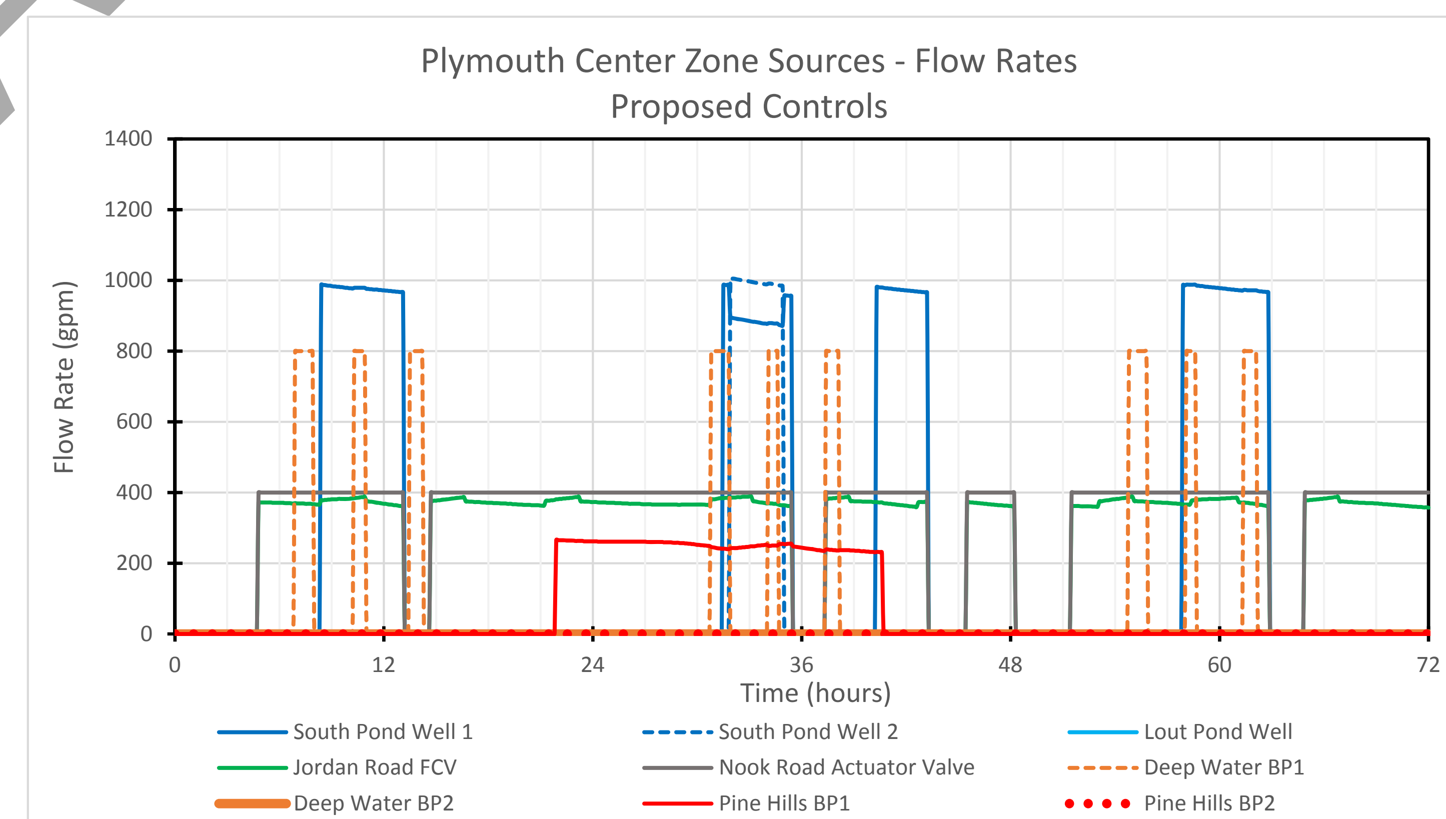


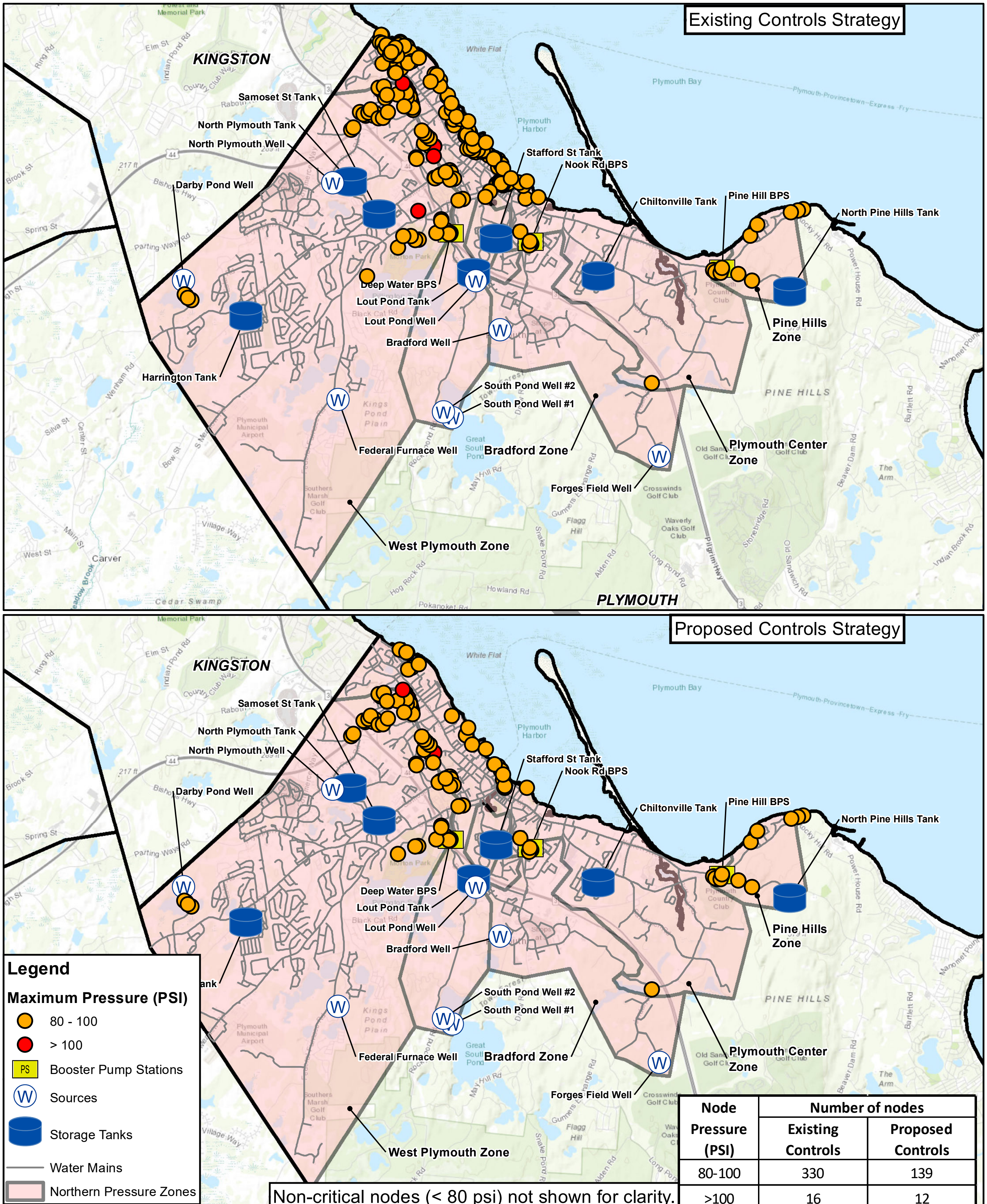
Figure 7-15
ADD Hydraulic Performance Comparison
Plymouth Center Pressure Zone











Node Pressure (PSI)	Number of nodes	
	Existing Controls	Proposed Controls
80-100	330	139
>100	16	12

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

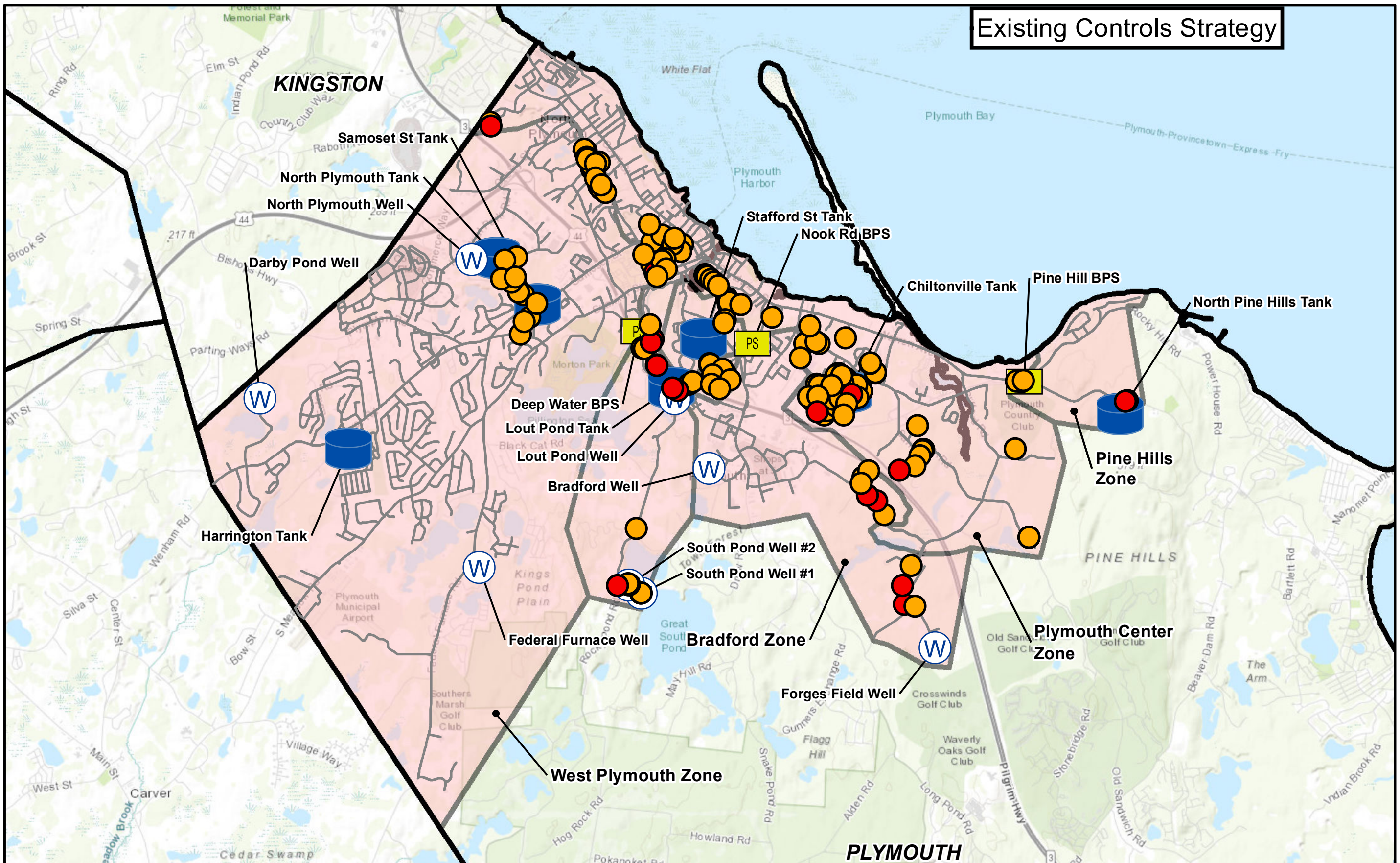
0 4,500 9,000 18,000 Feet

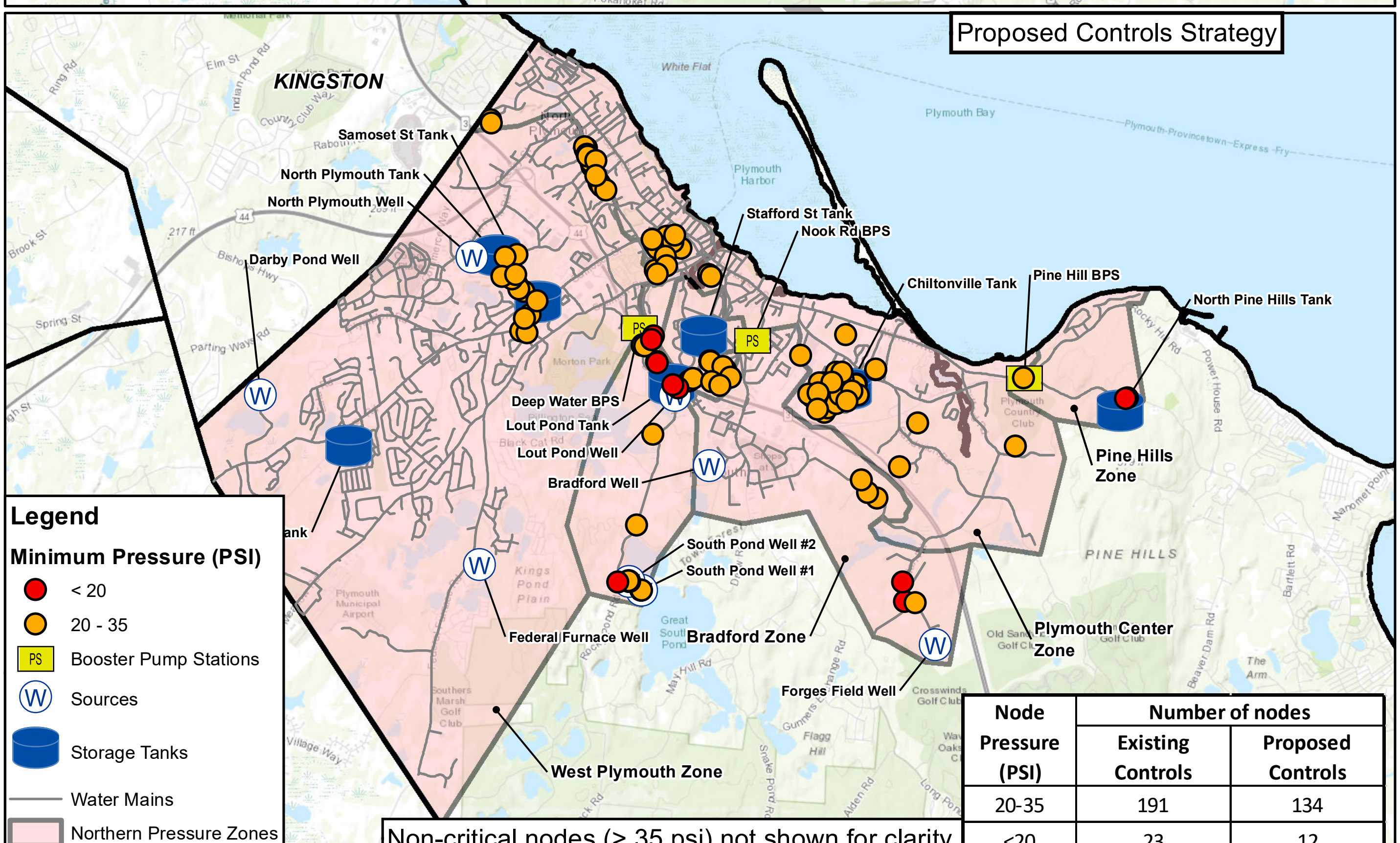
1 in = 9,000 feet

Environmental Partners GROUP

A partnership for engineering solutions.

Figure 7-16:
Northern Pressure Zones
MDD Maximum Pressures
November 2019





Node Pressure (PSI)	Number of nodes	
	Existing Controls	Proposed Controls
20-35	191	134
<20	23	12

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

0 4,500 9,000 18,000 Feet

1 in = 9,000 feet

Environmental Partners GROUP

A partnership for engineering solutions.

Figure 7-17: Northern Pressure Zones MDD Minimum Pressures

November 2019

Figure 7-18
MDD Hydraulic Performance Comparison
Pine Hills Pressure Zone

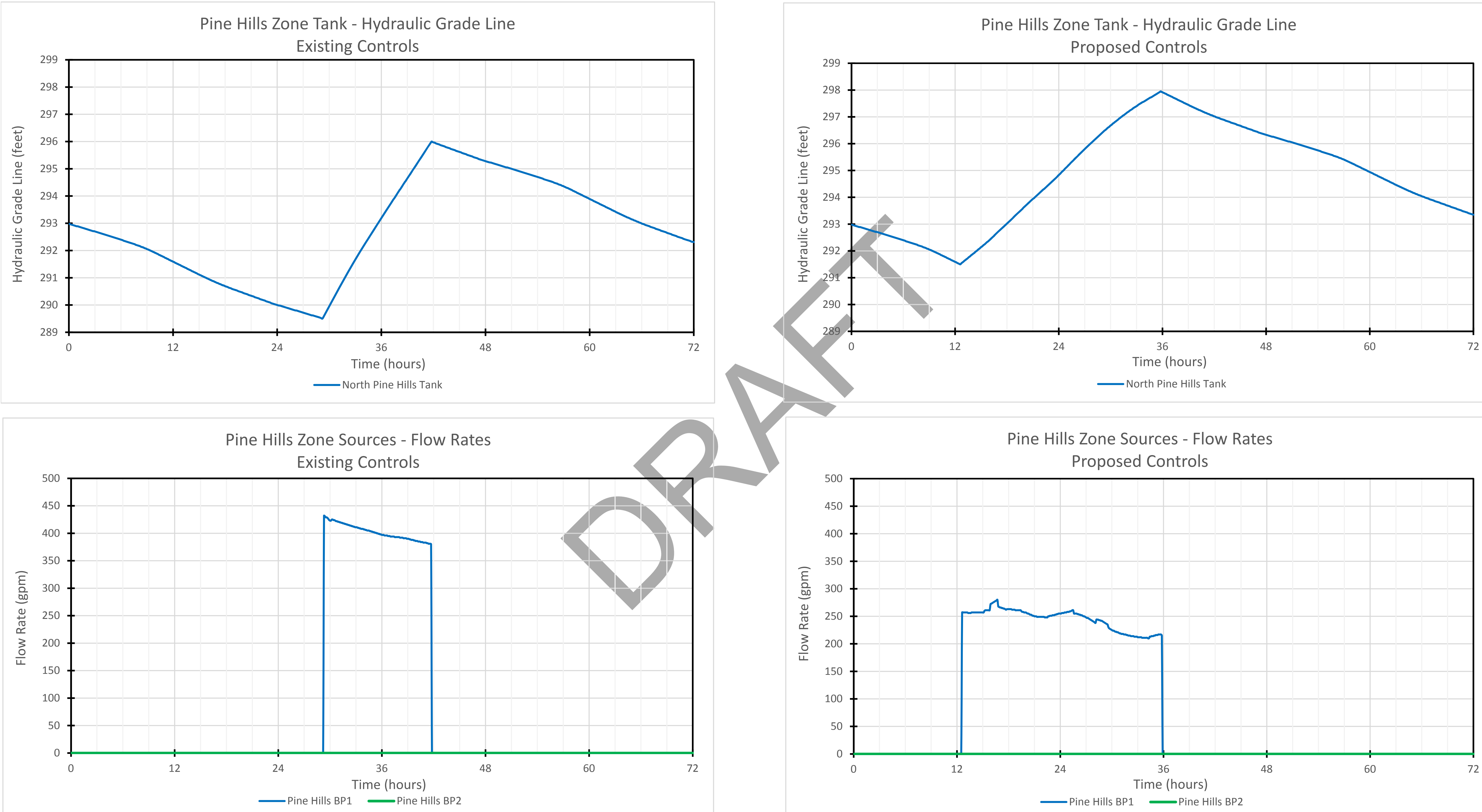
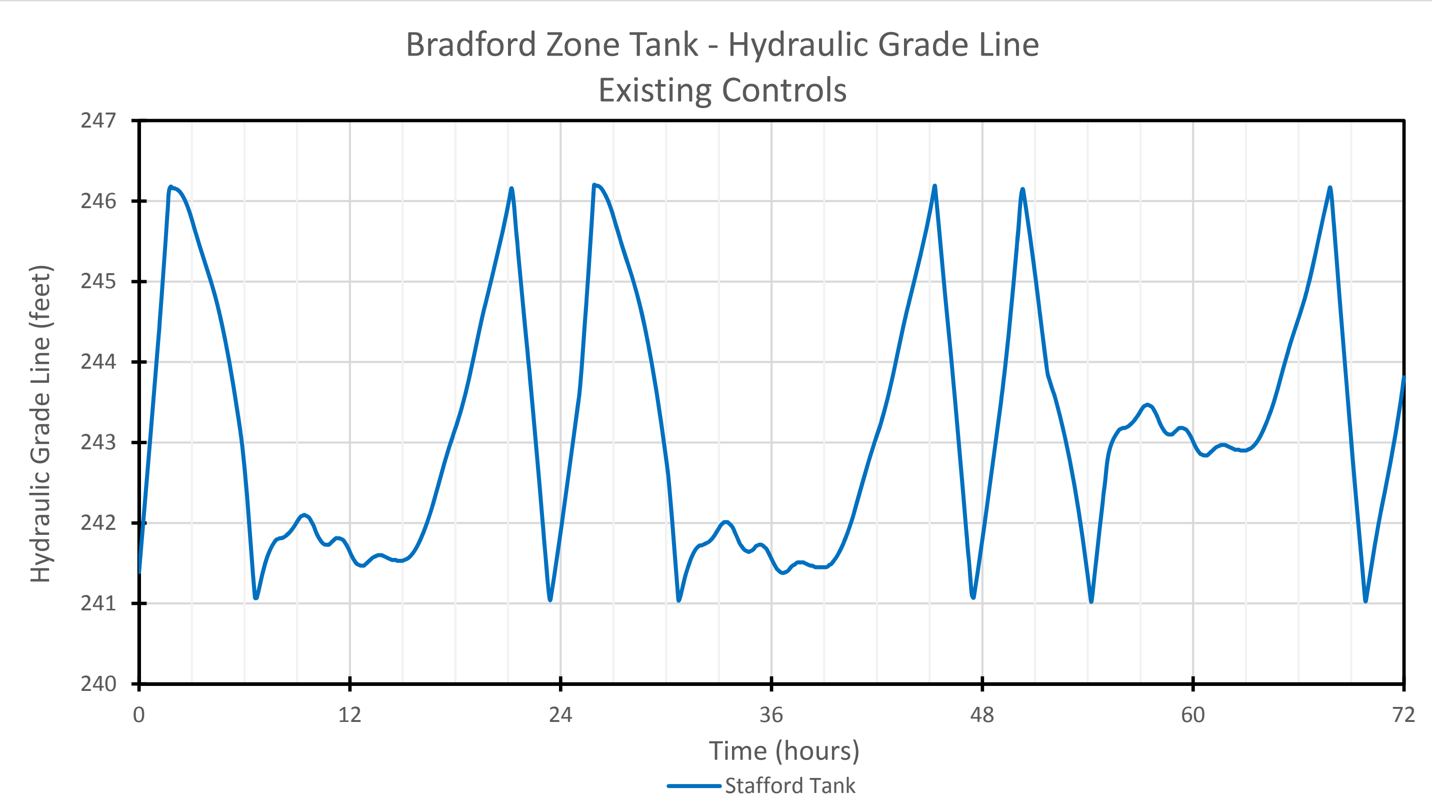
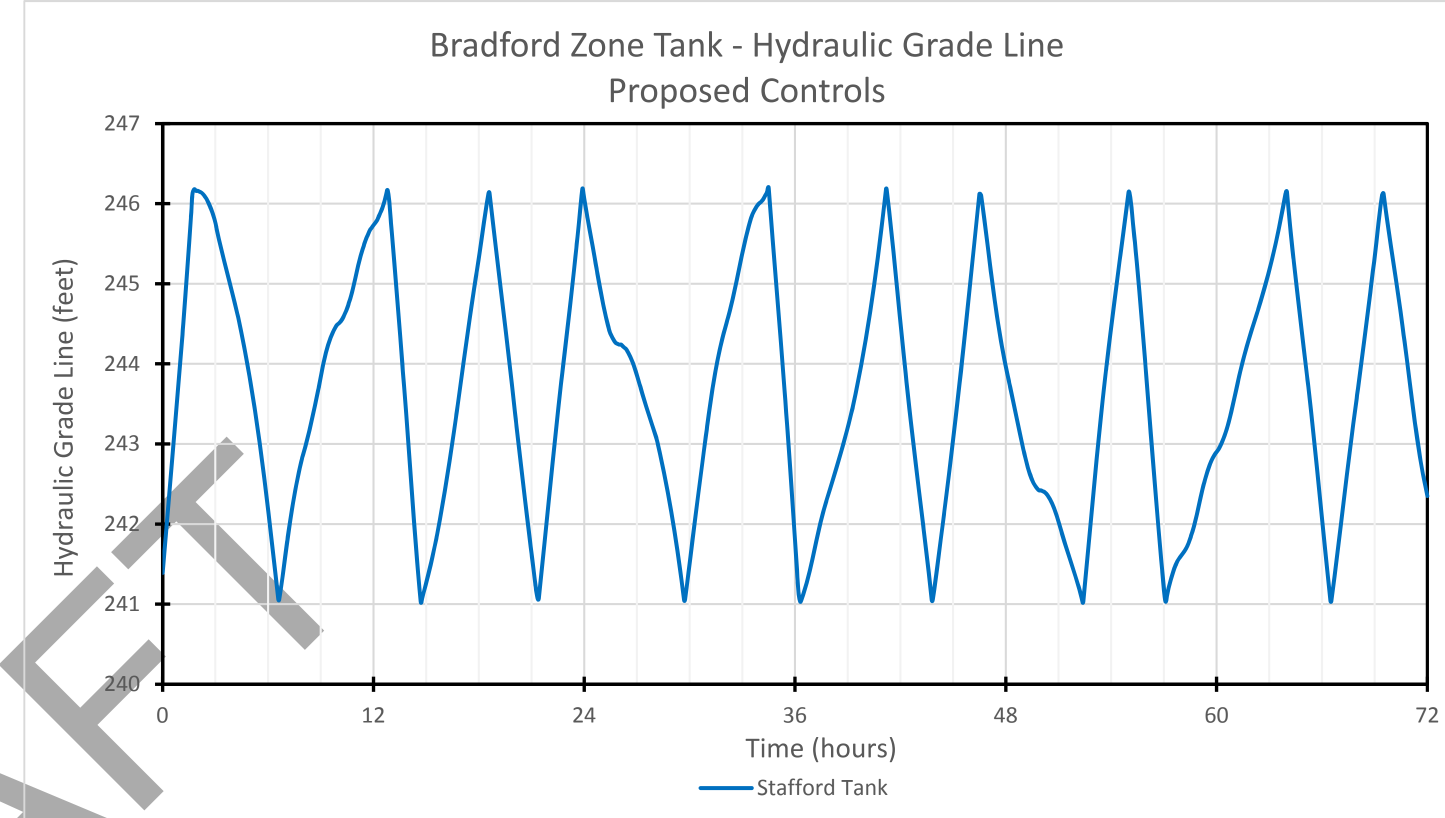
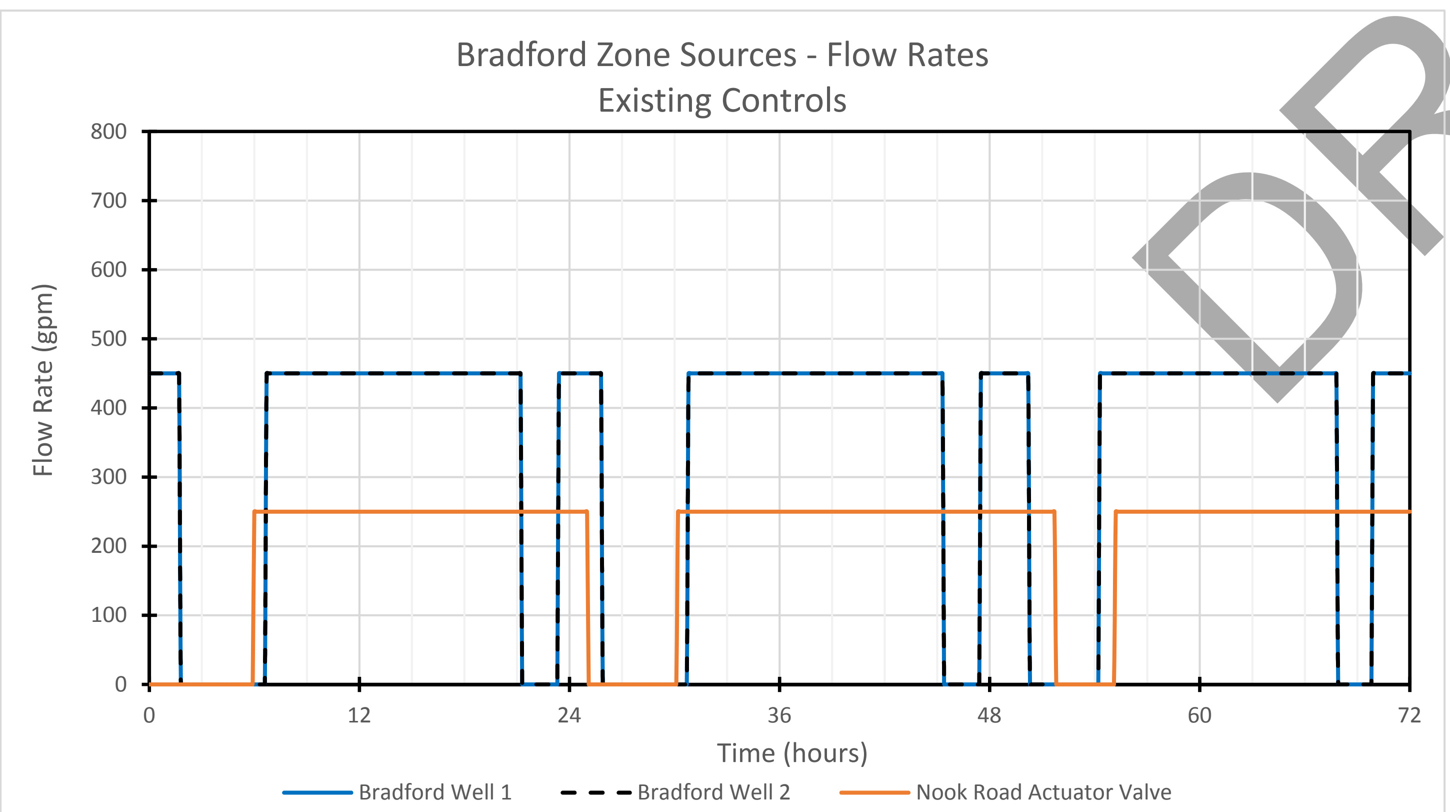


Figure 7-19
MDD Hydraulic Performance Comparison
Bradford Pressure Zone







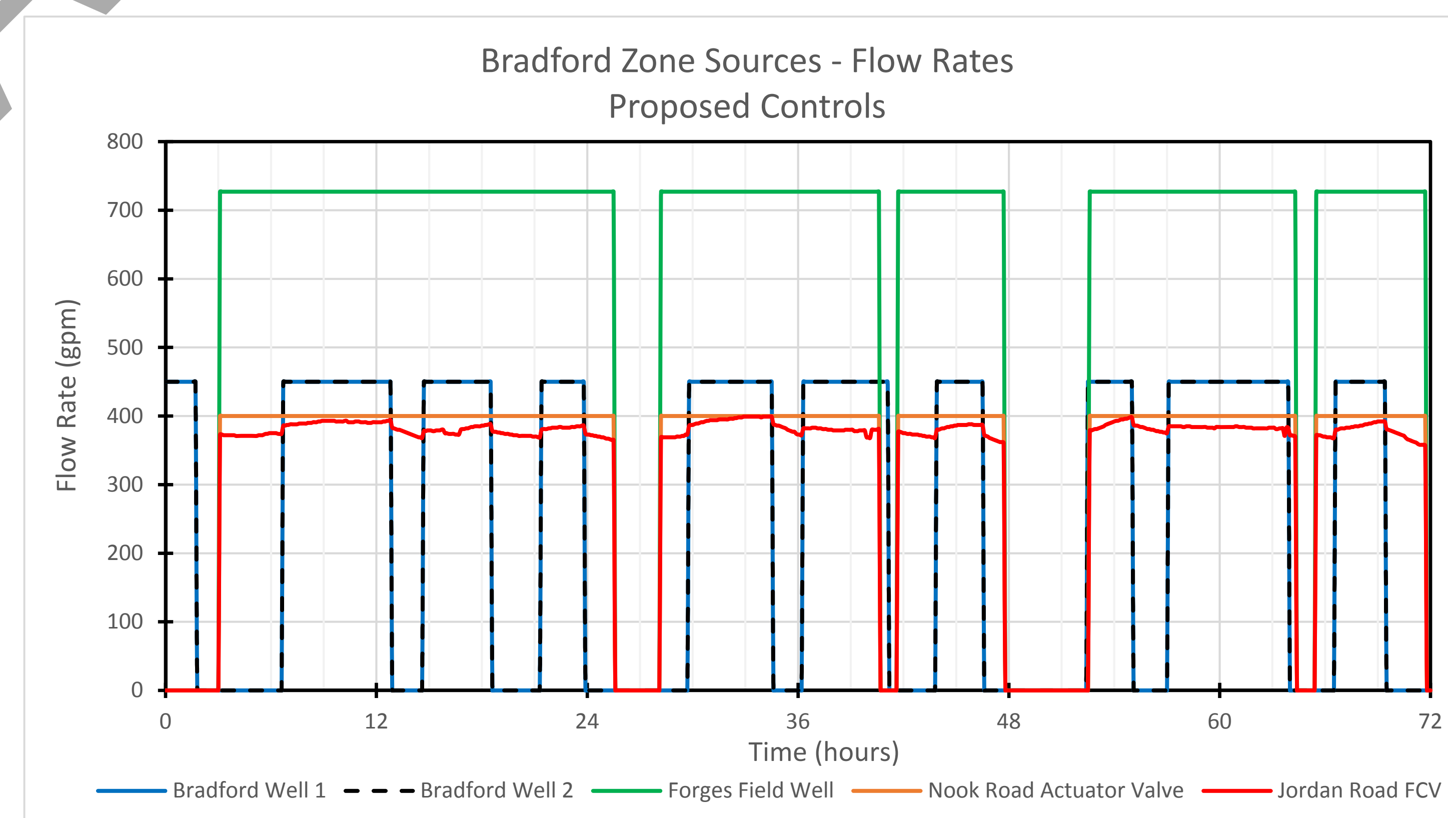
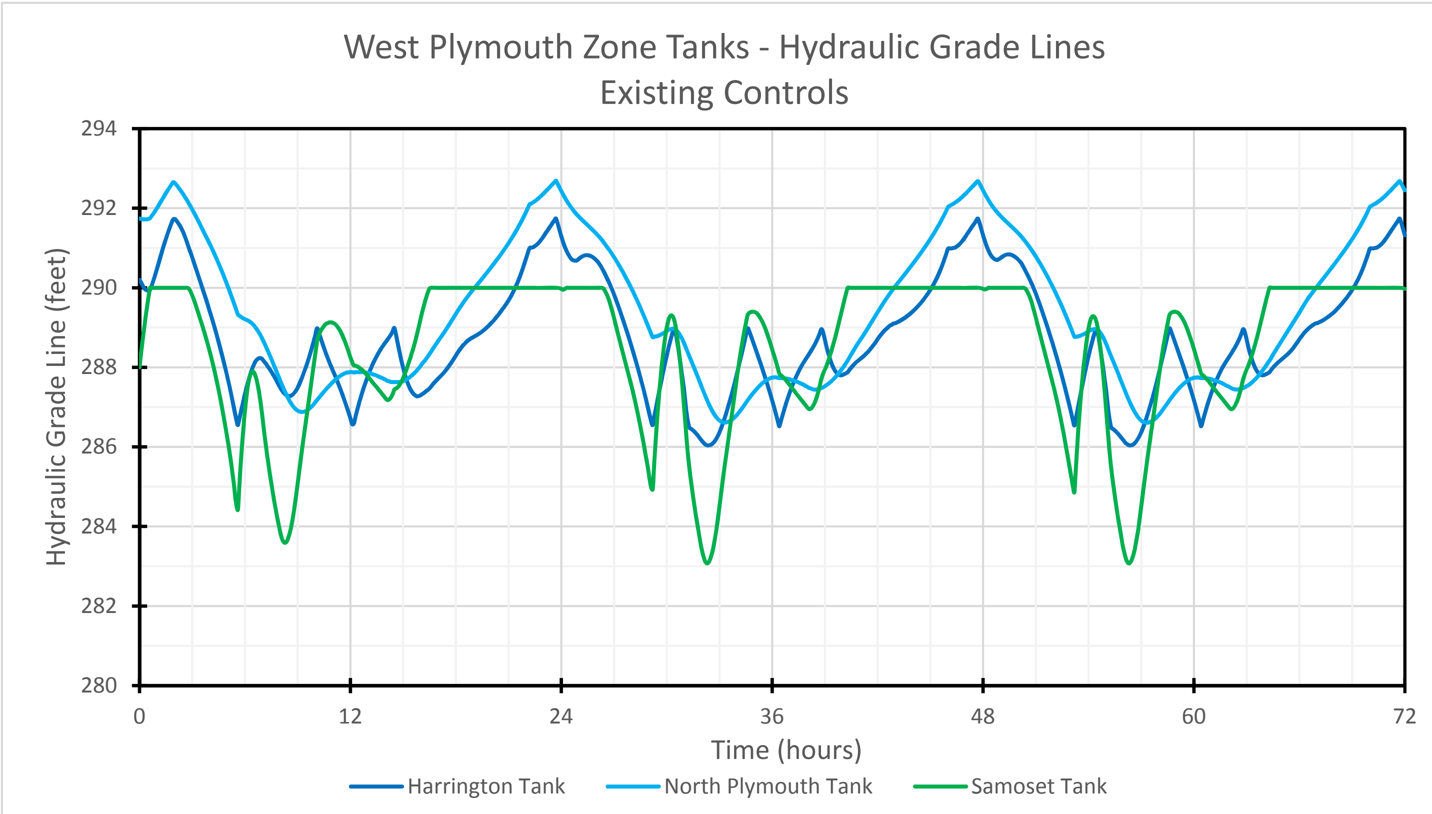
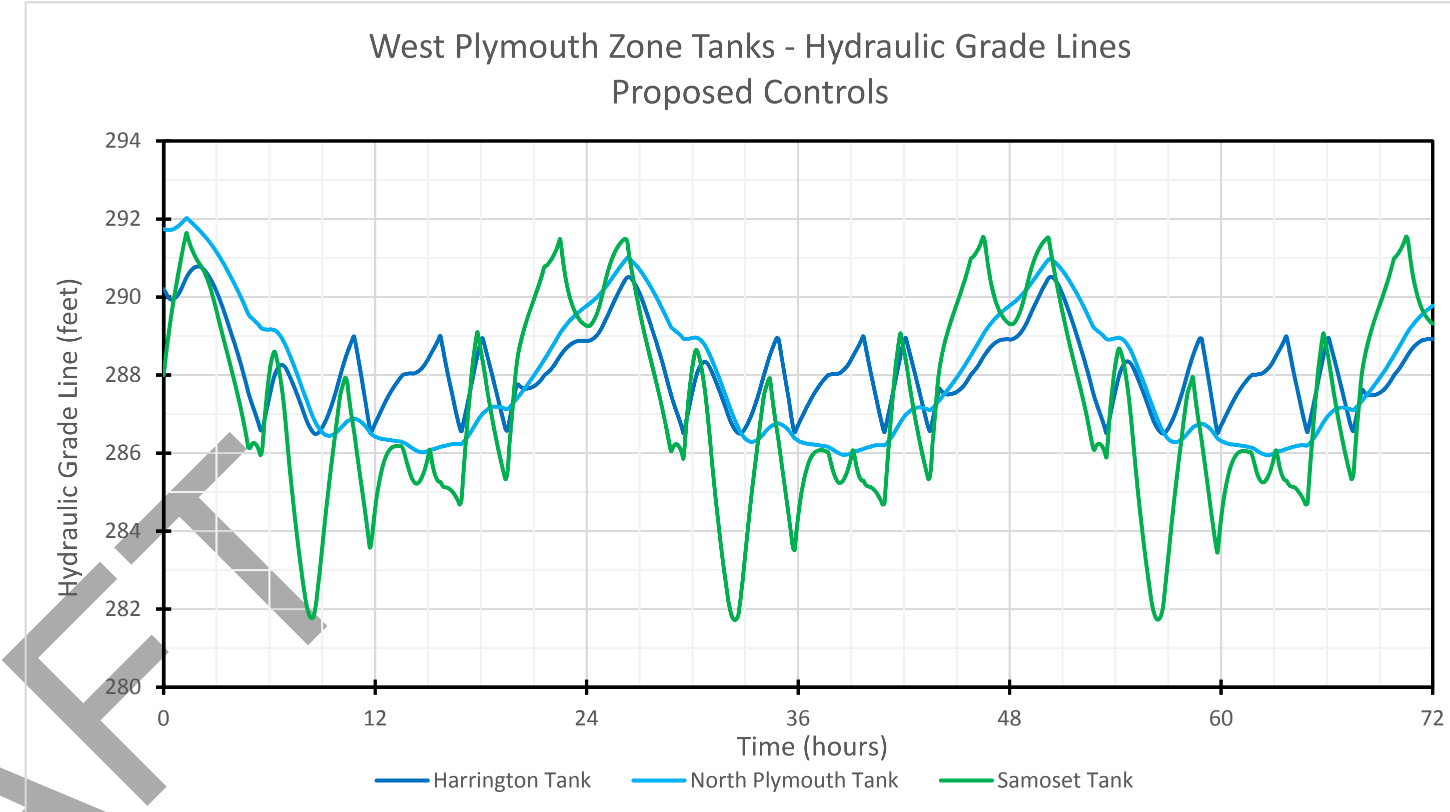
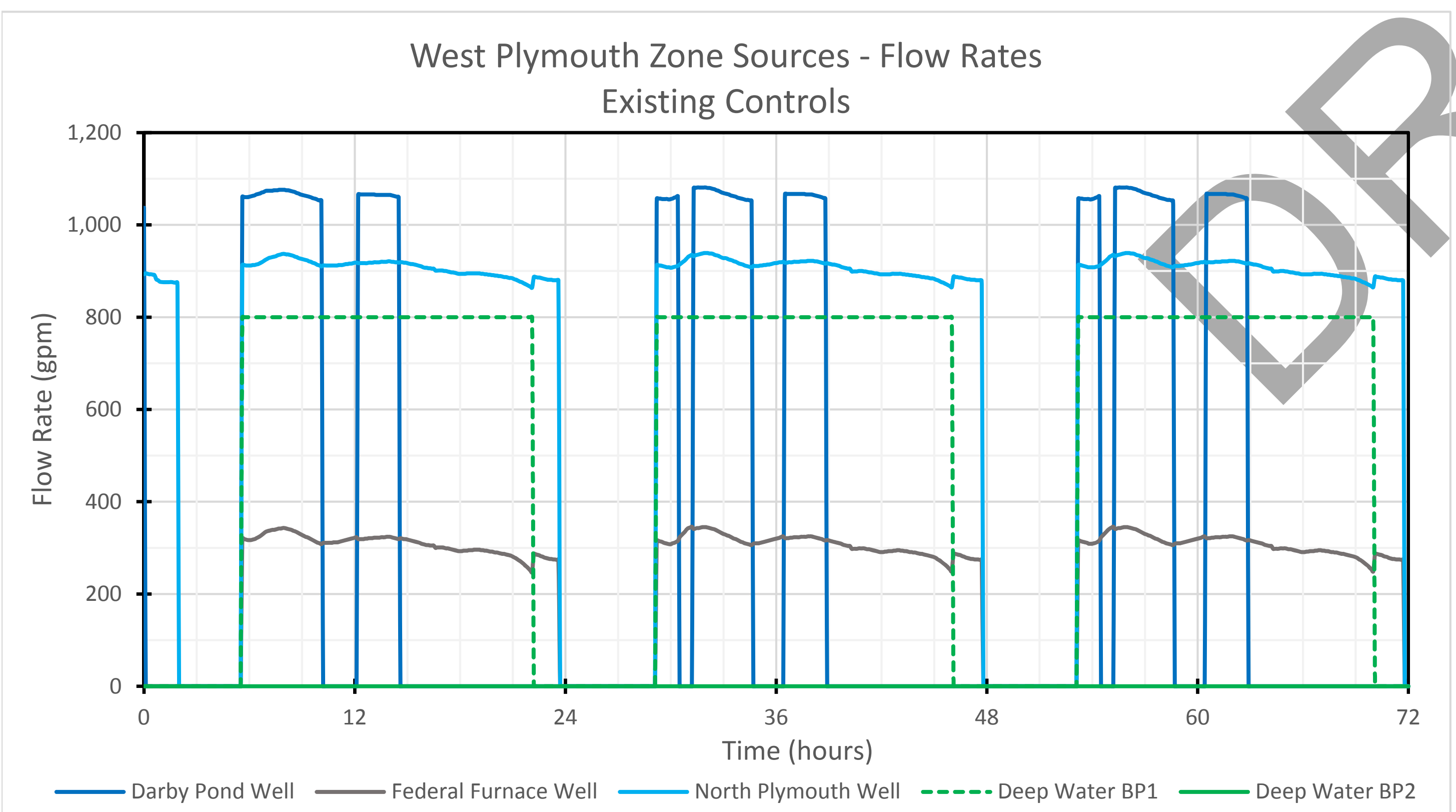


Figure 7-20
MDD Hydraulic Performance Comparison
West Plymouth Pressure Zone







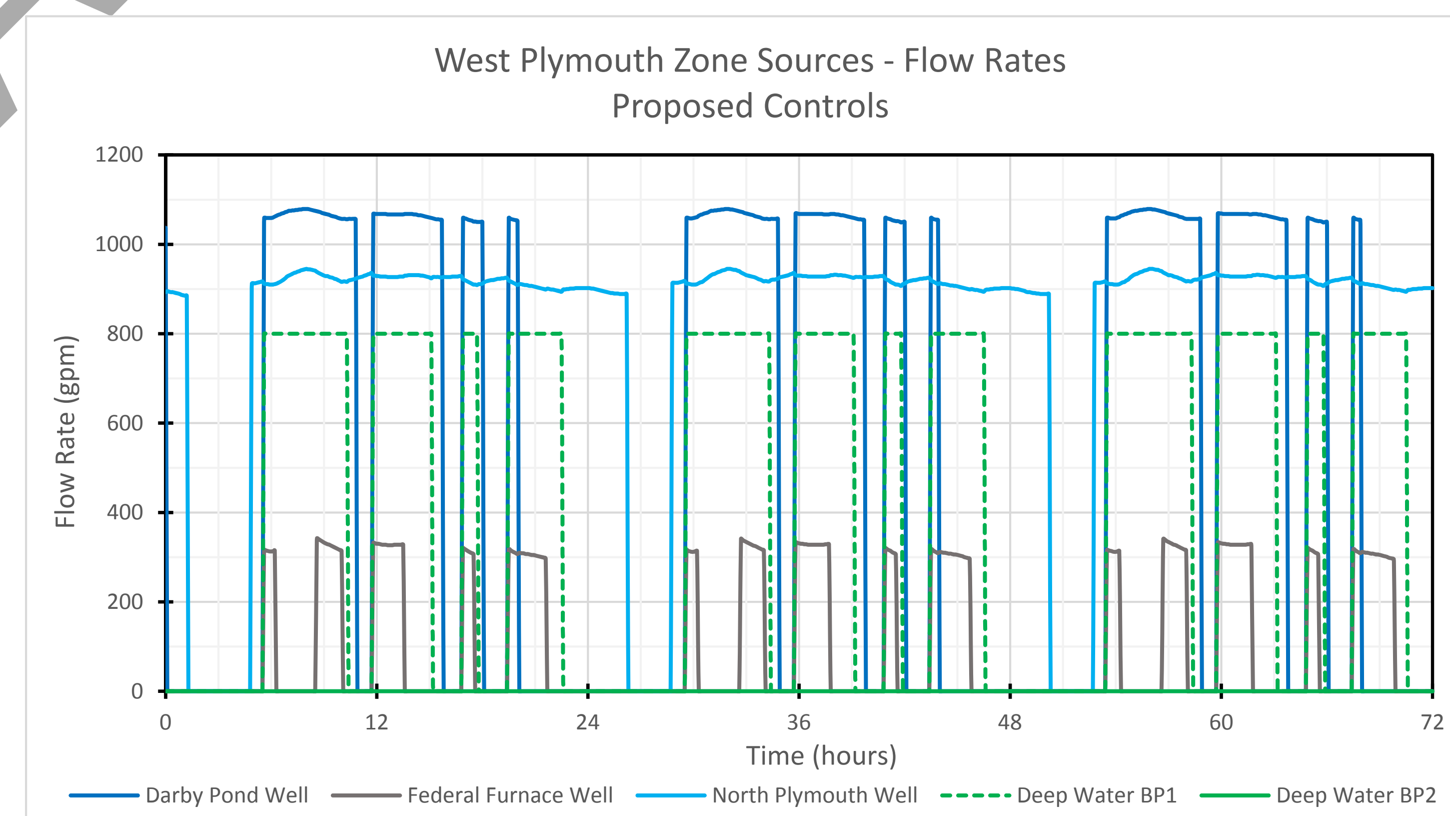
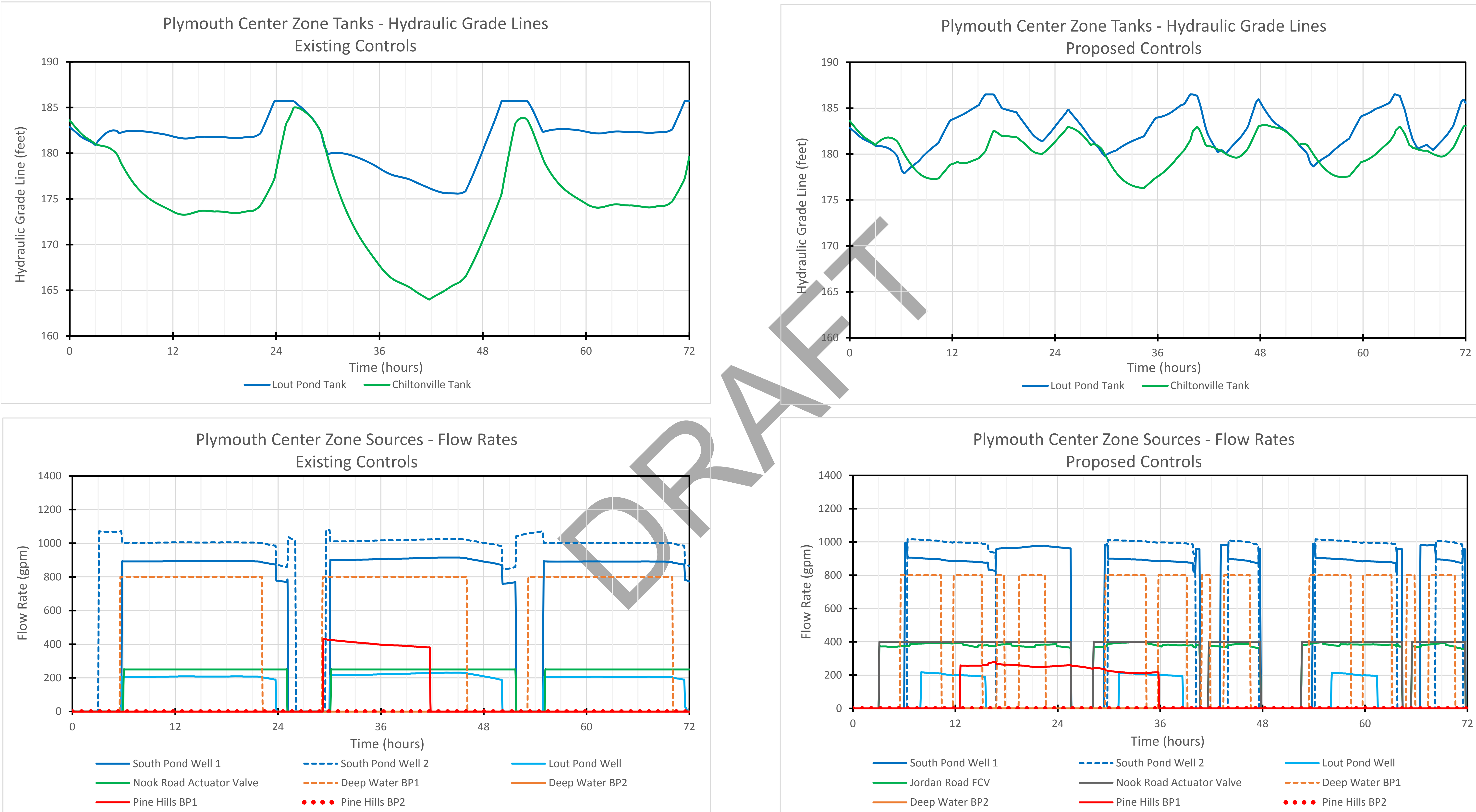
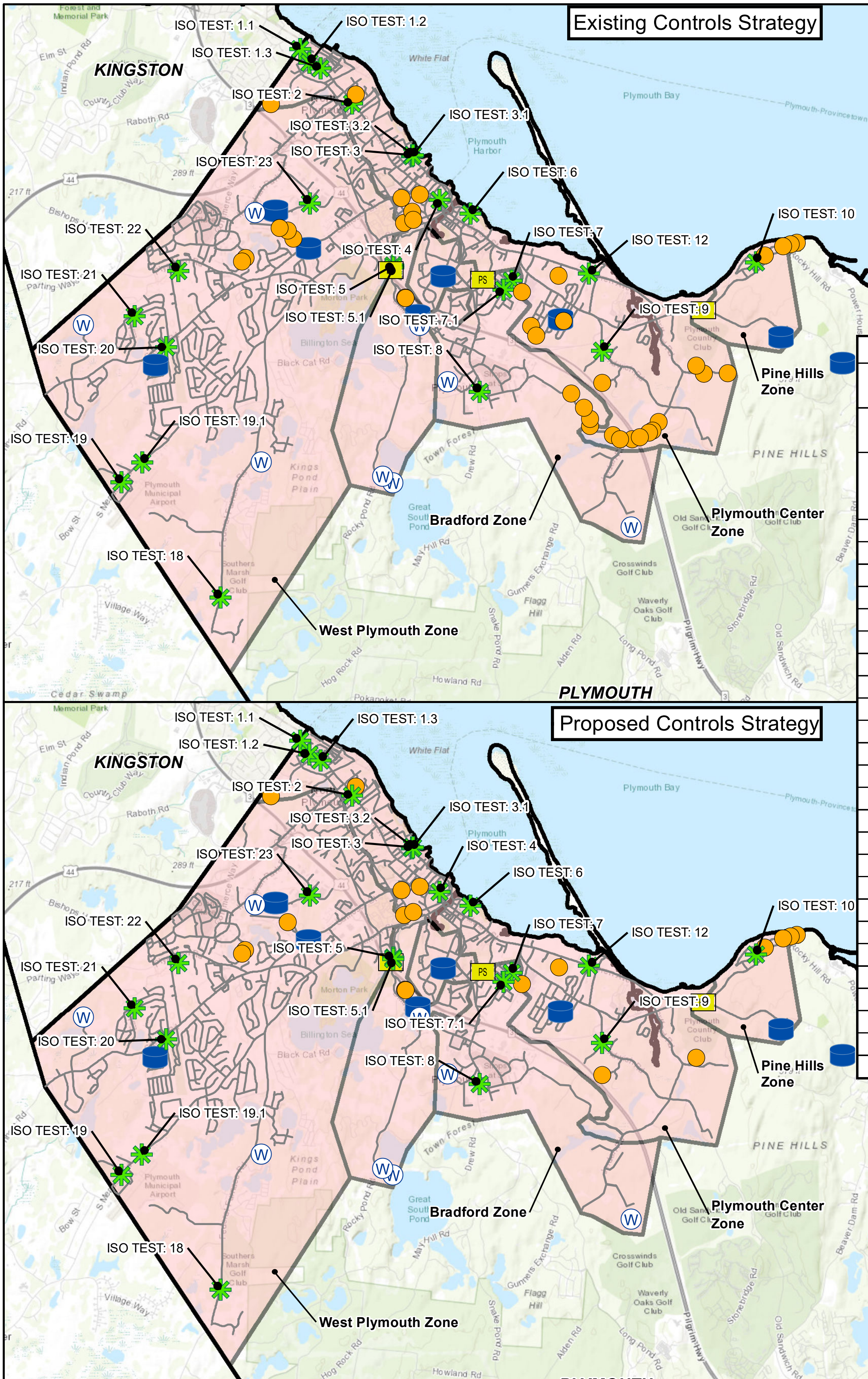


Figure 7-21
MDD Hydraulic Performance Comparison
Plymouth Center Pressure Zone





Fire Flow Deficient Nodes			
Existing Controls	39		
Proposed Controls	20		
ISO Test	Required Fire Flow	Existing Fire Flow	Proposed Fire Flow
1	7000	2700	2950
1.1	3000	2275	2475
1.2	6000	2275	2475
1.3	6000	2275	2475
2	3500	2975	3225
3	4500	3950	4350
3.1	1750	3950	4350
3.2	4500	3950	4350
4	3000	4150	4700
5	4500	3750	4275
5.1	1000	3750	4275
6	5000	4375	4800
7	5000	3675	4675
7.1	750	3675	4675
8	3500	2725	3925
9	500	875	1350
10	1000	825	800
12	3000	2625	4950
18	3000	1600	1600
19	4500	1200	1200
19.1	2250	1200	1200
20	750	6500	6525
21	1000	3700	3700
22	3000	1725	1725
23	2250	5100	5100

Legend

- Fire Flow Deficient Nodes
- Booster Pump Stations
- Sources
- Storage Tanks
- ISO Test Locations
- Water Mains
- Northern Pressure Zones

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

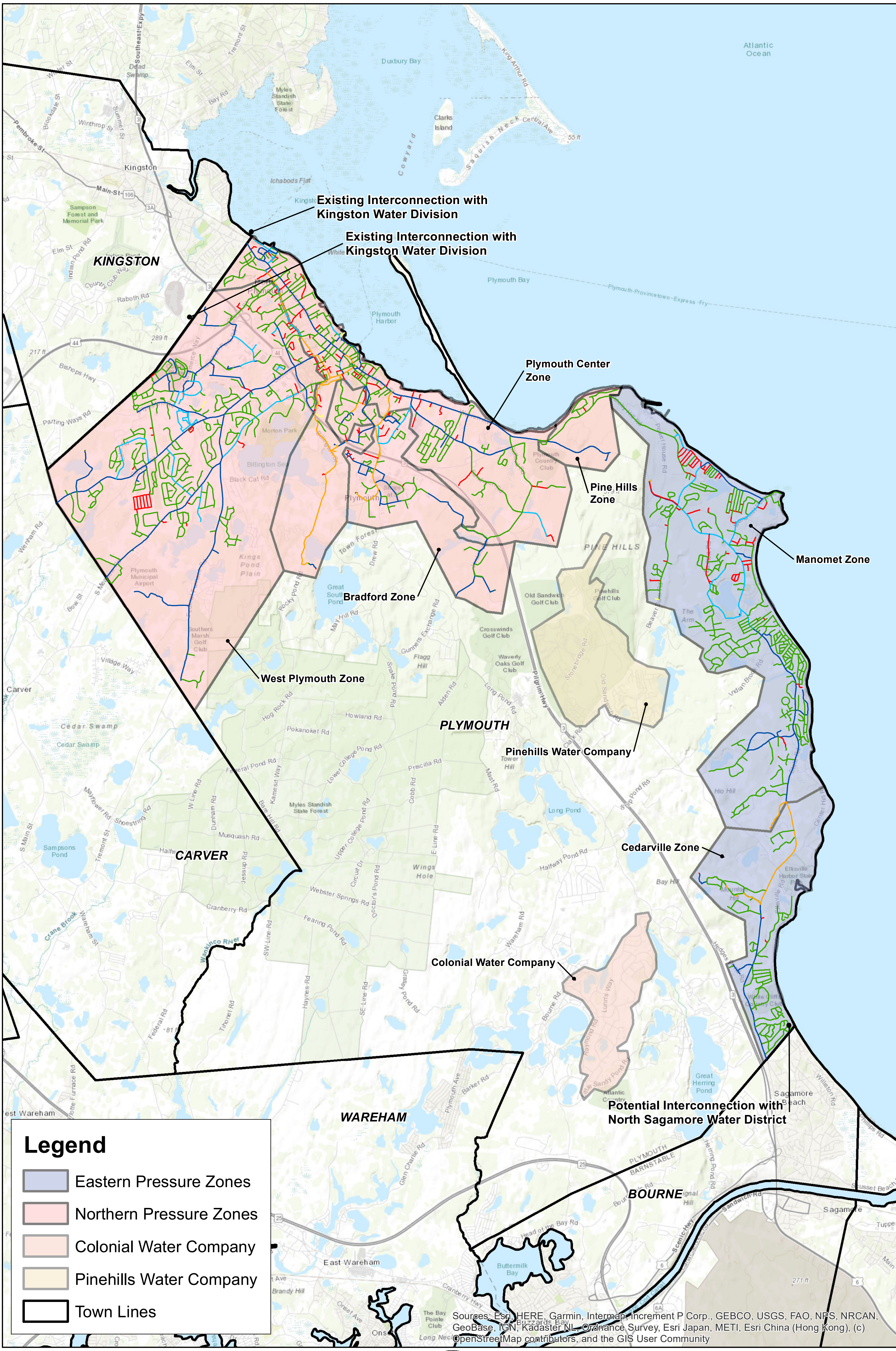
0 4,500 9,000 18,000 Feet

1 in = 9,000 feet

Environmental Partners GROUP
A partnership for engineering solutions.

Figure 7-22: Northern Pressure Zones Fire Flow Deficiencies

November 2019



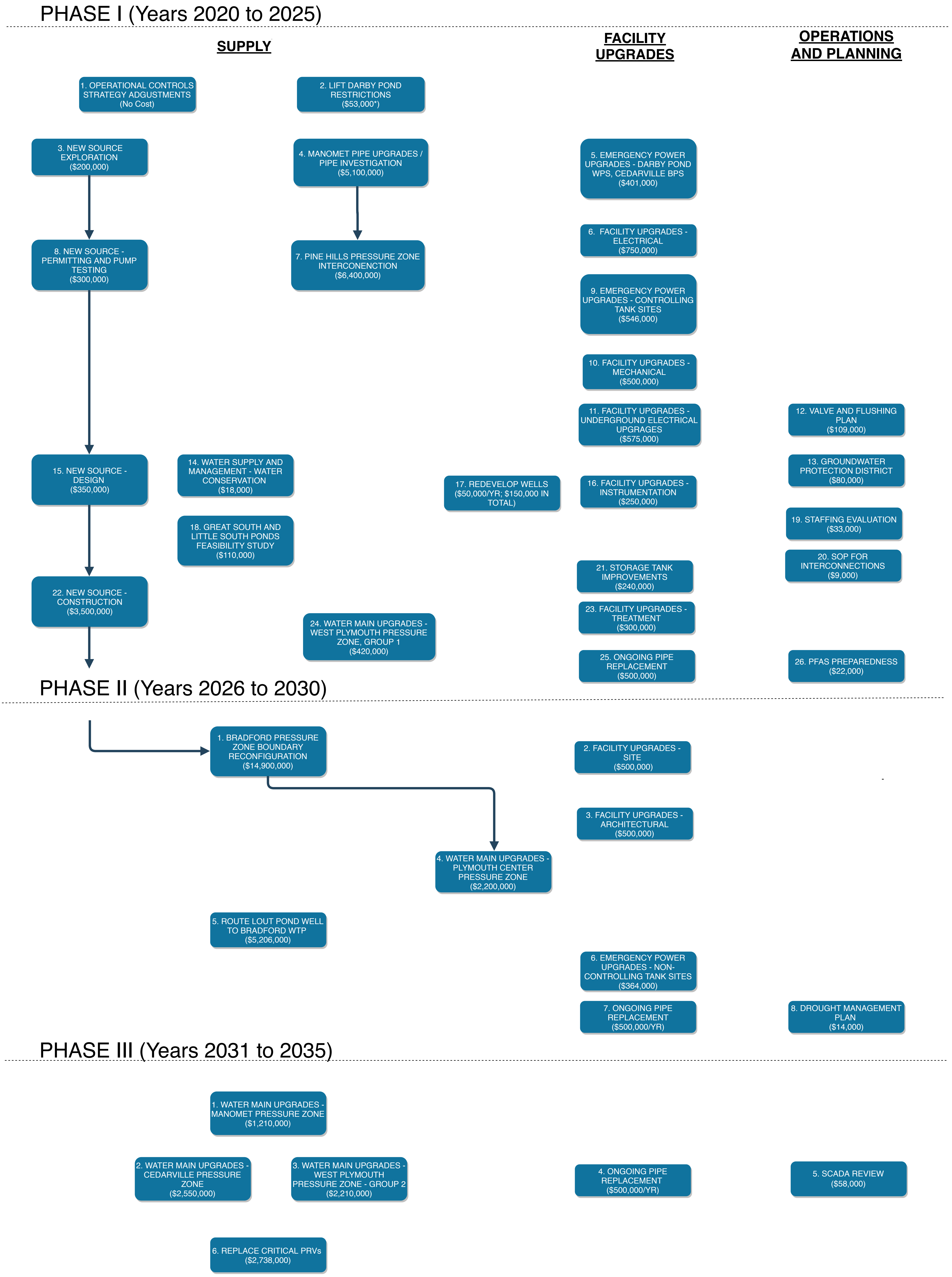
0 3,500 7,000 14,000 Feet

1 in = 7,000 feet

Environmental Partners GROUP
A partnership for engineering solutions.

Figure 8-1:
Existing and Potential Interconnections
Plymouth, MA
November 2019

Figure 9-1: Recommended Improvements Phasing Plan



Notes:

1. → Indicates the recommended improvements are dependent.

2. Recommendations are arranged based on priority.

* Indicates that the cost does not include the Cranberry Bog property acquisition.

Environmental Partners GROUP
A partnership for engineering solutions

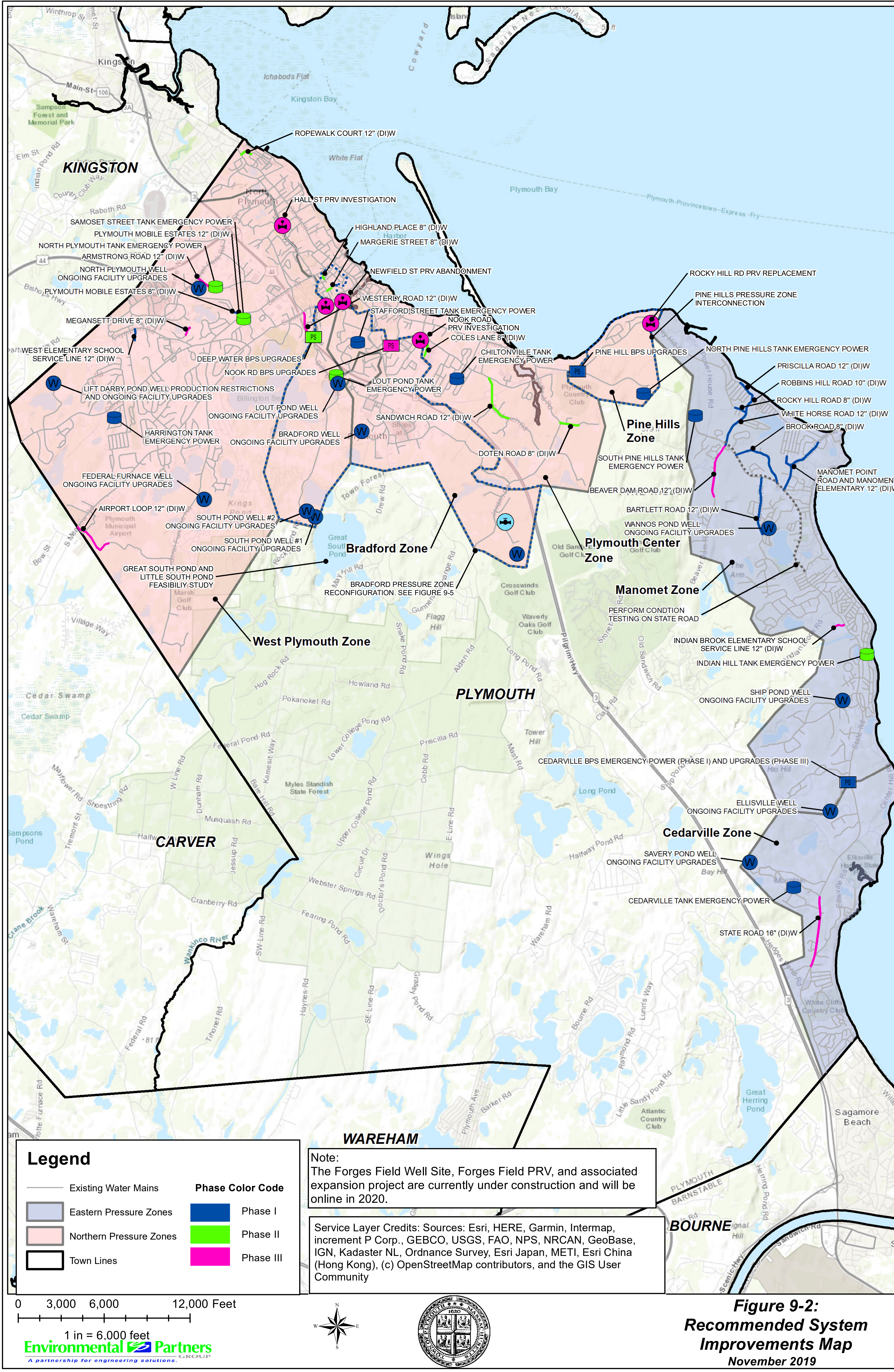
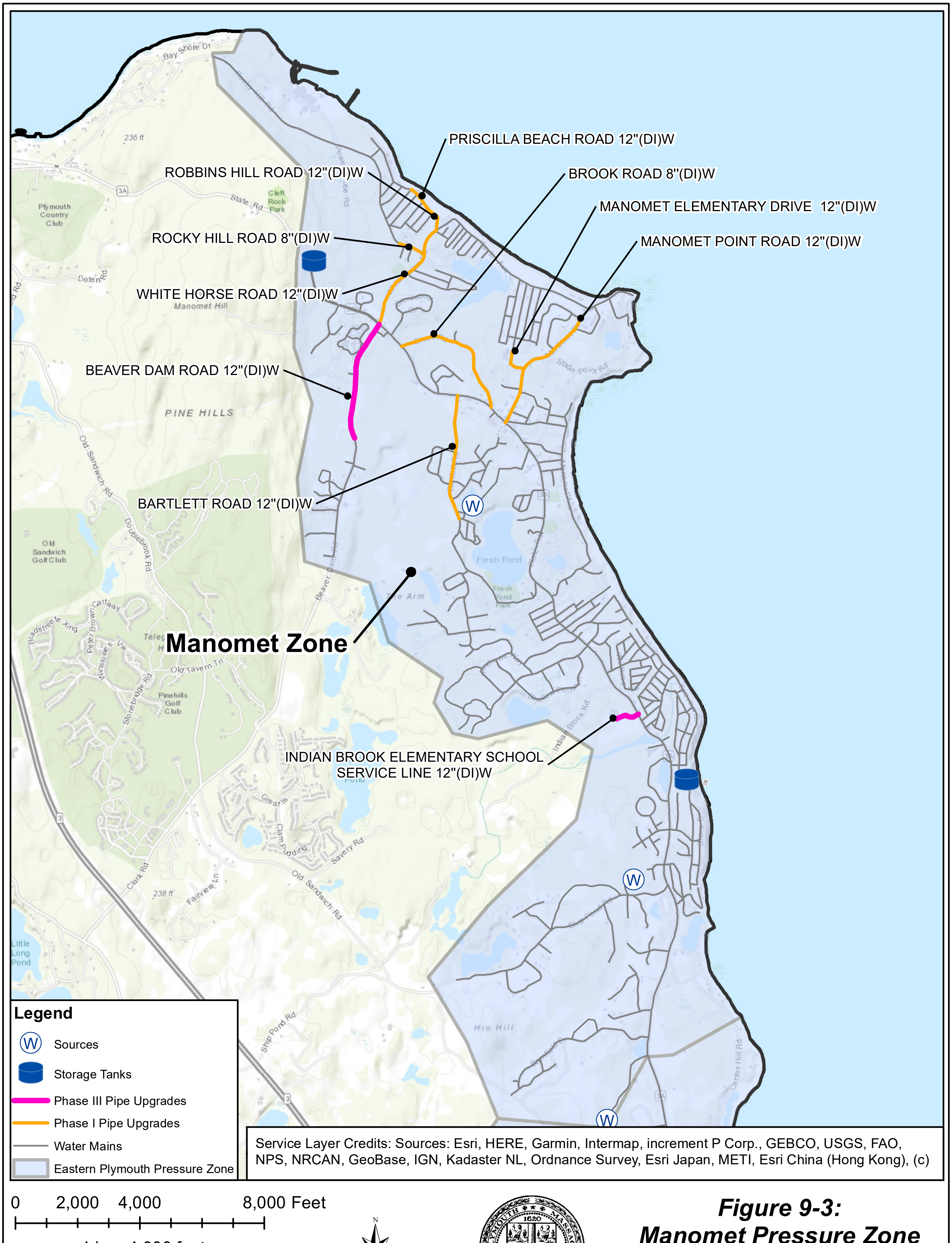


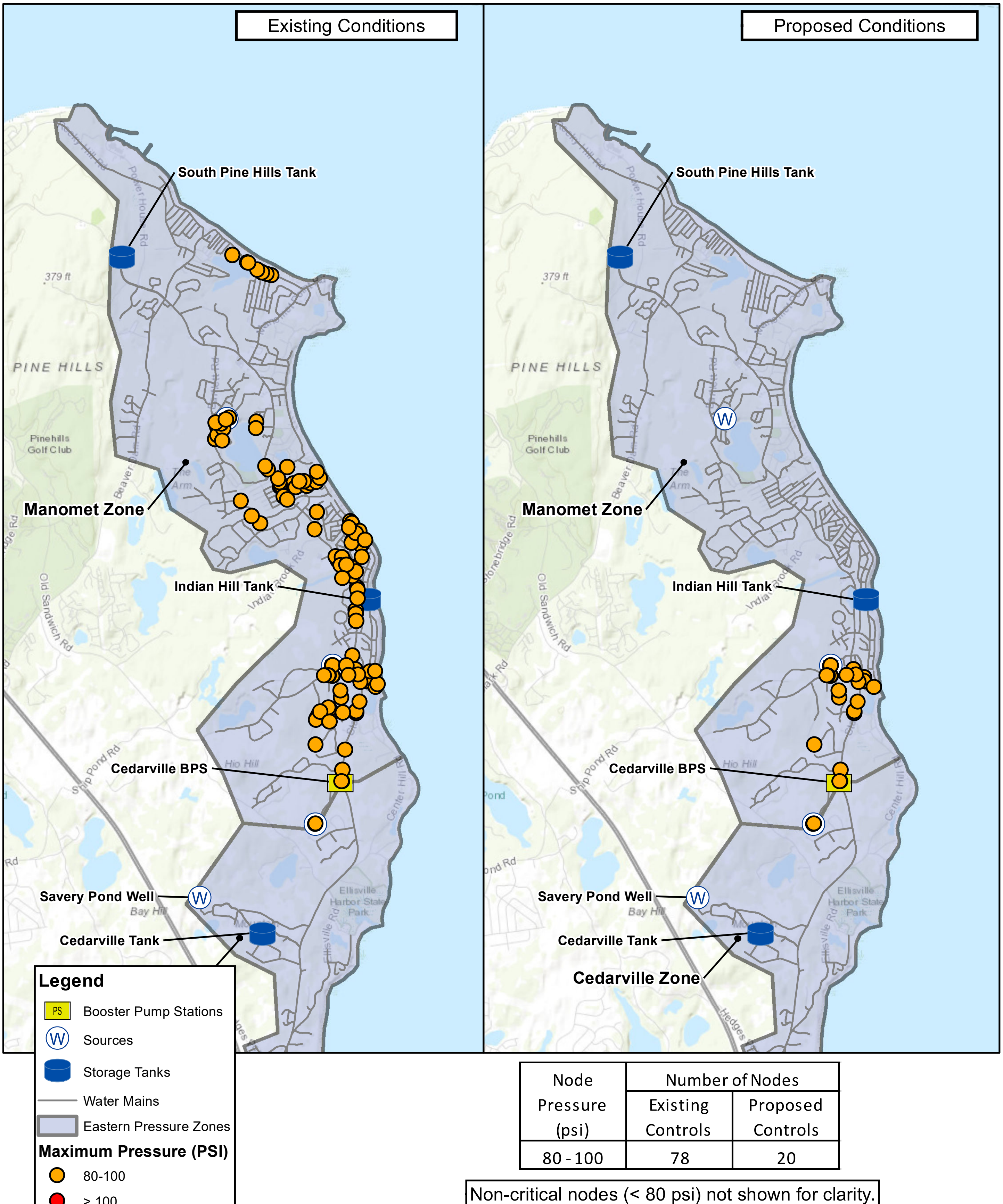
Figure 9-2: Recommended System Improvements Map

November 2019



Environmental Partners GROUP
A partnership for engineering solutions.

Figure 9-3:
Manomet Pressure Zone Water Main Improvements
November 2019



Node Pressure (psi)	Number of Nodes	
	Existing Controls	Proposed Controls
80 - 100	78	20

Non-critical nodes (< 80 psi) not shown for clarity.

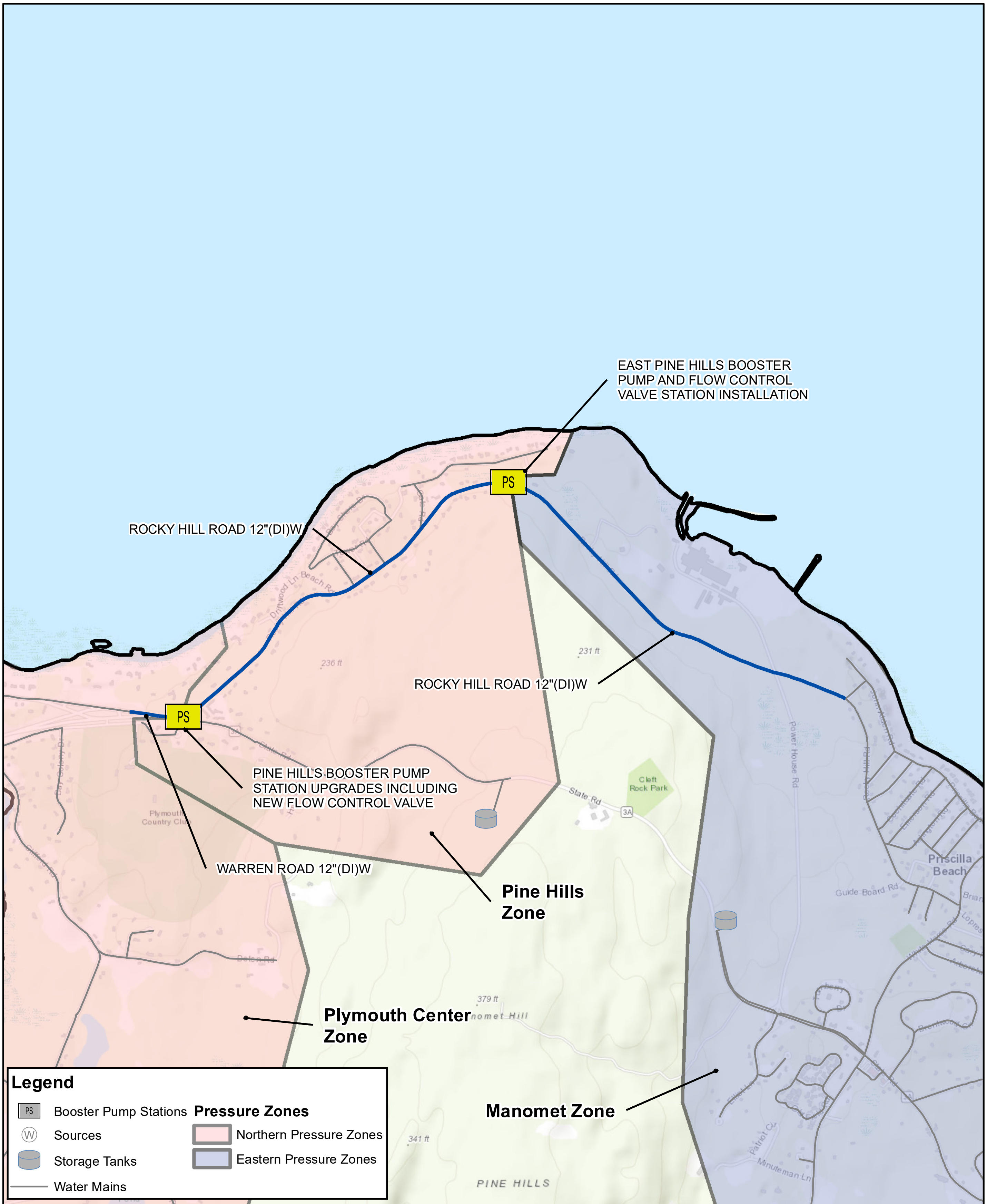
Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

0 3,200 6,400 12,800 Feet

1 in = 6,500 feet

Environmental Partners Group
A partnership for engineering solutions.

Figure 9-4:
Manomet Improvements MDD Maximum Pressures
November 2019



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

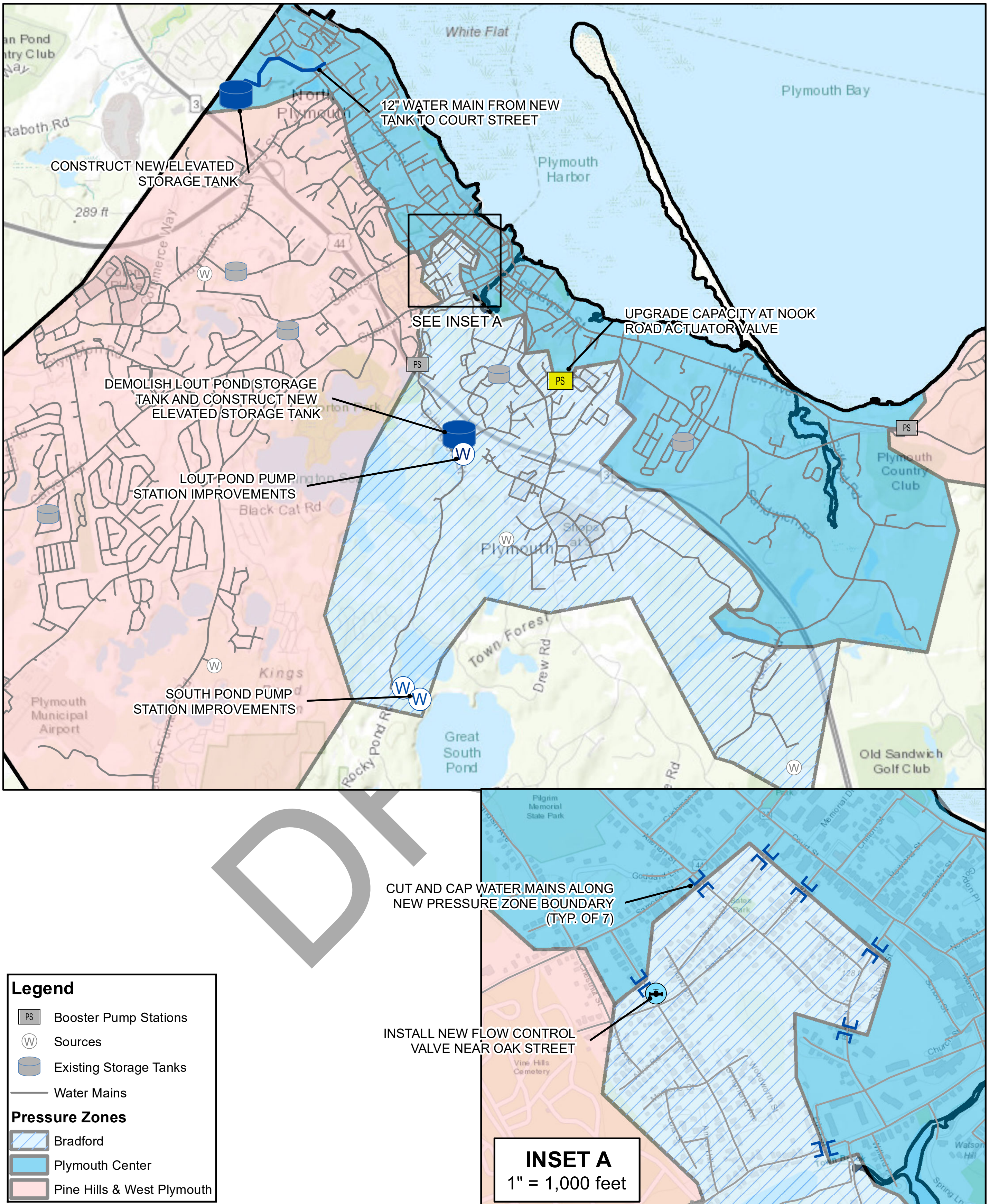
0 1,000 2,000 4,000 Feet

1 in = 2,000 feet

Environmental Partners Group

A partnership for engineering solutions.

Figure 9-5:
Pine Hills Pressure Zone Interconnection
November 2019



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

0 2,500 5,000 10,000 Feet

1 in = 5,000 feet

Environmental Partners Group
A partnership for engineering solutions.

Figure 9-6: Northern Pressure Zones Reconfiguration

November 2019

Appendix A

Parting Ways Source Exploration

A.1 SOUTH PARTING WAYS NEW SOURCE WATER SUPPLY EXPLORATION

The South Parting Ways Site is located in the North Plymouth water system zone. In July 2019, EP conducted a subsurface investigation at the South Parting Ways site to evaluate the subsurface conditions for possible development as a new public water supply source. The scope and results of this investigation are discussed in the following sections.

A.1.1 Site Characterization

The South Parting Ways Site (the Site) consists of one parcel, located within and owned by the Town of Plymouth. The 400-foot Zone I buffer inside the parcel leaves a total of approximately 2.62 acres of potential well area (Figure 2). The Site is located within an area of limited level protected open space (Figure 3). There is one potential vernal pool located approximately 250 feet southwest from the Site. Four wetlands and one cranberry bog are located within 1,000-feet of the Site. Wetlands are located within the western portion of the Site (Figure 4). No potential sources of contamination are identified within a 0.5-mile radius of the Site except for the power-line easement approximately 350-feet south and several residential UST sites with reportable releases that have been closed under DEP requirements.

The Site is located within the Buzzards Bay Basin and MassGIS mapping indicates that the Site is underlain by a high yield aquifer (Figures 5 and 6). The Buzzards Bay Basin does not have a SWMI Groundwater Withdrawal Category (GWC). The surficial geology consists of coarse glacial stratified deposits. Several cranberry bogs, swamp and peat are located southeast and southwest of the Site (Figure 7).

Multiple groundwater supply wells are located within a 0.5-mile radius of the Site (Figure 8). Four water supply well couplets (eight wells total) are located northwest of the Site on property owned by the Congregation of the Sisters of Divine Providence, with the nearest wells located approximately 0.34 miles northwest of the Site. The Site is located inside an Interim Wellhead Protection Area and sits just outside multiple DEP Approved Zone IIs including three in Kingston and two in Plymouth.

A.1.2 Single Well Investigation

EP contracted Maher Services (Maher) of North Reading, MA, a Massachusetts certified water supply well driller, to install borings and a test well and conduct a short term pumping test. Initial investigation activities were performed to evaluate the site for locating a single production well. One 4-inch test well (TW-1) and one 2-inch observation well (OW-1) were installed using a sonic drilling rig. TW-1 was located such that the DEP required 400-foot Zone I radius (310 CMR 22.00) was located completely on the Town's parcel (shown on Figure 2). Following is a summary of observed subsurface hydrogeologic conditions at the site:

- Potential aquifer material was identified between 90 and 103 feet bgs.
- Potential aquifer material consists of fine to coarse silty sand, some gravel, and trace cobble.
- Refusal for TW-1/OW-1 was encountered at 114 feet bgs.

In addition to these two wells, one boring (B-1) was drilled approximately 265 feet to the west and encountered poor aquifer conditions until refusal at 119 feet bgs.

A 2-hour pumping test was performed on August 7, 2019. The well screen at TW-1 was set from 93 to 103 feet bgs. Following is a summary of the 2-hour pump test and groundwater quality results.

- Static water level was at 46.24 feet bgs.
- Pump rate was 35 GPM.
- Water level in the 2-foog observation well (OW-1) after 2-hours of pumping was at 53.61 feet bgs.
- Draw down after 2-hours was 7.37 feet.
- Specific Capacity was 4.75 GPM/foot of drawdown.
- Well Yield was 198.32 GPM (285,000 GPD) with 5 foot buffer at top of screen (per 310 CMR 22 for single production well).
- Field water quality testing results are summarized in the following table:

Table B-1 – South Parting Ways Field Water Quality Testing Results

Analyte	Results (mg/L)	Secondary MCL
Temperature	6.6°C	Not Applicable
Dissolved Oxygen	14.60 mg/L	Not Applicable
Specific Conductivity	134.1 µS/cm	Not Applicable
Salinity	0.06 PPT	Not Applicable
Turbidity	0.3 NTU	Not Applicable
Odor	None	3 threshold odor numbers

- Laboratory analytical results are summarized in the following table and laboratory reports are included in:

Table B-2 – South Parting Ways Laboratory Water Quality Testing Results

Analyte	Results (mg/L)	MCL/OSRG (mg/L)
Aluminum	ND	0.05 – 0.2
Calcium	5.40	Not Applicable
Copper	ND	1
Hardness	25.5	Not Applicable
Manganese	0.017	0.05
Iron	ND	0.3
Magnesium	ND	Not Applicable
Potassium	1.08	Not Applicable
Silver	ND	0.1
Zinc	ND	5
Analyte	**Results (mg/L)**	**MCL/OSRG (mg/L)**
Nitrate as N	0.369	10
Nitrite as N	ND	1
Alkalinity	24	Not Applicable
Chloride	10.9	250
Sulfate	4.3	250
Total Dissolved Solids	78	500
pH	7.04	6.5 – 8.5
Herbicides	ND	Varies
Pesticides	ND	Varies
Volatile Organic Compounds (VOCs)		
Toluene	0.0022	1
Other Analytes	ND	Varies

As indicated above, water quality is within DEP Drinking Water Standards (MCLs), Secondary MCLs and Drinking Water Guidelines.

A.1.3 Conclusions and Recommendations

Borings were drilled in two locations at the Parting Ways site until drilling refusal was encountered (approximately 114 to 119 feet bgs). Potential aquifer material was identified at one location (TW-1) and a preliminary 2-hour pump test was conducted. The results of the pump test indicate that the potential well yield at location TW-1 is approximately 198 gpm or (285,000 gpd). Water quality is excellent and within Massachusetts Drinking Water Standards and Guidelines.

The TW-1 location is approximately 2,000 feet from a 12-inch water main in the West Plymouth Zone, approximately 1.75 miles from the North Plymouth Well, and approximately 0.6 miles from the Darby

Pond Well. This Site is located approximately 2,000 feet from a 12-inch water main in the West Plymouth Zone and could be connected to the water system relatively easily. As such, EP recommends that the Division preserve this site for potential future development. Should the Division proceed with a water supply well at the South Parting Ways site, additional observation wells should be installed and tested to optimize the production well location and well yield. This site is on hold pending future exploration work for a more favorable site.

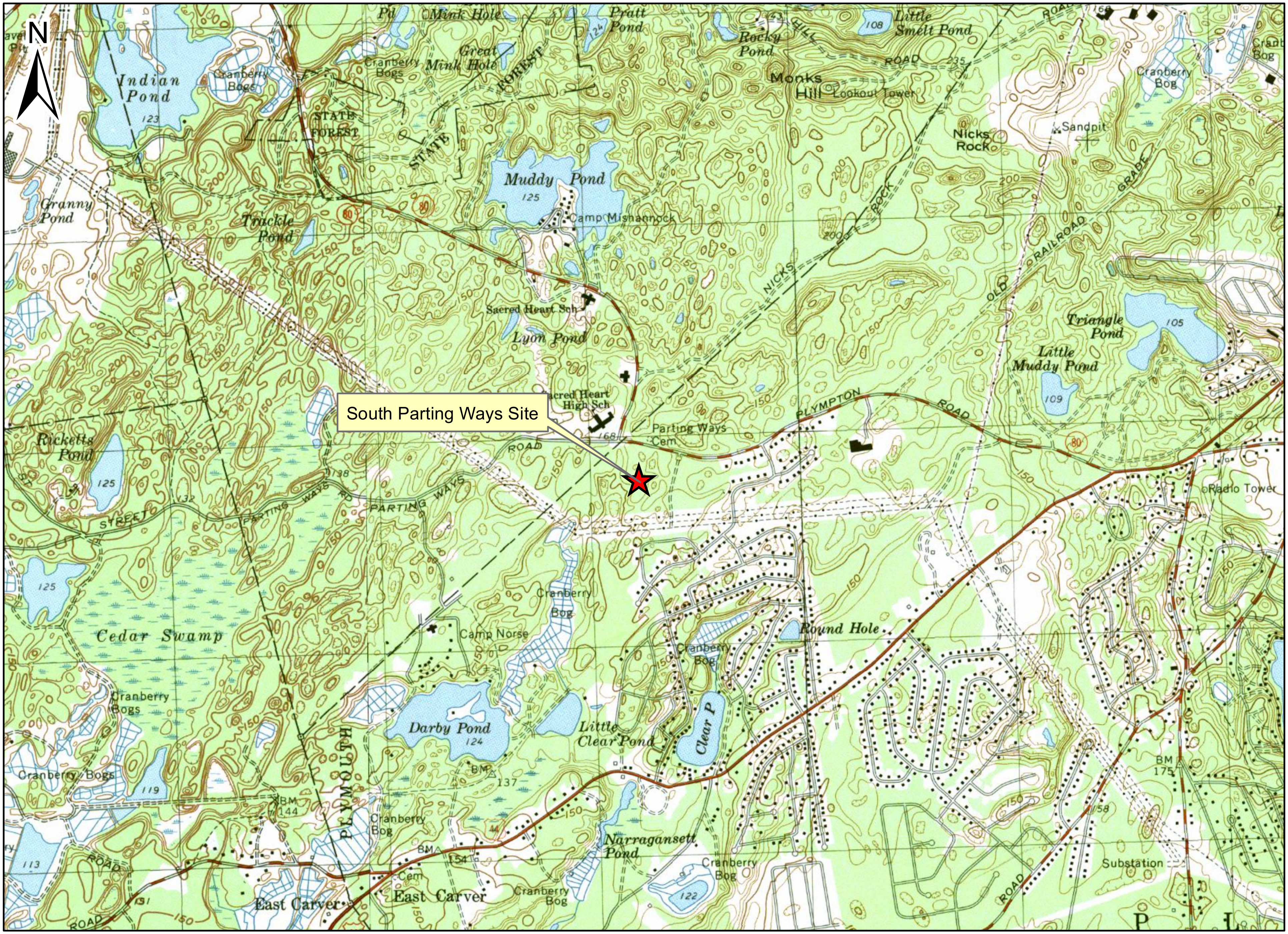
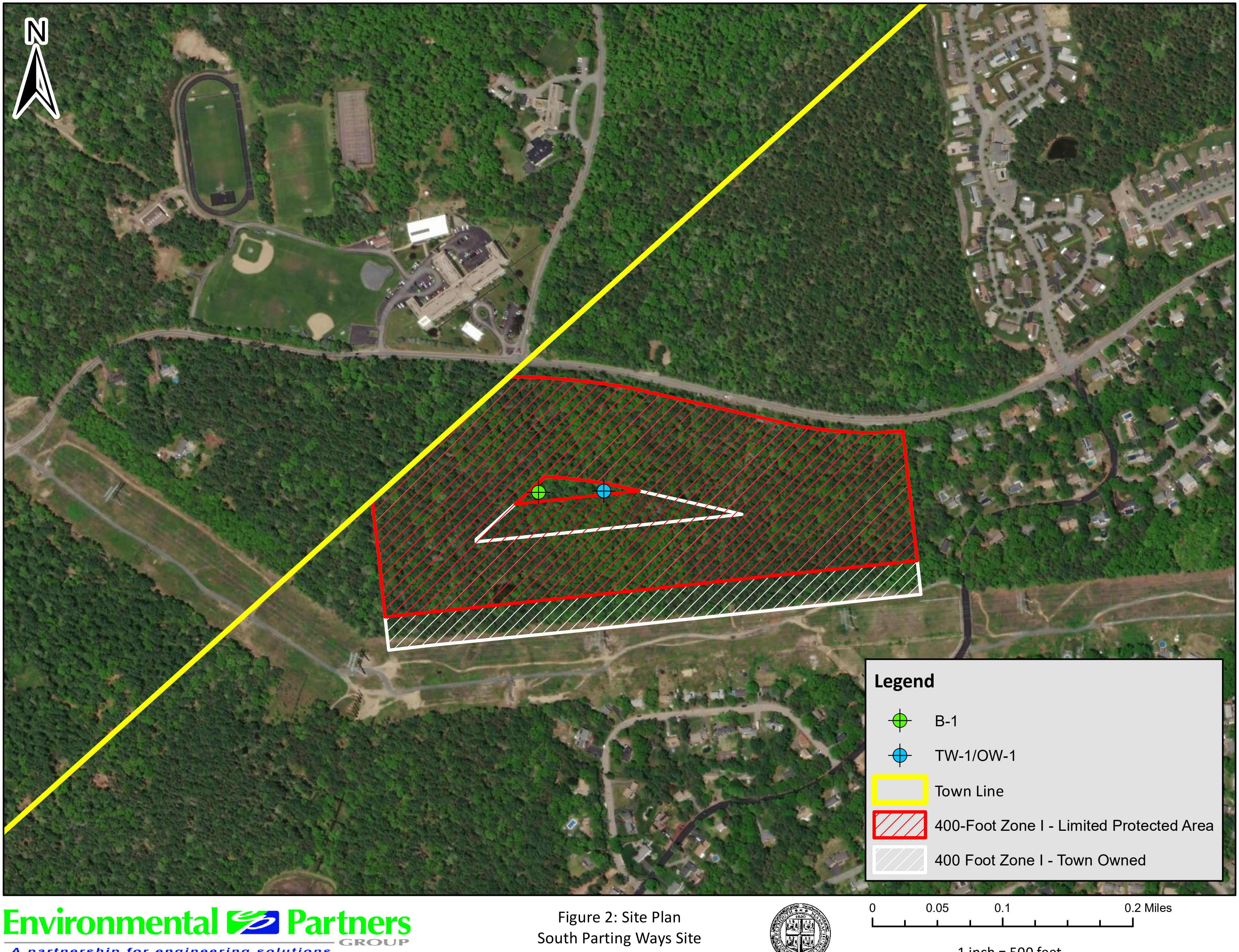


Figure 1: Locus Map
South Parting Ways Site
Plymouth, Massachusetts

0 0.25 0.5 1 Miles

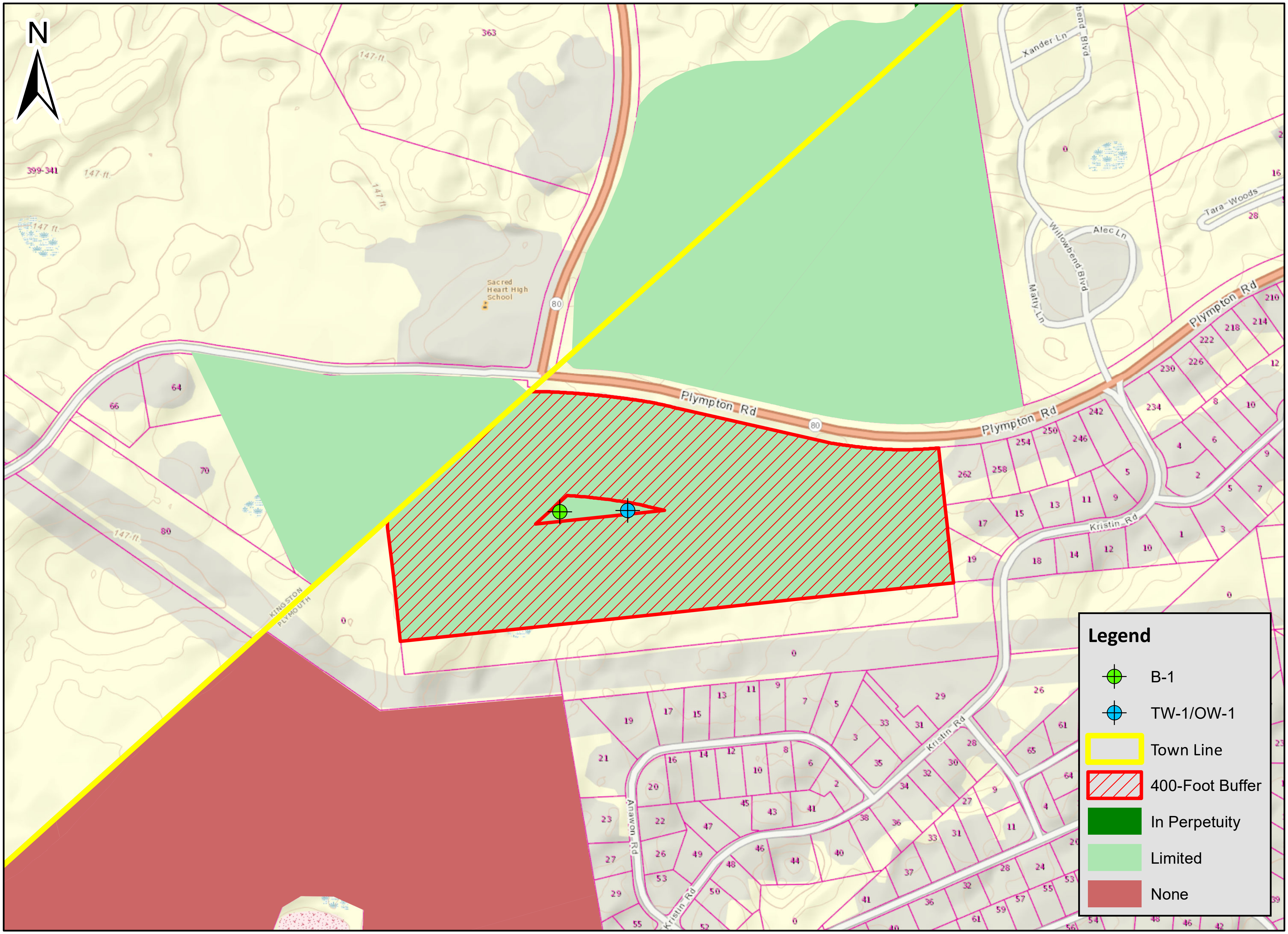
1 inch = 2,000 feet

Environmental Partners GROUP
A partnership for engineering solutions.



Environmental Partners GROUP
A partnership for engineering solutions.

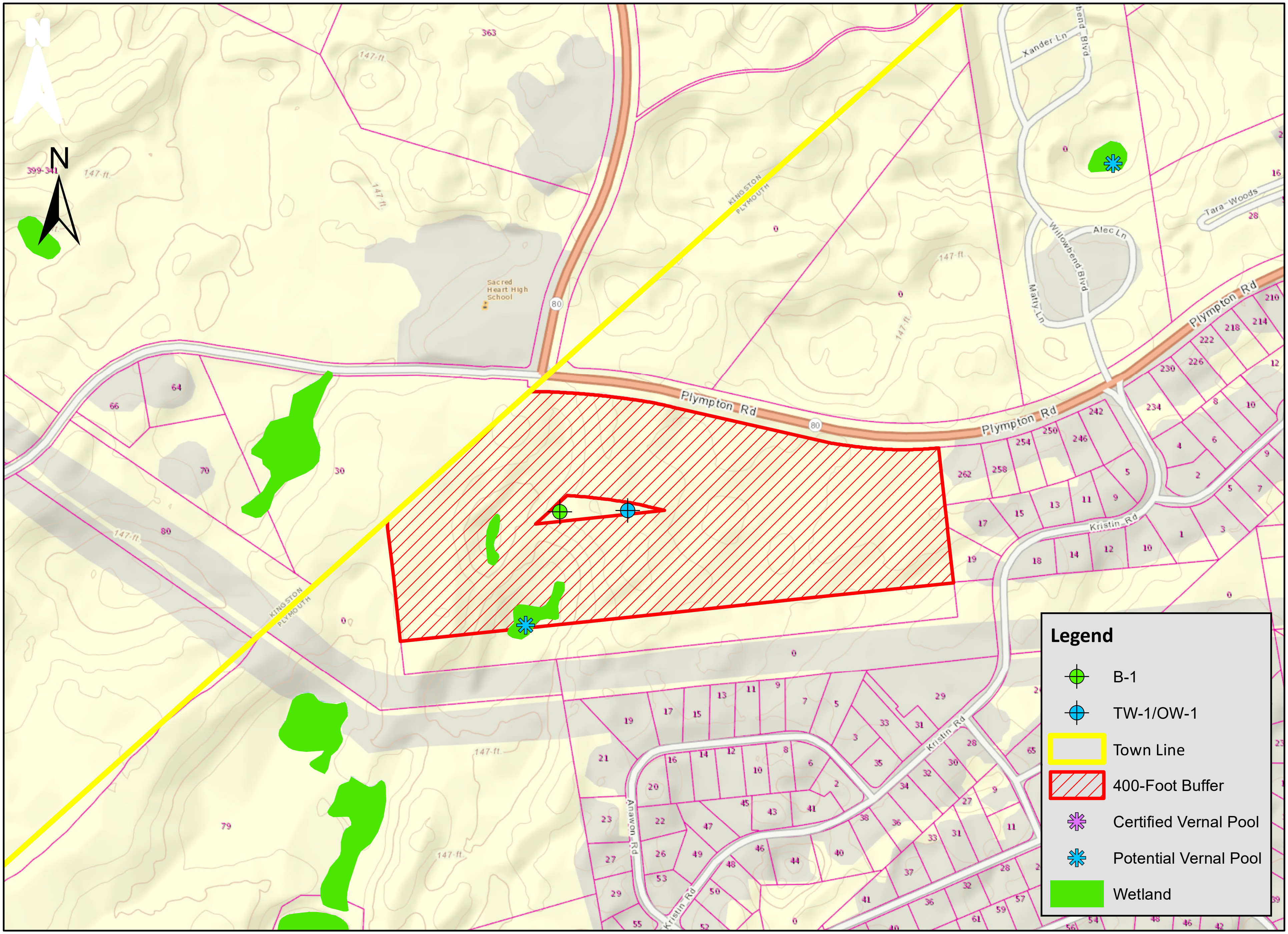
Figure 2: Site Plan
South Parting Ways Site
Plymouth, Massachusetts



Environmental Partners Group
A partnership for engineering solutions.

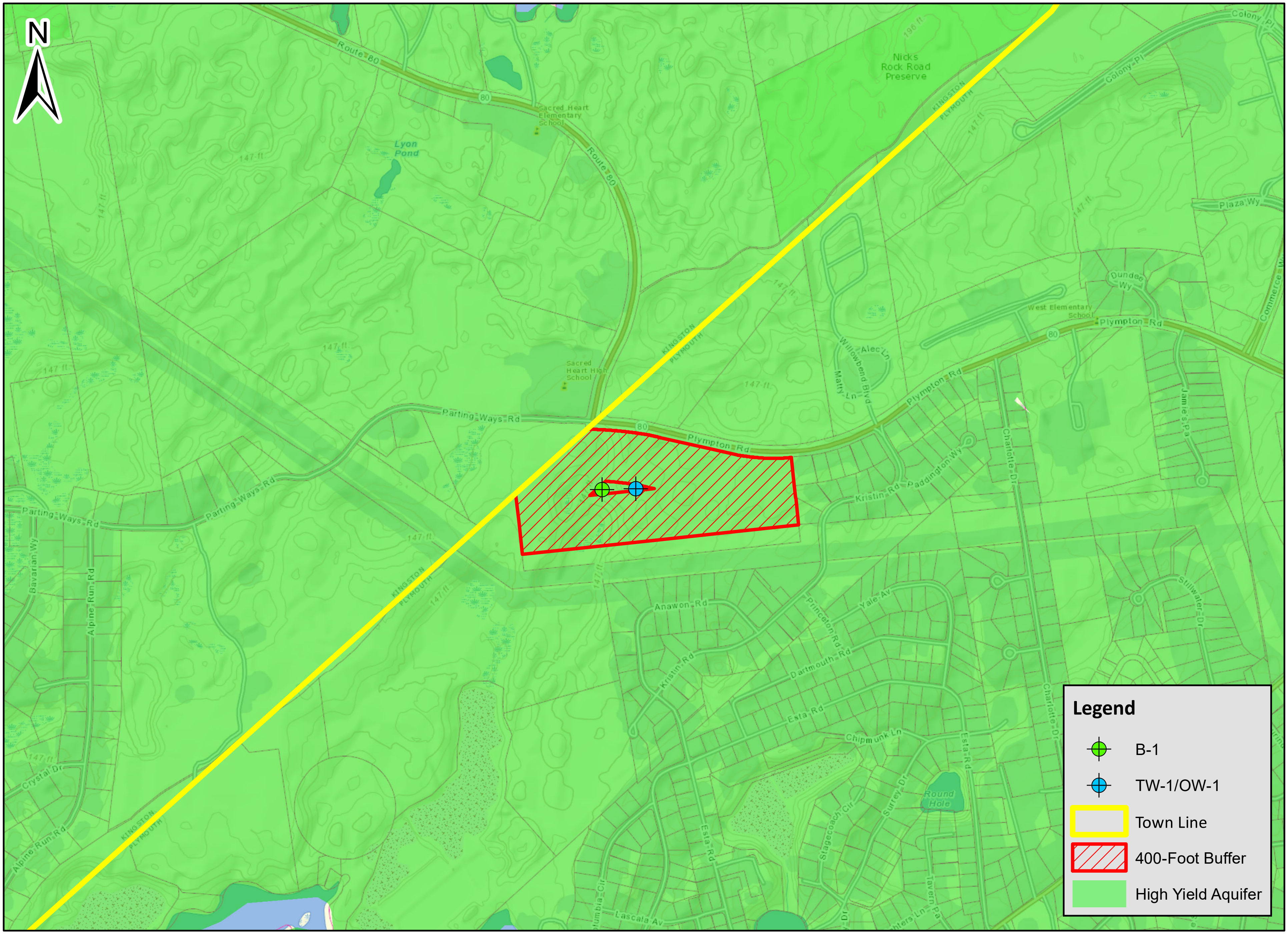
Figure 3: Open Space Protection
South Parting Ways Site
Plymouth, Massachusetts

0 0.05 0.1 0.2 Miles
1 inch = 500 feet



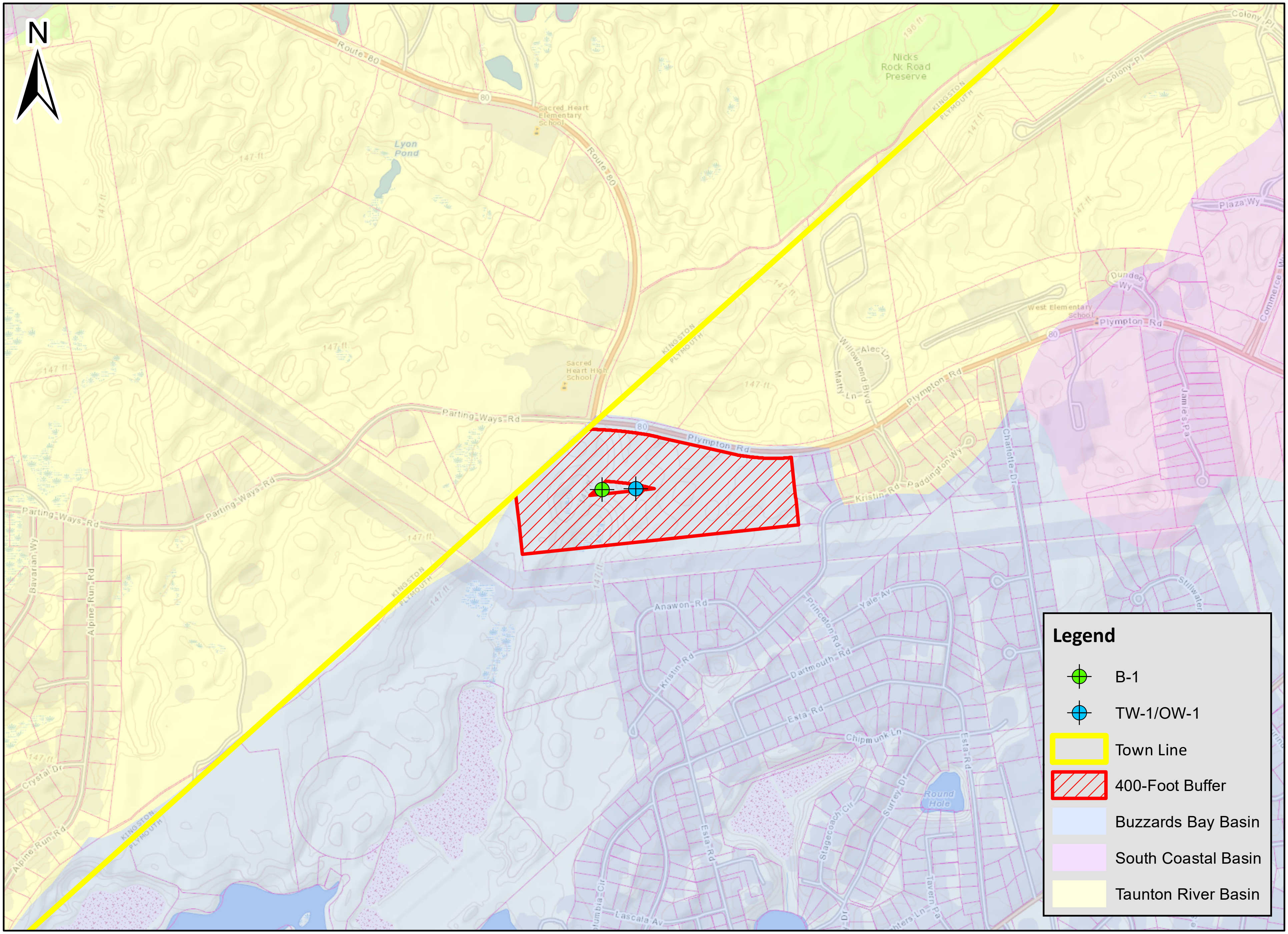
Environmental Partners GROUP
A partnership for engineering solutions.

Figure 3: Wetland Resource Areas
South Parting Ways Site
Plymouth, Massachusetts



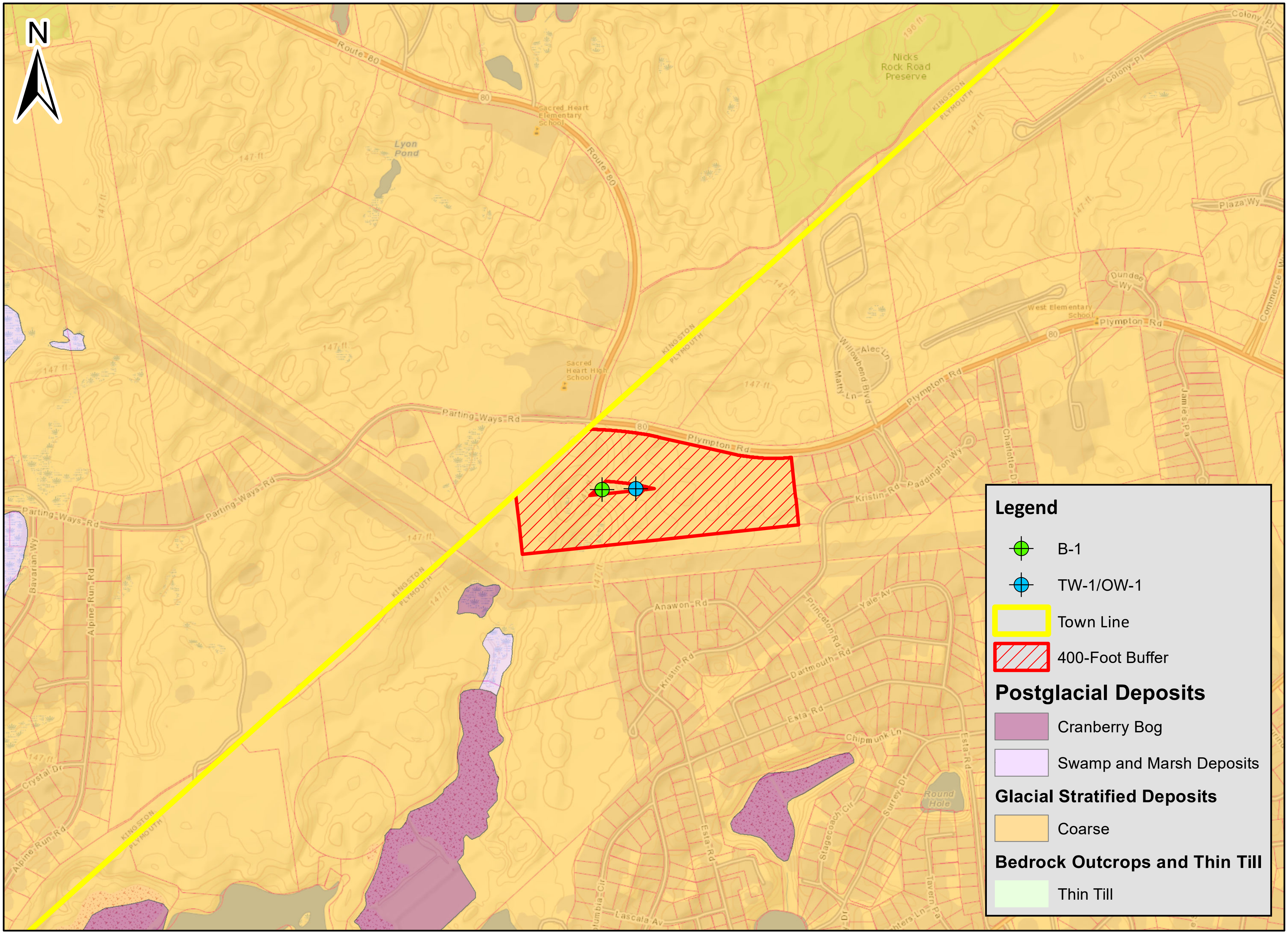
Environmental Partners GROUP
A partnership for engineering solutions.

Figure 6: Sub-Basins
South Parting Ways Site
Plymouth, Massachusetts



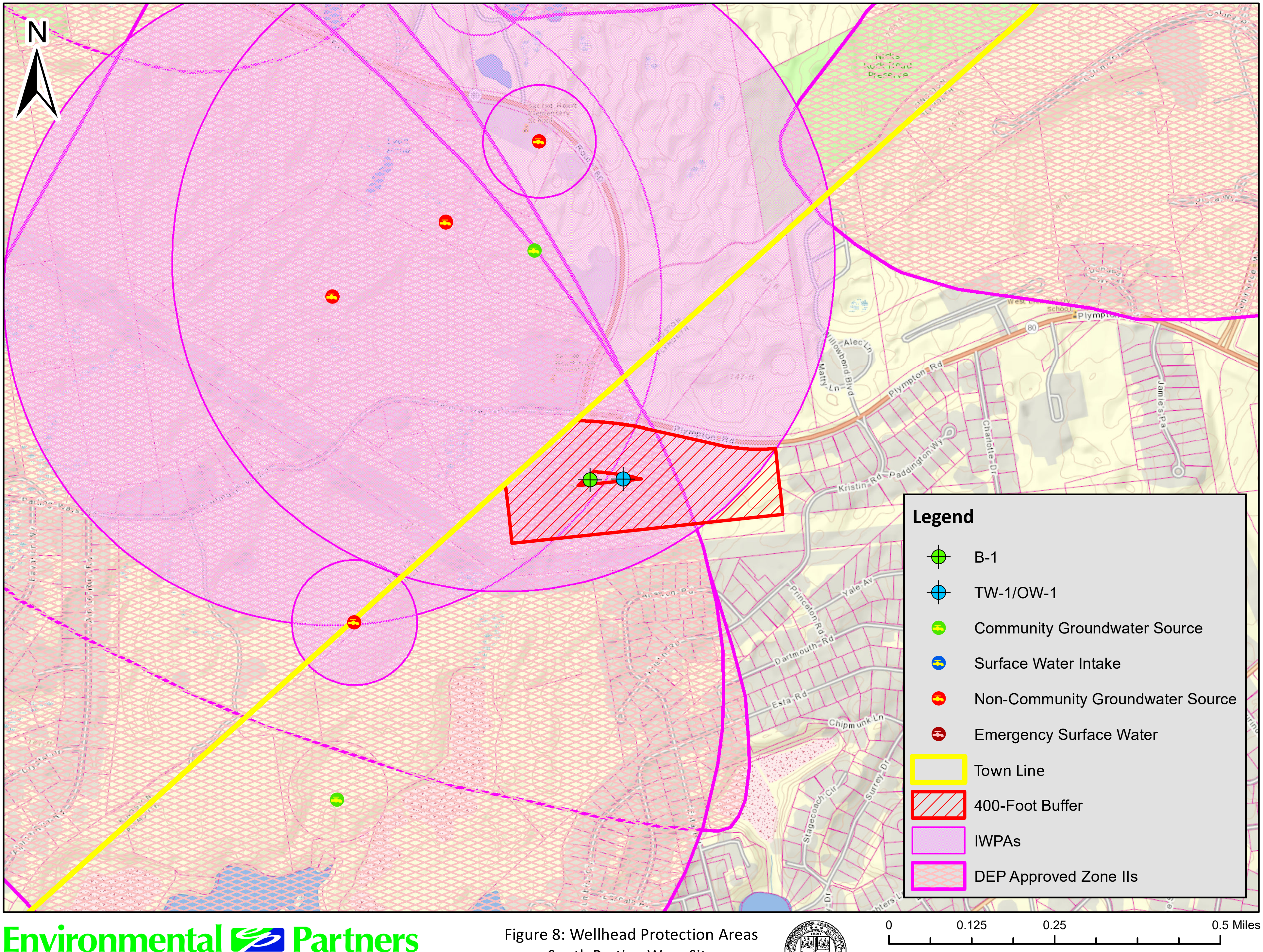
Environmental Partners Group
A partnership for engineering solutions.

Figure 6: Sub-Basins
South Parting Ways Site
Plymouth, Massachusetts



Environmental Partners GROUP
A partnership for engineering solutions.

Figure 7: Surficial Geology
South Parting Ways Site
Plymouth, Massachusetts



Environmental Partners GROUP
A partnership for engineering solutions.

Figure 8: Wellhead Protection Areas
South Parting Ways Site
Plymouth, Massachusetts

Appendix B

Briggs Site Groundwater Modeling Report

Briggs Site Preliminary Zone II

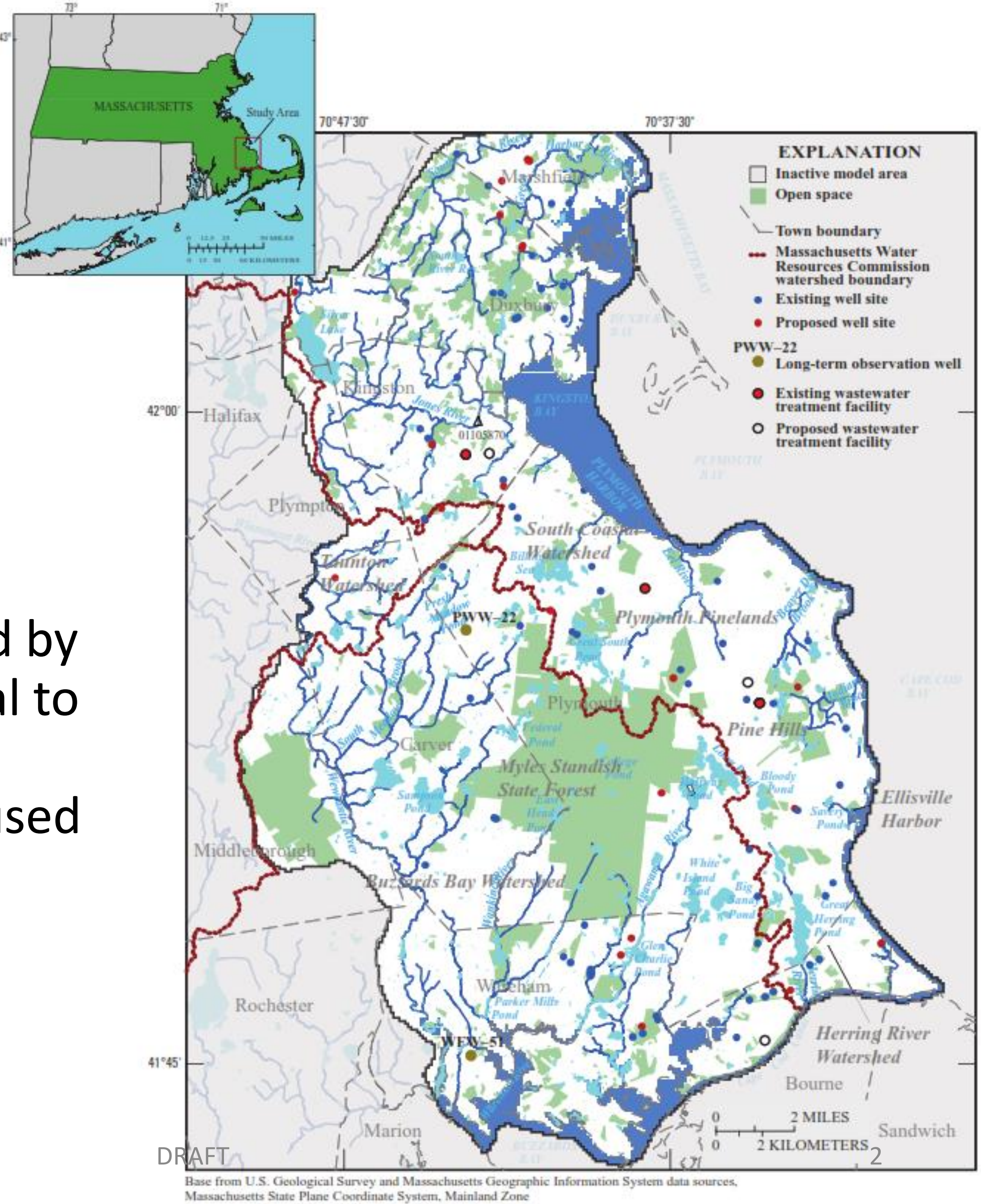
S. Plymouth, MA

9/6/2019

McLane Environmental LLC
Consulting Scientists & Engineers

Groundwater Flow Model

- The modified USGS Plymouth-Carver-Kingston-Duxbury MODFLOW model developed and utilized by McLane Environmental to develop a Zone II for Forges Field site was used as a starting point



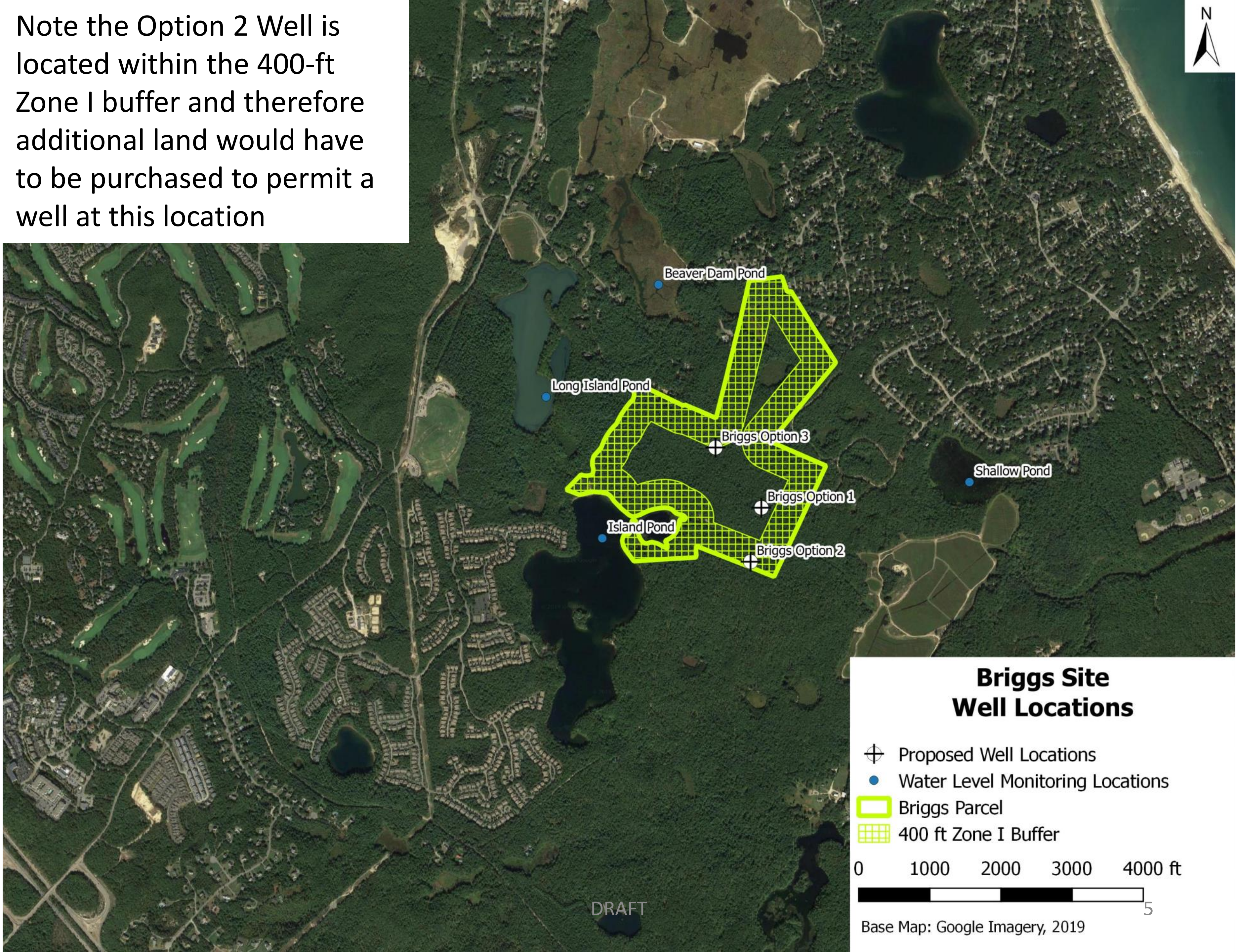
Model Modifications

- Refinement of the model grid near the Briggs Site
- Refinement of local geology based on the minimum calculated hydraulic conductivity (223 ft/d in Table 1) from Horsely Witten's (HW's) pumping test. This value was utilized for layers 4-7 of the model (-15 ft NGVD29 or ~90 ft bgs to bedrock, estimated at -100 ft NGVD29 or 175 ft bgs)
- Addition of 3 Pumping wells, corresponding to HW Option 1, 2, and 3; each well was screened in model layer 5 (~110 – 130 ft bgs)
- The Forges Field well was pumped at 1 MGD year round

Model Runs

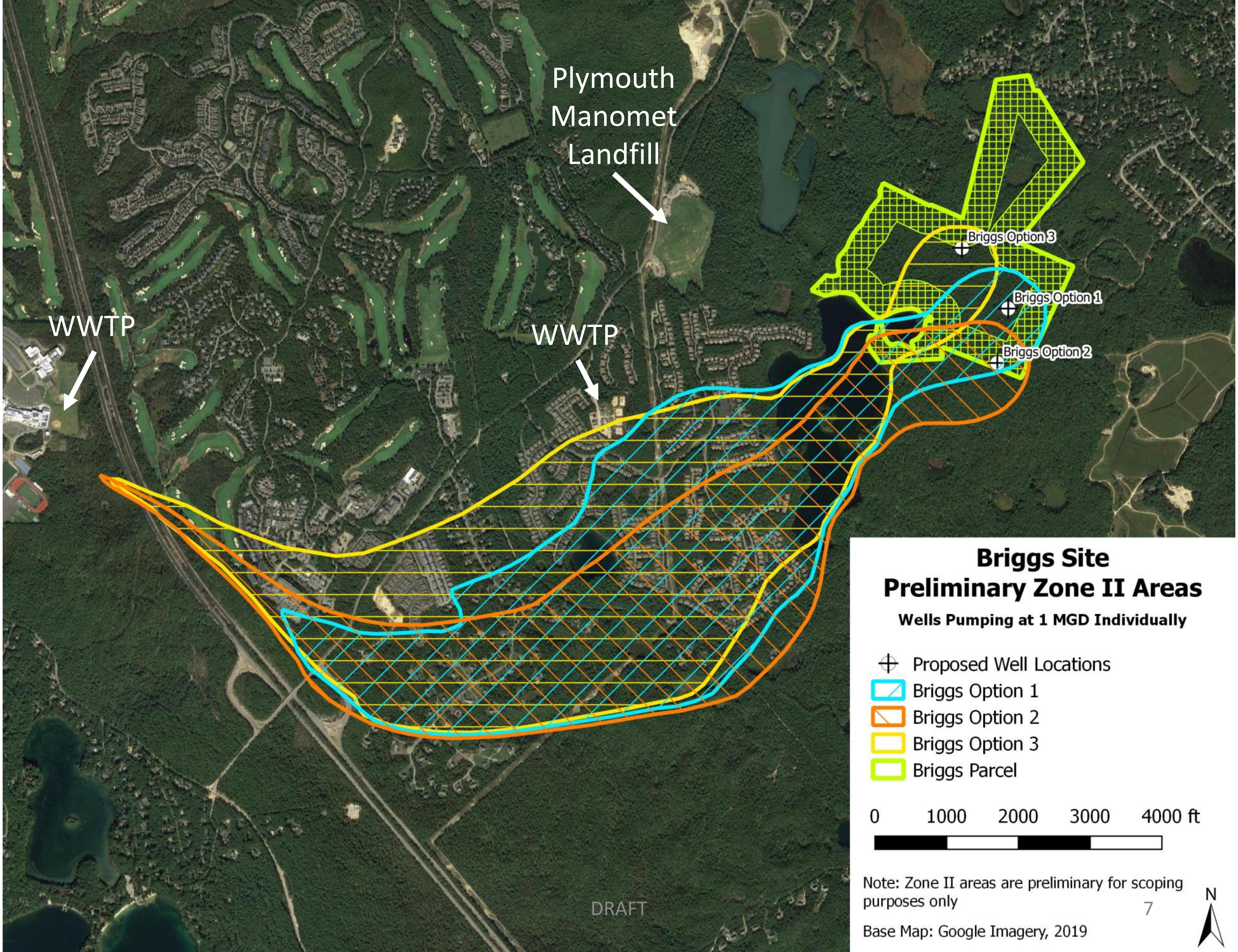
- 15 year transient run to set up initial conditions
- Zone II Runs - 180 day, no recharge from initial flat water table at:
  - 0.5 MGD Option 1
  - 1.0 MGD Option 1, 2, and 3
  - 2.0 MGD Option 1
- 15 year transient run with last 10 years pumping at:
  - 0.5 MGD Option 1
  - 1.0 MGD Option 1

Note the Option 2 Well is located within the 400-ft Zone I buffer and therefore additional land would have to be purchased to permit a well at this location



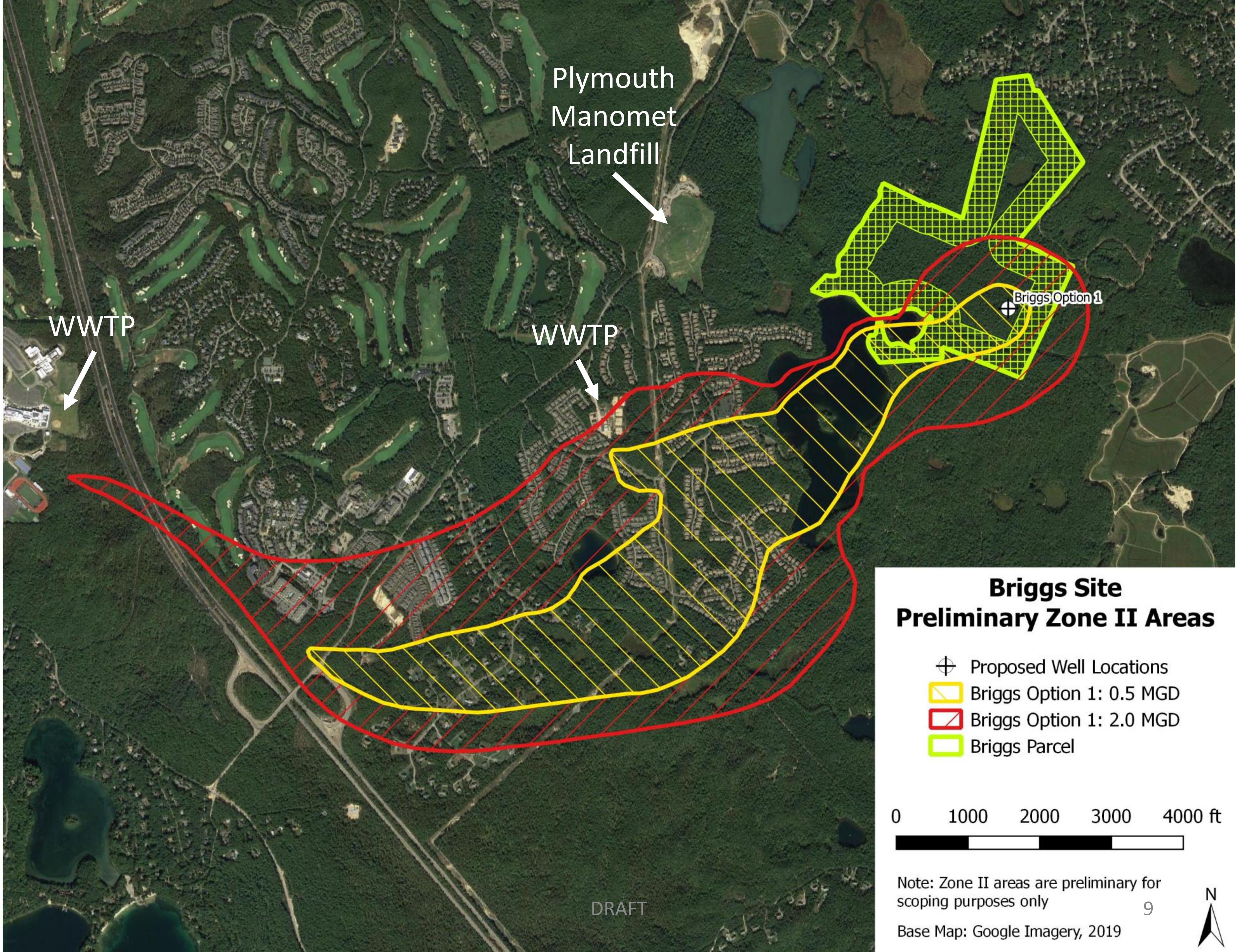
Zone II Model Runs: Options 1, 2, and 3

- Precipitation was removed from the model
- Initial water levels set to pre-pumping conditions
- Model was run using steady state pumping of <u>1 MGD</u> at each well option to compare resulting Zone II areas
- Zone II areas were delineated by releasing particles from the water table, tracking them forward through time until they reached a discharge point, and delineating the area of particles captured by the pumping well


Plymouth Manomet Landfill
WWTP
WWTP
Briggs Option 3
Briggs Option 1
Briggs Option 2
Briggs Site
Preliminary Zone II Areas
Wells Pumping at 1 MGD Individually
Proposed Well Locations
Briggs Option 1
Briggs Option 2
Briggs Option 3
Briggs Parcel
0 1000 2000 3000 4000 ft
Note: Zone II areas are preliminary for scoping purposes only
Base Map: Google Imagery, 2019
N
DRAFT

Zone II Model Runs: Option 1 – 0.5 MGD and 2.0 MGD

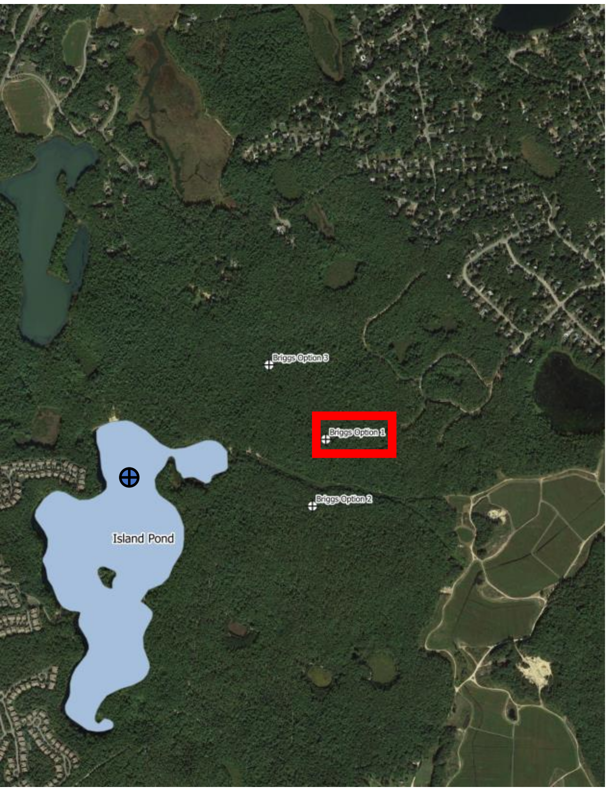
- Precipitation was removed from the model
- Initial water levels set to pre-pumping conditions
- Model was run using steady state pumping of 0.5 MGD and 2.0 MGD at only the Option 1 well to examine the increase in the Zone II area from increased pumping
- Zone II areas were delineated by releasing particles from the water table, tracking them forward through time until they reached a discharge point, and delineating the area of particles captured by the pumping well


Plymouth Manomet Landfill
WWTP
WWTP
Briggs Option 1
Briggs Site
Preliminary Zone II Areas
Proposed Well Locations
Briggs Option 1: 0.5 MGD
Briggs Option 1: 2.0 MGD
Briggs Parcel
0 1000 2000 3000 4000 ft
Note: Zone II areas are preliminary for scoping purposes only
Base Map: Google Imagery, 2019
N
DRAFT

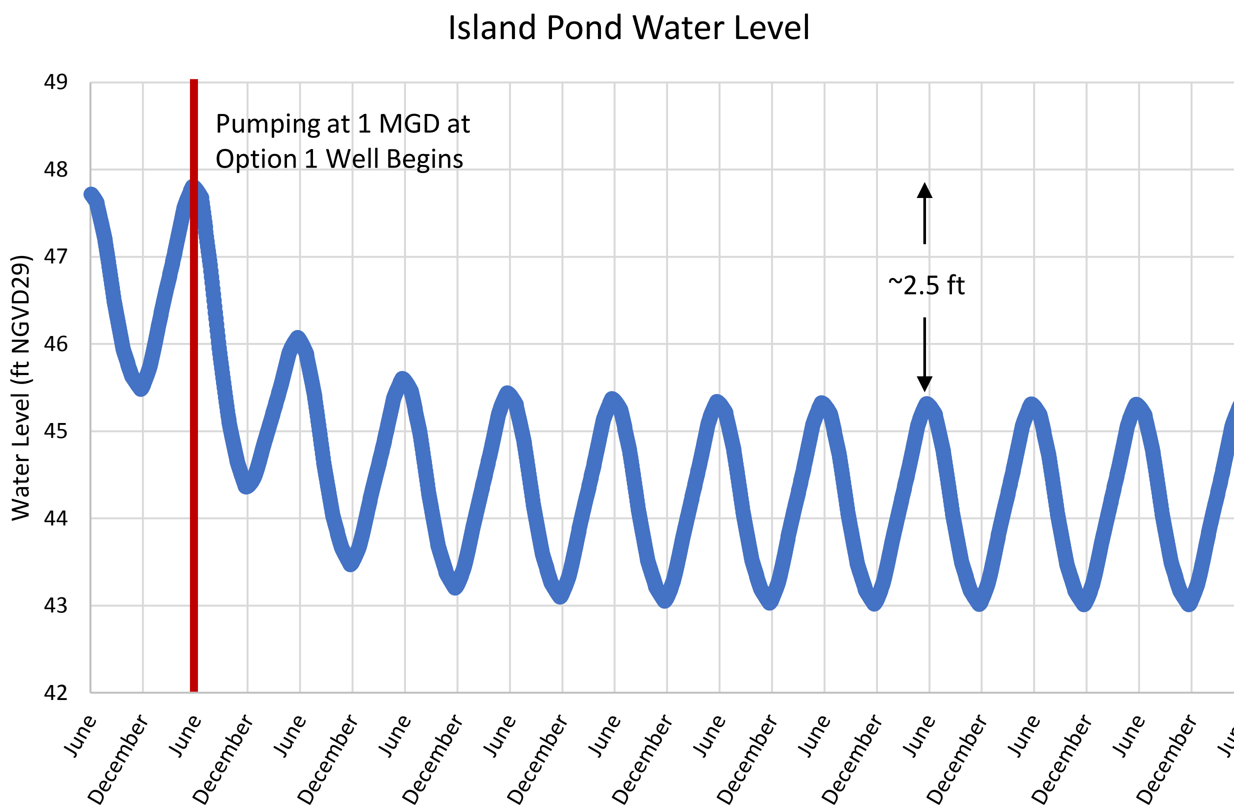
Long Term Drawdown in Ponds

- 15 year transient models were used with transient seasonal recharge
- After a 5 year spin up time, the Option 1 Well began pumping at a specified steady rate (<u>0.5 MGD and 1 MGD</u>)
- The nearby ponds (Island Pond, Long Island Pond, Shallow Pond, and Beaver Pond) were monitored over time to determine the impact of pumping on their seasonal water levels

Preliminary Drawdown in Island Pond with Option 1 Pumping at 1 MGD

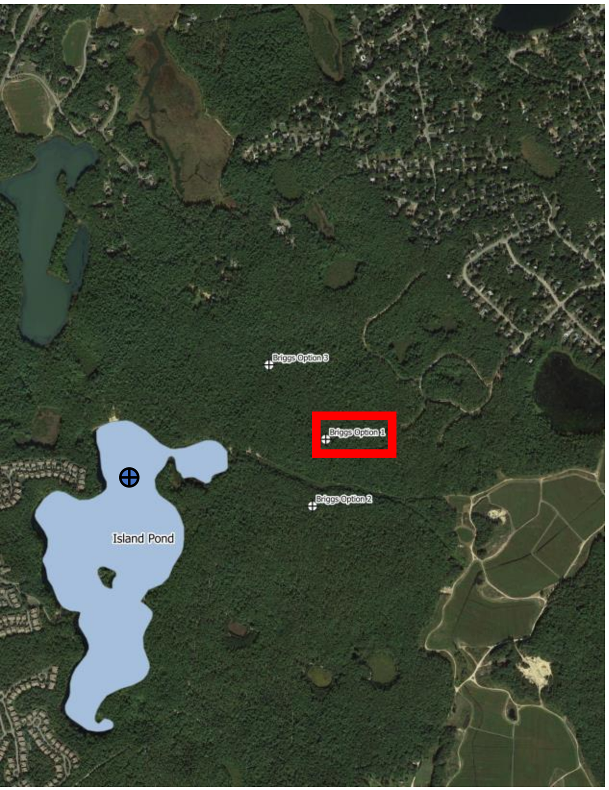


⊕ - Approximate Model Monitoring Well Location

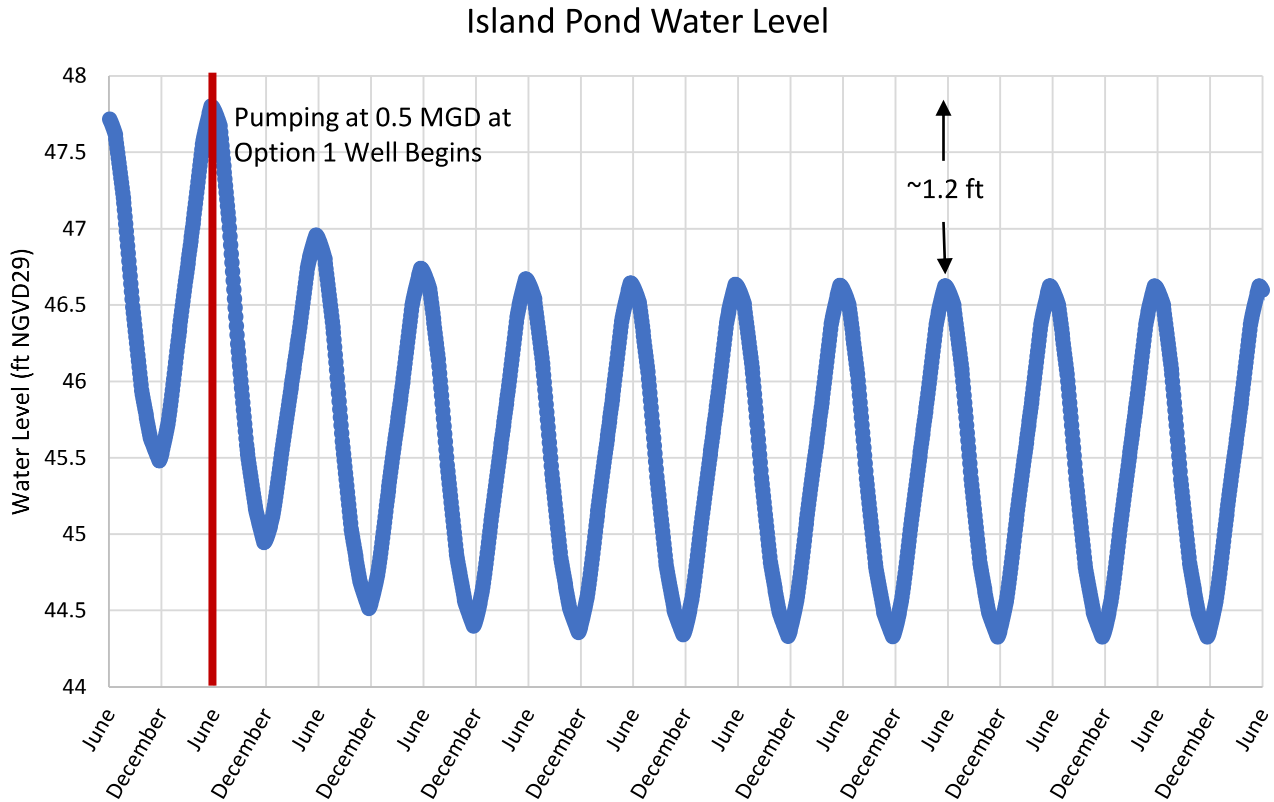


Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.

Preliminary Drawdown in Island Pond with Option 1 Pumping at 0.5 MGD



⊕ - Approximate Model Monitoring Well Location

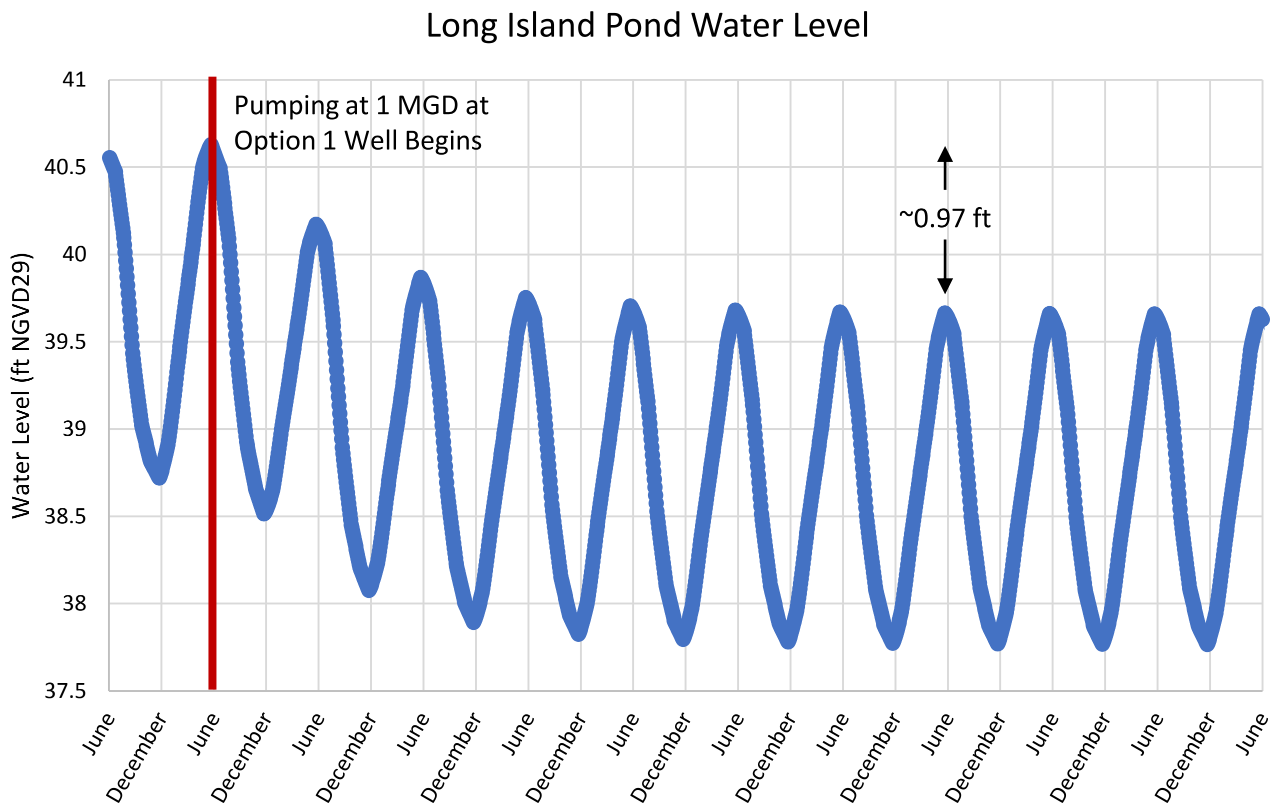


Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.

DRAFT

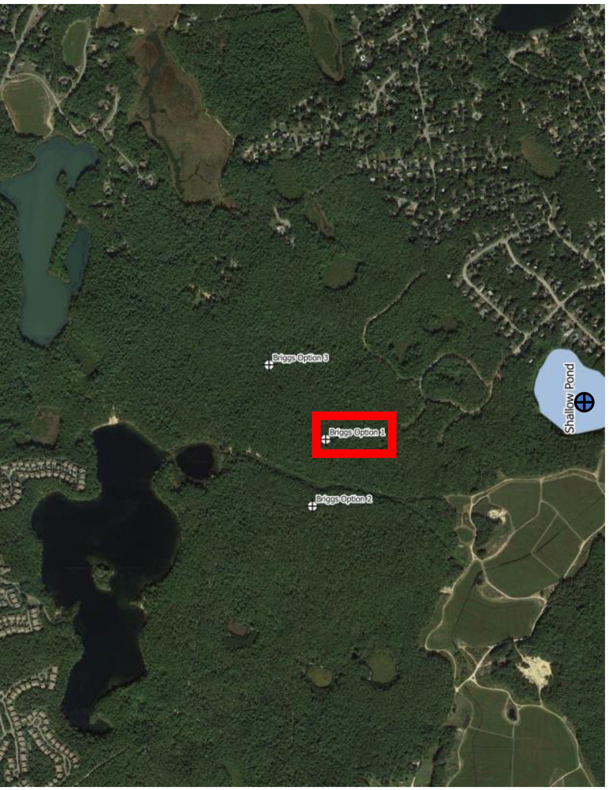
Preliminary Drawdown in Long Island Pond with Option 1 Pumping at 1 MGD

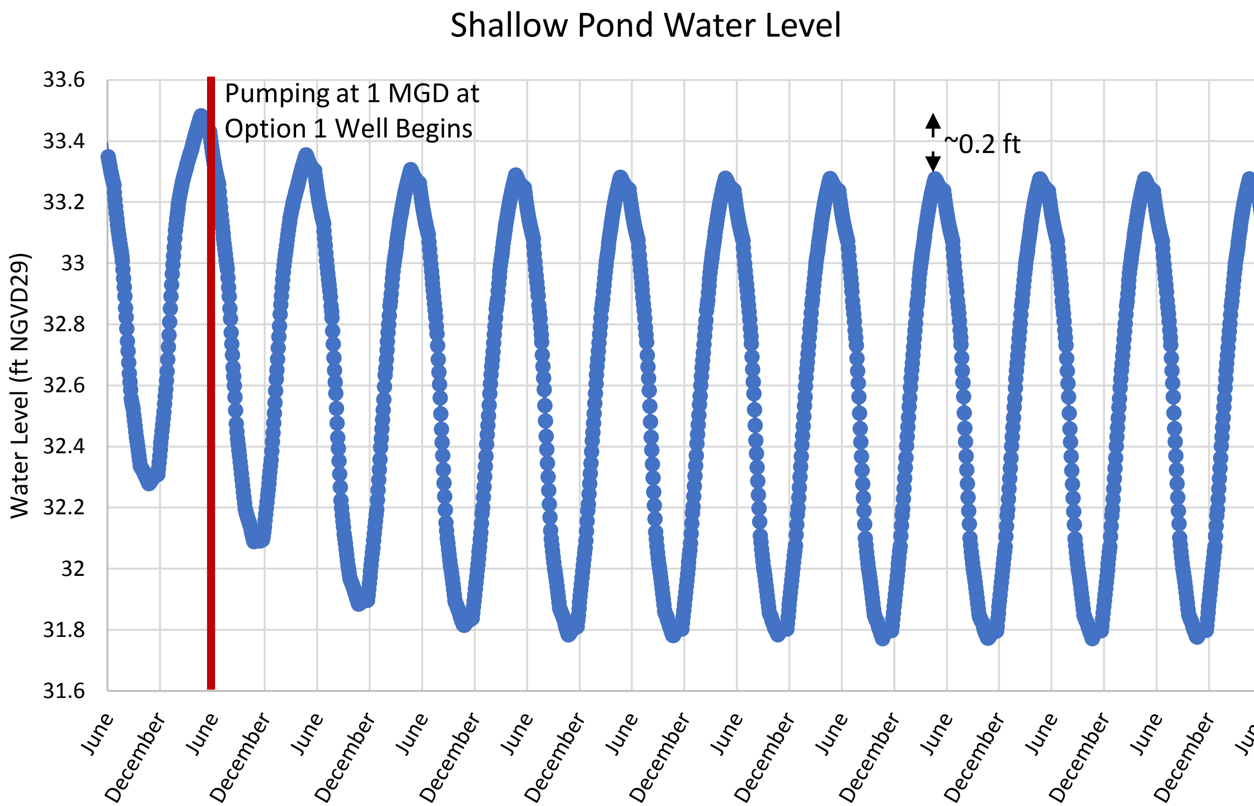
⊕ - Approximate Model Monitoring Well Location



Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.

Preliminary Drawdown in Shallow Pond with Option 1 Pumping at 1 MGD





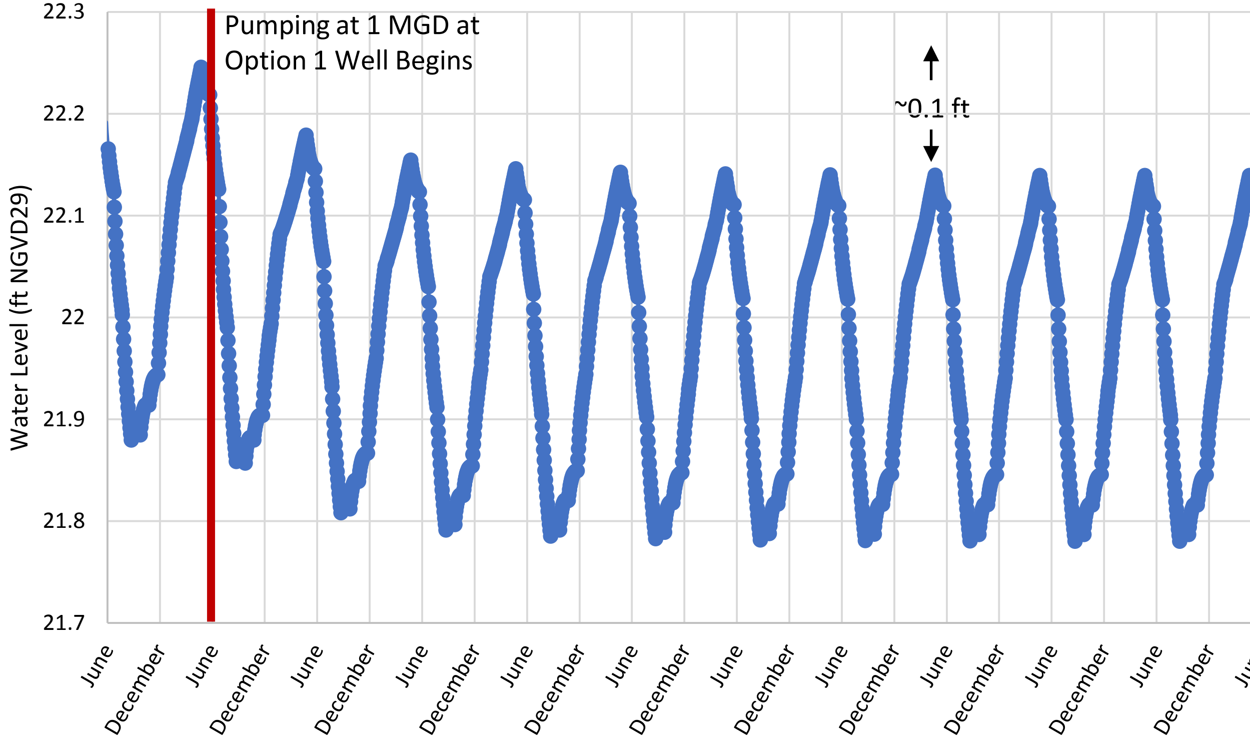
Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.

⊕ - Approximate Model Monitoring Well Location

Preliminary Drawdown in Beaver Dam Pond with Option 1 Pumping at 1 MGD

⊕ - Approximate Model Monitoring Well Location

Beaver Dam Pond Water Level



Results based on preliminary modeling using a modified version of the USGS Plymouth-Carver-Kingston-Duxbury Aquifer System MODFLOW model.

Appendix C

Entergy Parcels Desktop Study

C.1 Entergy Parcels

With the closing of the Entergy Pilgrim Power Plant in Plymouth on May 31, 2019, the Entergy parcels were identified as a potential area for new source water supply exploration. The Entergy parcels have fewer environmental receptors nearby, relative to other potential water supply sites identified.

Environmental Partners reviewed the Entergy owned land and delineated those areas that could support a 400-foot Zone I radius. The 400-foot Zone I buffer was applied to property boundaries and to any roadway, powerline easements, etc. Figure 5-24 attached is an aerial photo of the Entergy parcel with 400-foot Zone I buffers. Several fire roads are identified within the Entergy parcel. A 400-foot Zone I buffer is not drawn around these roadways, as they were considered non-essential roadways that could be acquired by the Division to maintain ownership and control of the Zone I area. This assumption would be evaluated further if a potential water supply wellsite were identified where there is a fire road crossing.

The available Entergy parcels that could support ownership and control of the 400-foot Zone I were further evaluated based on the additional desktop screening criterial listed.

Areas along the east side of the Entergy parcel were not considered for a potential water supply source, because of environmental receptor issues. The east side of the Entergy parcel is located within or adjacent to the Eel River Watershed (a designated cold water fishery) and the Forges Field new source water supply site, currently being developed by the Division, is located within the Eel River Watershed. Screening of potential sites is discussed below.

C.1.1 Surficial Geology

Figure 5-25 attached is a USGS Surficial Geology Map (2018) with the Entergy parcels outlined. As shown on this map in green, much of the Entergy land is underlain by non-aquifer material (compact till). Three areas are identified with potential aquifer material (coarse deposits) shown on Figure 5-24 and designated Site #1, Site #2 and Site #3. Two additional sites were selected for further evaluation (Sites #4 and #5) that are located on the Entergy parcel, close to the mapped coarse deposits. The rationale being that the compact till may be underlain by some coarse deposits.

C.1.2 Land Uses

Figure 5-26 is a land use map. All five Sites are located in forested areas. At all five sites a well can be located such that the well and associated 400-foot Zone I consists completely of forest. Land uses within ½-mile of each site are discussed below.

Site #1 – land uses within ½ mile consist predominately of forest, very low, low, medium and high density residential, and multifamily, with a small area of participatory recreation (baseball field), commercial, a cemetery, powerline easement, and small areas of non-forested and forested wetland.

Site #2 – land uses within ½ mile consist predominately of forest, very low, low, medium and high density residential, and multifamily, with a small area of participatory recreation, forested wetland, a cranberry bog, and ocean. Site #1 is located 3,200 feet from Cape Cod Bay.

Public water supply wells located in areas too close to the coastline may be impacted by saltwater intrusion or saltwater upconing as a result of wellfield pumping, rendering the wells non-potable. Therefore, the northern portion of Parcel #2 is considered less favorable than the southern portion because of proximity to Plymouth Bay. The southern portion of Site #2 is located 1,600 feet from Cape Cod Bay and has a ground elevation of approximately 82 feet above sea level. According to USGS modeling, the water table elevation is approximately 24 feet above sea level. Based on a water table elevation of 24 feet above sea level, the Ghyben-Herzberg Relation was used to estimate the depth of fresh water in the aquifer below sea level to be approximately 960 ft.

Site #3 – land uses within ½ mile consist predominately of forest. There is one area of commercial use that appears to be a boat storage site, open land, and some industrial (Pilgrim Nuclear Power Plant). Site #3 is located 3,300 feet from Cape Cod Bay and is furthest from the coastline. Proximity to the Pilgrim Nuclear Power Plant may eliminate this area as a potential water supply source.

Site #4 – land uses within ½ mile consist predominately of forest, very low and low density residential, and multifamily, a small areas of commercial, powerline easement, small areas of non-forested and forested wetland.

Site #5 – land uses within ½ mile consist primarily of forest, cranberry bogs, low density and multifamily residential, and powerline easement.

C.1.3 Environmental Receptors

Figure 5-27 is a site plan showing environmental receptors within ½ mile of the potential sites.

Site #1 has a potential vernal pool with small area of wetland on the parcel and three other potential vernal pools and a small area of wetland within a ½-mile radius. A sanitary discharge site is located at the edge of the ½-mile radius and probably a package treatment plant for the multifamily residential properties.

Site #2 has a potential vernal pool on the parcel and three other potential vernal pools and a wetland area within a ½-mile radius.

Site #3 has two potential vernal pools and an area of wetlands within a ½-mile radius. The Pilgrim Nuclear Power Plant is located approximately ½-mile from Site #3 and is a MA and EPA/RCRA-regulated Hazardous Waste generator.

Site #4 has four potential vernal pools and some cranberry bogs within a ½-mile radius and a sanitary discharge site that is probably a package treatment plant for the multifamily residential properties.

Site #5 has three potential vernal pools and some cranberry bogs within a ½-mile radius.

C.1.4 Aquifers

Figure 5-28 is a map showing aquifer zones. All five potential water supply sites are shown as being underlain by high yield aquifer material.

C.1.5 Release Sites

In addition to the Energy Nuclear Power Plant, two additional hazardous waste sites of concern are identified in the vicinity of the potential water supply sites, shown on Figure 5-26. The two sites are MassDEP MCP state release sites and are located in the vicinity of Sites #1 and #2. The closest release site is located at 506 State Road and is the location of a former gasoline station. The initial release notification for the site was 1995 (RTN 5-0011713) and a subsequent release notification was reported on October 10, 2012 (RTN 4-4-0024233). The 2012 notification was for a release to the environmental indicated by the presence of a subsurface non-aqueous phase liquid (NAPL) having a measured thickness greater than ½-inch. Approximately one foot of gasoline NAPL was measured in a groundwater monitoring well. The measured depth to water at the Site is approximately 45 feet below grade. The suspected source of the release is a former 2,000-gallon gasoline underground storage tank. Historically, the site had 18,000 gallons of gasoline in underground storage tanks. Reported groundwater flow direction is towards the north-northeast. The site is listed as Phase V, which is ongoing Operation and Maintenance and a permanent or temporary solutions statement has not been achieved.

A second release site is identified that was reported in March 2008 for the release of petroleum hydrocarbons and 2-methylnapthalene to soils. The site is listed has having a Class A-2 RAO, dated July 2008. This site is located across the street from the gasoline release site.

These two release sites are located approximately 1,700 feet south-southeast and upgradient of Site #1, 2,200 feet south-southeast and upgradient of Site #2 and 2,400 feet east-southeast and cross-gradient of Site #4 and 4,000 feet downgradient from Site #5.

C.1.6 Elevations

Figure 5-29 is a map showing elevations. Areas with higher elevations tend to have thicker compact till, which is considered non-aquifer material. Also, the depth to the water table is deeper in the areas with higher elevations. Sites #1 and #2 are all located at an elevation less than 100 feet. Site #3 is located at an elevation of approximately 250 feet indicating the potential presence of thick compact till, even though the surficial geology map indicates the presence of coarse deposits. Site #4 was selected to be located as close to the mapped coarse deposits and also be located at the lowest elevation. Site #4 is located at an elevation of approximately 150 feet and Site #5 is located at an elevation of approximately 225 feet.

C.1.7 Conclusions

Five potential water supply sites within the Entergy owned parcels of land were identified for further desktop screening (shown on Figure 5-24). The results of this additional desktop screening indicate that:

Site #1 is a considered as having a low potential for water supply development because of the close proximity of a hazardous waste site (1,700 feet upgradient) with NAPL (gasoline). The site appears to be underlain by good aquifer material. Land uses within a ½-mile radius are consistent with water supply development requirements. Potential environmental receptors identified within a ½-mile radius are potential vernal pools and small areas of wetlands. Additional subsurface explorations is not recommended for this parcel.

Site #2 is considered as having a low potential for water supply development because this site is located downgradient from a hazardous waste site (3,700 feet) with NAPL (gasoline) and relatively close to the coastline and Cape Cod Bay. As such, development of a water supply well at this site may be impacted by the reported gasoline release and/or saltwater upconing or saltwater intrusion, rendering the water supply non-potable.

Site #3 is considered as having a low potential for water supply development because the site is located within a ½-mile of the Pilgrim Nuclear Power Plant, which is a Massachusetts and EPA/RCRA-regulated Hazardous Waste generator. Also, the potential for aquifer material is questionable because the site is located at a relatively high elevation, suggesting the presence of thick compact till (non-aquifer material) beneath the coarse deposits.

Site #4 is considered a low potential water supply exploration site. This site was selected to be located near the edge of the area mapped as compact till and at the lowest elevation (150 feet). The site is located 2,400 feet cross-gradient from the state hazardous waste site with gasoline NAPL and as such, it's not directly evident whether the gasoline release could impact water quality at this site. A subsurface investigation would be required to determine if the area is underlain by coarse deposits suitable for public water supply development. In addition, assessment and/or modeling would need to be done to determine if a public water supply well at this location could be impacted by the state hazardous waste sites.

Site #5 is considered a potential water supply. Land uses within a ½-mile radius are consistent with water supply development. This site was selected to be located near the edge of the area mapped as compact till and at an elevation of approximately 200 feet. No hazardous waste sites are identified that would impact water quality. Additional subsurface investigation would be required to determine if the area is underlain by coarse deposits suitable for public water supply development.

In summary, preliminary assessment of the Entergy Parcels indicate that potential new source water supply sites in this area may be limited by available aquifer material and proximity to hazardous waste sites or potential hazardous waste sites. Additional subsurface investigation should be performed at the Site #5 location to determine if this location is a potential public water supply site. The presence of few environmental receptors near Site #5, relative to all other potential water supply sites identified, would support that additional subsurface investigation is recommended.

Appendix D

ISO Public Protection Classification Summary Report

1000 Bishops Gate Blvd. Ste 300
Mt. Laurel, NJ 08054-5404

t1.800.444.4554 Opt.2
f1.800.777.3929

June 24, 2019

Ms. Melissa Arrighi, Manager
Plymouth
26 Court Street
Plymouth, Massachusetts, 02360

RE: Plymouth, Plymouth County, Massachusetts
Public Protection Classification: 03/3Y
Effective Date: October 01, 2019

Dear Ms. Melissa Arrighi,

We wish to thank you and Chief G. Edward Bradley for your cooperation during our recent Public Protection Classification (PPC) survey. ISO has completed its analysis of the structural fire suppression delivery system provided in your community. The resulting classification is indicated above.

If you would like to know more about your community's PPC classification, or if you would like to learn about the potential effect of proposed changes to your fire suppression delivery system, please call us at the phone number listed below.

ISO's Public Protection Classification Program (PPC) plays an important role in the underwriting process at insurance companies. In fact, most U.S. insurers – including the largest ones – use PPC information as part of their decision- making when deciding what business to write, coverage's to offer or prices to charge for personal or commercial property insurance.

Each insurance company independently determines the premiums it charges its policyholders. The way an insurer uses ISO's information on public fire protection may depend on several things – the company's fire-loss experience, ratemaking methodology, underwriting guidelines, and its marketing strategy.

Through ongoing research and loss experience analysis, we identified additional differentiation in fire loss experience within our PPC program, which resulted in the revised classifications. We based the differing fire loss experience on the fire suppression capabilities of each community. The new classifications will improve the predictive value for insurers while benefiting both commercial and residential property owners. We've published the new classifications as "X" and "Y" — formerly the "9" and "8B" portion of the split classification, respectively. For example:

- A community currently graded as a split 6/9 classification will now be a split 6/6X classification; with the "6X" denoting what was formerly classified as "9."
- Similarly, a community currently graded as a split 6/8B classification will now be a split 6/6Y classification, the "6Y" denoting what was formerly classified as "8B."

- Communities graded with single "9" or "8B" classifications will remain intact.
- Properties over 5 road miles from a recognized fire station would receive a class 10.

PPC is important to communities and fire departments as well. Communities whose PPC improves may get lower insurance prices. PPC also provides fire departments with a valuable benchmark, and is used by many departments as a valuable tool when planning, budgeting and justifying fire protection improvements.

ISO appreciates the high level of cooperation extended by local officials during the entire PPC survey process. The community protection baseline information gathered by ISO is an essential foundation upon which determination of the relative level of fire protection is made using the Fire Suppression Rating Schedule.

The classification is a direct result of the information gathered, and is dependent on the resource levels devoted to fire protection in existence at the time of survey. Material changes in those resources that occur after the survey is completed may affect the classification. Although ISO maintains a pro-active process to keep baseline information as current as possible, in the event of changes please call us at 1-800-444-4554, option 2 to expedite the update activity.

ISO is the leading supplier of data and analytics for the property/casualty insurance industry. Most insurers use PPC classifications for underwriting and calculating premiums for residential, commercial and industrial properties. The PPC program is not intended to analyze all aspects of a comprehensive structural fire suppression delivery system program. It is not for purposes of determining compliance with any state or local law, nor is it for making loss prevention or life safety recommendations.

If you have any questions about your classification, please let us know.

Sincerely,

Alex Shubert

Alex Shubert
Manager -National Processing Center

cc: Chief G. Edward Bradley, Chief, Plymouth Fire Department
Miss Steve Souza, Water Superintendent, Buzzards Bay Water District
Mr. Rich Tierney, Water Superintendent, Plymouth Town of
Mr. Dan Gorczyca, Manager, Plymouth-Agawam Springs Water Co
Mr. Don Rugg, Water Superintendent, Plymouth-Pinehills
Mr. Allen Melanson, Water Superintendent, Plymouth-The Ponds
Chief Michael Botieri, Chief Administrative Officer, Plymouth

Public Protection Classification (PPC™) Summary Report

Plymouth

MASSACHUSETTS

Prepared by

Insurance Services Office, Inc.
1000 Bishops Gate Blvd., Ste. 300
P.O. Box 5404
Mt. Laurel, New Jersey 08054-5404
1-800-444-4554

Report Created June 24, 2019

Effective October 1, 2019

Background Information

Introduction

ISO collects and evaluates information from communities in the United States on their structure fire suppression capabilities. The data is analyzed using our Fire Suppression Rating Schedule (FSRS) and then a Public Protection Classification (PPC™) grade is assigned to the community. The surveys are conducted whenever it appears that there is a possibility of a PPC change. As such, the PPC program provides important, up-to-date information about fire protection services throughout the country.

The FSRS recognizes fire protection features only as they relate to suppression of first alarm structure fires. In many communities, fire suppression may be only a small part of the fire department's overall responsibility. ISO recognizes the dynamic and comprehensive duties of a community's fire service, and understands the complex decisions a community must make in planning and delivering emergency services. However, in developing a community's PPC grade, only features related to reducing property losses from structural fires are evaluated. Multiple alarms, simultaneous incidents and life safety are not considered in this evaluation. The PPC program evaluates the fire protection for small to average size buildings. Specific properties with a Needed Fire Flow in excess of 3,500 gpm are evaluated separately and assigned an individual PPC grade.

A community's investment in fire mitigation is a proven and reliable predictor of future fire losses. Statistical data on insurance losses bears out the relationship between excellent fire protection – as measured by the PPC program – and low fire losses. So, insurance companies use PPC information for marketing, underwriting, and to help establish fair premiums for homeowners and commercial fire insurance. In general, the price of fire insurance in a community with a good PPC grade is substantially lower than in a community with a poor PPC grade, assuming all other factors are equal.

ISO is an independent company that serves insurance companies, communities, fire departments, insurance regulators, and others by providing information about risk. ISO's expert staff collects information about municipal fire suppression efforts in communities throughout the United States. In each of those communities, ISO analyzes the relevant data and assigns a PPC grade – a number from 1 to 10. Class 1 represents an exemplary fire suppression program, and Class 10 indicates that the area's fire suppression program does not meet ISO's minimum criteria.

ISO's PPC program evaluates communities according to a uniform set of criteria, incorporating nationally recognized standards developed by the National Fire Protection Association and the American Water Works Association. A community's PPC grade depends on:

- **Needed Fire Flows**, which are representative building locations used to determine the theoretical amount of water necessary for fire suppression purposes.
- **Emergency Communications**, including emergency reporting, telecommunicators, and dispatching systems.
- **Fire Department**, including equipment, staffing, training, geographic distribution of fire companies, operational considerations, and community risk reduction.
- **Water Supply**, including inspection and flow testing of hydrants, alternative water supply operations, and a careful evaluation of the amount of available water compared with the amount needed to suppress fires up to 3,500 gpm.

Data Collection and Analysis

ISO has evaluated and classified over 46,000 fire protection areas across the United States using its FSRS. A combination of meetings between trained ISO field representatives and the dispatch center coordinator, community fire official, and water superintendent is used in conjunction with a comprehensive questionnaire to collect the data necessary to determine the PPC grade. In order for a community to obtain a grade better than a Class 9, three elements of fire suppression features are reviewed. These three elements are Emergency Communications, Fire Department, and Water Supply.

A review of the **Emergency Communications** accounts for 10% of the total classification. This section is weighted at **10 points,** as follows:

- Emergency Reporting 3 points
- Telecommunicators 4 points
- Dispatch Circuits 3 points

A review of the **Fire Department** accounts for 50% of the total classification. ISO focuses on a fire department's first alarm response and initial attack to minimize potential loss. The fire department section is weighted at **50 points,** as follows:

- Engine Companies 6 points
- Reserve Pumpers 0.5 points
- Pump Capacity 3 points
- Ladder/Service Companies 4 points
- Reserve Ladder/Service Trucks 0.5 points
- Deployment Analysis 10 points
- Company Personnel 15 points
- Training 9 points
- Operational considerations 2 points
- Community Risk Reduction 5.5 points (in addition to the 50 points above)

A review of the **Water Supply** system accounts for 40% of the total classification. ISO reviews the water supply a community uses to determine the adequacy for fire suppression purposes. The water supply system is weighted at **40 points,** as follows:

- Credit for Supply System 30 points
- Hydrant Size, Type & Installation 3 points
- Inspection & Flow Testing of Hydrants 7 points

There is one additional factor considered in calculating the final score – **Divergence**.

Even the best fire department will be less than fully effective if it has an inadequate water supply. Similarly, even a superior water supply will be less than fully effective if the fire department lacks the equipment or personnel to use the water. The FSRS score is subject to modification by a divergence factor, which recognizes disparity between the effectiveness of the fire department and the water supply.

The Divergence factor mathematically reduces the score based upon the relative difference between the fire department and water supply scores. The factor is introduced in the final equation.

PPC Grade

The PPC grade assigned to the community will depend on the community's score on a 100-point scale:

PPC	Points
1	90.00 or more
2	80.00 to 89.99
3	70.00 to 79.99
4	60.00 to 69.99
5	50.00 to 59.99
6	40.00 to 49.99
7	30.00 to 39.99
8	20.00 to 29.99
9	10.00 to 19.99
10	0.00 to 9.99

The classification numbers are interpreted as follows:

- Class 1 through (and including) Class 8 represents a fire suppression system that includes an FSRS creditable dispatch center, fire department, and water supply.
- Class 8B is a special classification that recognizes a superior level of fire protection in otherwise Class 9 areas. It is designed to represent a fire protection delivery system that is superior except for a lack of a water supply system capable of the minimum FSRS fire flow criteria of 250 gpm for 2 hours.
- Class 9 is a fire suppression system that includes a creditable dispatch center, fire department but no FSRS creditable water supply.
- Class 10 does not meet minimum FSRS criteria for recognition, including areas that are beyond five road miles of a recognized fire station.

New PPC program changes effective July 1, 2014

We have revised the PPC program to capture the effects of enhanced fire protection capabilities that reduce fire loss and fire severity in Split Class 9 and Split Class 8B areas (as outlined below). This new structure benefits the fire service, community, and property owner.

New classifications
Through ongoing research and loss experience analysis, we identified additional differentiation in fire loss experience within our PPC program, which resulted in the revised classifications. We based the differing fire loss experience on the fire suppression capabilities of each community. The new PPC classes will improve the predictive value for insurers while benefiting both commercial and residential property owners. Here are the new classifications and what they mean.

Split classifications
When we develop a split classification for a community — for example 5/9 — the first number is the class that applies to properties within 5 road miles of the responding fire station and 1,000 feet of a creditable water supply, such as a fire hydrant, suction point, or dry hydrant. The second number is the class that applies to properties within 5 road miles of a fire station but beyond 1,000 feet of a creditable water supply. We have revised the classification to reflect more precisely the risk of loss in a community, replacing Class 9 and 8B in the second part of a split classification with revised designations.

What's changed with the new classifications?
We've published the new classifications as "X" and "Y" — formerly the "9" and "8B" portion of the split classification, respectively. For example:

- A community currently displayed as a split 6/9 classification will now be a split 6/6X classification; with the "6X" denoting what was formerly classified as "9".
- Similarly, a community currently graded as a split 6/8B classification will now be a split 6/6Y classification, the "6Y" denoting what was formerly classified as "8B".
- Communities graded with single "9" or "8B" classifications will remain intact.

Prior Classification	New Classification
1/9	1/1X
2/9	2/2X
3/9	3/3X
4/9	4/4X
5/9	5/5X
6/9	6/6X
7/9	7/7X
8/9	8/8X
9	9

Prior Classification	New Classification
1/8B	1/1Y
2/8B	2/2Y
3/8B	3/3Y
4/8B	4/4Y
5/8B	5/5Y
6/8B	6/6Y
7/8B	7/7Y
8/8B	8/8Y
8B	8B

What's changed?

As you can see, we're still maintaining split classes, but it's how we represent them to insurers that's changed. The new designations reflect a reduction in fire severity and loss and have the potential to reduce property insurance premiums.

Benefits of the revised split class designations

- To the fire service, the revised designations identify enhanced fire suppression capabilities used throughout the fire protection area
- To the community, the new classes reward a community's fire suppression efforts by showing a more reflective designation
- To the individual property owner, the revisions offer the potential for decreased property insurance premiums

New water class

Our data also shows that risks located more than 5 but less than 7 road miles from a responding fire station with a creditable water source within 1,000 feet had better loss experience than those farther than 5 road miles from a responding fire station with no creditable water source. We've introduced a new classification —10W — to recognize the reduced loss potential of such properties.

What's changed with Class 10W?

Class 10W is property-specific. Not all properties in the 5-to-7-mile area around the responding fire station will qualify. The difference between Class 10 and 10W is that the 10W-graded risk or property is within 1,000 feet of a creditable water supply. Creditable water supplies include fire protection systems using hauled water in any of the split classification areas.

What's the benefit of Class 10W?

10W gives credit to risks within 5 to 7 road miles of the responding fire station and within 1,000 feet of a creditable water supply. That's reflective of the potential for reduced property insurance premiums.

What does the fire chief have to do?

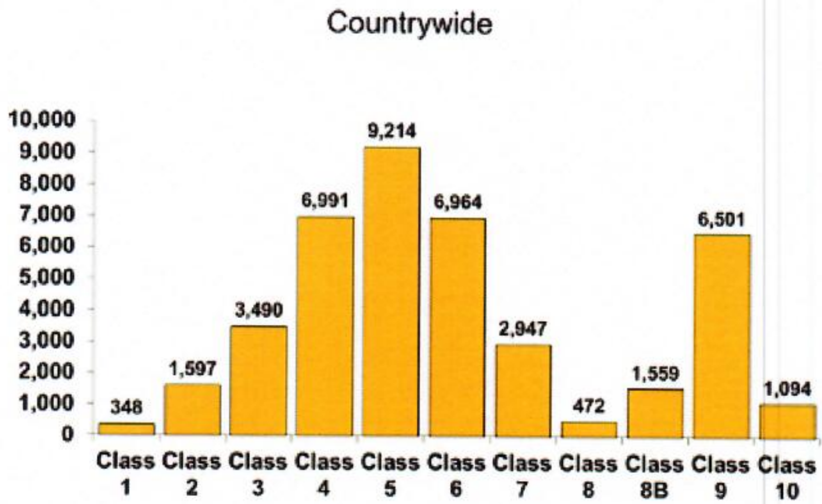
Fire chiefs don't have to do anything at all. The revised classifications went in place automatically effective July 1, 2014 (July 1, 2015 for Texas).

What if I have additional questions?

Feel free to contact ISO at 800.444.4554 or email us at PPC-Cust-Serv@iso.com.

Distribution of PPC Grades

The 2019 published countrywide distribution of communities by the PPC grade is as follows:



Assistance

The PPC program offers help to communities, fire departments, and other public officials as they plan for, budget, and justify improvements. ISO is also available to assist in the understanding of the details of this evaluation.

The PPC program representatives can be reached by telephone at (800) 444-4554. The technical specialists at this telephone number have access to the details of this evaluation and can effectively speak with you about your questions regarding the PPC program. What's more, we can be reached via the internet at www.isomitigation.com/talk/.

We also have a website dedicated to our Community Hazard Mitigation Classification programs at www.isomitigation.com. Here, fire chiefs, building code officials, community leaders and other interested citizens can access a wealth of data describing the criteria used in evaluating how cities and towns are protecting residents from fire and other natural hazards. This website will allow you to learn more about the PPC program. The website provides important background information, insights about the PPC grading processes and technical documents. ISO is also pleased to offer Fire Chiefs Online — a special, secured website with information and features that can help improve your PPC grade, including a list of the Needed Fire Flows for all the commercial occupancies ISO has on file for your community. Visitors to the site can download information, see statistical results and also contact ISO for assistance.

In addition, on-line access to the FSRS and its commentaries is available to registered customers for a fee. However, fire chiefs and community chief administrative officials are given access privileges to this information without charge.

To become a registered fire chief or community chief administrative official, register at www.isomitigation.com.

PPC Review

ISO concluded its review of the fire suppression features being provided for Plymouth. The resulting community classification is **Class 03/3Y**.

If the classification is a single class, the classification applies to properties with a Needed Fire Flow of 3,500 gpm or less in the community. If the classification is a split class (e.g., 6/XX):

- The first class (e.g., "6" in a 6/XX) applies to properties within 5 road miles of a recognized fire station and within 1,000 feet of a fire hydrant or alternate water supply.
- The second class (XX or XY) applies to properties beyond 1,000 feet of a fire hydrant but within 5 road miles of a recognized fire station.
- Alternative Water Supply: The first class (e.g., "6" in a 6/10) applies to properties within 5 road miles of a recognized fire station with no hydrant distance requirement.
- Class 10 applies to properties over 5 road miles of a recognized fire station.
- Class 10W applies to properties within 5 to 7 road miles of a recognized fire station with a recognized water supply within 1,000 feet.
- Specific properties with a Needed Fire Flow in excess of 3,500 gpm are evaluated separately and assigned an individual classification.

FSRS Feature	Earned Credit	Credit Available
Emergency Communications		
414. Credit for Emergency Reporting	**3.00**	**3**
422. Credit for Telecommunicators	**4.00**	**4**
432. Credit for Dispatch Circuits	**2.91**	**3**
440. Credit for Emergency Communications	**9.91**	**10**
Fire Department		
513. Credit for Engine Companies	**5.13**	**6**
523. Credit for Reserve Pumpers	**0.50**	**0.50**
532. Credit for Pump Capacity	**3.00**	**3**
549. Credit for Ladder Service	**2.24**	**4**
553. Credit for Reserve Ladder and Service Trucks	**0.19**	**0.50**
561. Credit for Deployment Analysis	**5.12**	**10**
571. Credit for Company Personnel	**7.62**	**15**
581. Credit for Training	**4.62**	**9**
730. Credit for Operational Considerations	**2.00**	**2**
590. Credit for Fire Department	**30.42**	**50**
Water Supply		
616. Credit for Supply System	**22.95**	**30**
621. Credit for Hydrants	**3.00**	**3**
631. Credit for Inspection and Flow Testing	**3.40**	**7**
640. Credit for Water Supply	**29.35**	**40**
Divergence	**-2.51**	**--**
1050. Community Risk Reduction	**4.47**	**5.50**
Total Credit	**71.64**	**105.50**

Emergency Communications

Ten percent of a community's overall score is based on how well the communications center receives and dispatches fire alarms. Our field representative evaluated:

- Communications facilities provided for the general public to report structure fires
- Enhanced 9-1-1 Telephone Service including wireless
- Computer-aided dispatch (CAD) facilities
- Alarm receipt and processing at the communication center
- Training and certification of telecommunicators
- Facilities used to dispatch fire department companies to reported structure fires

	Earned Credit	Credit Available
414. Credit Emergency Reporting	**3.00**	3
422. Credit for Telecommunicators	**4.00**	4
432. Credit for Dispatch Circuits	**2.91**	3
Item 440. Credit for Emergency Communications:	**9.91**	**10**

Item 414 - Credit for Emergency Reporting (3 points)

The first item reviewed is Item 414 "Credit for Emergency Reporting (CER)". This item reviews the emergency communication center facilities provided for the public to report fires including 911 systems (Basic or Enhanced), Wireless Phase I and Phase II, Voice over Internet Protocol, Computer Aided Dispatch and Geographic Information Systems for automatic vehicle location. ISO uses National Fire Protection Association (NFPA) 1221, *Standard for the Installation, Maintenance and Use of Emergency Services Communications Systems* as the reference for this section.

Item 410. Emergency Reporting (CER)	Earned Credit	Credit Available
A./B. Basic 9-1-1, Enhanced 9-1-1 or No 9-1-1 For maximum credit, there should be an Enhanced 9-1-1 system, Basic 9-1-1 and No 9-1-1 will receive partial credit.	**20.00**	**20**
1. E9-1-1 Wireless Wireless Phase I using Static ALI (automatic location identification) Functionality (10 points); Wireless Phase II using Dynamic ALI Functionality (15 points); Both available will be 25 points	**25.00**	**25**
2. E9-1-1 Voice over Internet Protocol (VoIP) Static VoIP using Static ALI Functionality (10 points); Nomadic VoIP using Dynamic ALI Functionality (15 points); Both available will be 25 points	**25.00**	**25**
3. Computer Aided Dispatch Basic CAD (5 points); CAD with Management Information System (5 points); CAD with Interoperability (5 points)	**15.00**	**15**
4. Geographic Information System (GIS/AVL) The PSAP uses a fully integrated CAD/GIS management system with automatic vehicle location (AVL) integrated with a CAD system providing dispatch assignments. The individual fire departments being dispatched do not need GIS/AVL capability to obtain this credit.	**15.00**	**15**
Review of Emergency Reporting total:	**100.00**	**100**

Item 422- Credit for Telecommunicators (4 points)

The second item reviewed is Item 422 "Credit for Telecommunicators (TC)". This item reviews the number of Telecommunicators on duty at the center to handle fire calls and other emergencies. All emergency calls including those calls that do not require fire department action are reviewed to determine the proper staffing to answer emergency calls and dispatch the appropriate emergency response. The 2013 Edition of NFPA 1221, *Standard for the Installation, Maintenance and Use of Emergency Services Communications Systems,* recommends that ninety-five percent of emergency calls shall be answered within 15 seconds and ninety-nine percent of emergency calls shall be answered within 40 seconds. In addition, NFPA recommends that eighty percent of emergency alarm processing shall be completed within 60 seconds and ninety-five percent of alarm processing shall be completed within 106 seconds of answering the call.

To receive full credit for operators on duty, ISO must review documentation to show that the communication center meets NFPA 1221 call answering and dispatch time performance measurement standards. This documentation may be in the form of performance statistics or other performance measurements compiled by the 9-1-1 software or other software programs that are currently in use such as Computer Aided Dispatch (CAD) or Management Information System (MIS).

Item 420. Telecommunicators (CTC)	**Earned Credit**	**Credit Available**
A1. Alarm Receipt (AR) Receipt of alarms shall meet the requirements in accordance with the criteria of NFPA 1221	**20.00**	**20**
A2. Alarm Processing (AP) Processing of alarms shall meet the requirements in accordance with the criteria of NFPA 1221	**20.00**	**20**
B. Emergency Dispatch Protocols (EDP) Telecommunicators have emergency dispatch protocols (EDP) containing questions and a decision-support process to facilitate correct call categorization and prioritization.	**20.00**	**20**
C. Telecommunicator Training and Certification (TTC) Telecommunicators meet the qualification requirements referenced in NFPA 1061, *Standard for Professional Qualifications for Public Safety Telecommunicator,* and/or the Association of Public-Safety Communications Officials - International (APCO) *Project 33.* Telecommunicators are certified in the knowledge, skills, and abilities corresponding to their job functions.	**20.00**	**20**
D. Telecommunicator Continuing Education and Quality Assurance (TQA) Telecommunicators participate in continuing education and/or in-service training and quality-assurance programs as appropriate for their positions	**20.00**	**20**
Review of Telecommunicators total:	**100.00**	**100**

Item 432 - Credit for Dispatch Circuits (3 points)

The third item reviewed is Item 432 "Credit for Dispatch Circuits (CDC)". This item reviews the dispatch circuit facilities used to transmit alarms to fire department members. A "Dispatch Circuit" is defined in NFPA 1221 as "A circuit over which an alarm is transmitted from the communications center to an emergency response facility (ERF) or emergency response units (ERUs) to notify ERUs to respond to an emergency". All fire departments (except single fire station departments with full-time firefighter personnel receiving alarms directly at the fire station) need adequate means of notifying all firefighter personnel of the location of reported structure fires. The dispatch circuit facilities should be in accordance with the general criteria of NFPA 1221. "Alarms" are defined in this Standard as "A signal or message from a person or device indicating the existence of an emergency or other situation that requires action by an emergency response agency".

There are two different levels of dispatch circuit facilities provided for in the Standard – a primary dispatch circuit and a secondary dispatch circuit. In jurisdictions that receive 730 alarms or more per year (average of two alarms per 24-hour period), two separate and dedicated dispatch circuits, a primary and a secondary, are needed. In jurisdictions receiving fewer than 730 alarms per year, a second dedicated dispatch circuit is not needed. Dispatch circuit facilities installed but not used or tested (in accordance with the NFPA Standard) receive no credit.

The score for Credit for Dispatch Circuits (CDC) is influenced by monitoring for integrity of the primary dispatch circuit. There are up to 0.90 points available for this Item. Monitoring for integrity involves installing automatic systems that will detect faults and failures and send visual and audible indications to appropriate communications center (or dispatch center) personnel. ISO uses NFPA 1221 to guide the evaluation of this item. ISO's evaluation also includes a review of the communication system's emergency power supplies.

Item 432 "Credit for Dispatch Circuits (CDC)" = 2.91 points

Fire Department

Fifty percent of a community's overall score is based upon the fire department's structure fire suppression system. ISO's field representative evaluated:

- Engine and ladder/service vehicles including reserve apparatus
- Equipment carried
- Response to reported structure fires
- Deployment analysis of companies
- Available and/or responding firefighters
- Training

	Earned Credit	Credit Available
513. Credit for Engine Companies	**5.13**	6
523. Credit for Reserve Pumpers	**0.50**	0.5
532. Credit for Pumper Capacity	**3.00**	3
549. Credit for Ladder Service	**2.24**	4
553. Credit for Reserve Ladder and Service Trucks	**0.19**	0.5
561. Credit for Deployment Analysis	**5.12**	10
571. Credit for Company Personnel	**7.62**	15
581. Credit for Training	**4.62**	9
730. Credit for Operational Considerations	**2.00**	2
Item 590. Credit for Fire Department:	**30.42**	**50**

Basic Fire Flow

The Basic Fire Flow for the community is determined by the review of the Needed Fire Flows for selected buildings in the community. The fifth largest Needed Fire Flow is determined to be the Basic Fire Flow. The Basic Fire Flow has been determined to be 3500 gpm.

Item 513 - Credit for Engine Companies (6 points)

The first item reviewed is Item 513 "Credit for Engine Companies (CEC)". This item reviews the number of engine companies, their pump capacity, hose testing, pump testing and the equipment carried on the in-service pumpers. To be recognized, pumper apparatus must meet the general criteria of NFPA 1901, *Standard for Automotive Fire Apparatus* which include a minimum 250 gpm pump, an emergency warning system, a 300 gallon water tank, and hose. At least 1 apparatus must have a permanently mounted pump rated at 750 gpm or more at 150 psi.

The review of the number of needed pumpers considers the response distance to built-upon areas; the Basic Fire Flow; and the method of operation. Multiple alarms, simultaneous incidents, and life safety are not considered.

The greatest value of A, B, or C below is needed in the fire district to suppress fires in structures with a Needed Fire Flow of 3,500 gpm or less: **7 engine companies**

a) **7 engine companies** to provide fire suppression services to areas to meet NFPA 1710 criteria or within 1½ miles.

b) **3 engine companies** to support a Basic Fire Flow of 3500 gpm.

c) **7 engine companies** based upon the fire department's method of operation to provide a minimum two engine response to all first alarm structure fires.

The FSRS recognizes that there are **6 engine companies** in service.

The FSRS also reviews Automatic Aid. Automatic Aid is considered in the review as assistance dispatched automatically by contractual agreement between two communities or fire districts. That differs from mutual aid or assistance arranged case by case. ISO will recognize an Automatic Aid plan under the following conditions:

- It must be prearranged for first alarm response according to a definite plan. It is preferable to have a written agreement, but ISO may recognize demonstrated performance.
- The aid must be dispatched to all reported structure fires on the initial alarm.
- The aid must be provided 24 hours a day, 365 days a year.

FSRS Item 512.D "Automatic Aid Engine Companies" responding on first alarm and meeting the needs of the city for basic fire flow and/or distribution of companies are factored based upon the value of the Automatic Aid plan (up to 1.00 can be used as the factor). The Automatic Aid factor is determined by a review of the Automatic Aid provider's communication facilities, how they receive alarms from the graded area, inter-department training between fire departments, and the fire ground communications capability between departments.

For each engine company, the credited Pump Capacity (PC), the Hose Carried (HC), the Equipment Carried (EC) all contribute to the calculation for the percent of credit the FSRS provides to that engine company.

Item 513 "Credit for Engine Companies (CEC)" = 5.13 points

Item 523 - Credit for Reserve Pumpers (0.50 points)

The item is Item 523 "Credit for Reserve Pumpers (CRP)". This item reviews the number and adequacy of the pumpers and their equipment. The number of needed reserve pumpers is 1 for each 8 needed engine companies determined in Item 513, or any fraction thereof.

Item 523 "Credit for Reserve Pumpers (CRP)" = 0.50 points

Item 532 – Credit for Pumper Capacity (3 points)

The next item reviewed is Item 532 "Credit for Pumper Capacity (CPC)". The total pump capacity available should be sufficient for the Basic Fire Flow of 3500 gpm. The maximum needed pump capacity credited is the Basic Fire Flow of the community.

Item 532 "Credit for Pumper Capacity (CPC)" = 3.00 points

Item 549 – Credit for Ladder Service (4 points)

The next item reviewed is Item 549 "Credit for Ladder Service (CLS)". This item reviews the number of response areas within the city with 5 buildings that are 3 or more stories or 35 feet or more in height, or with 5 buildings that have a Needed Fire Flow greater than 3,500 gpm, or any combination of these criteria. The height of all buildings in the city, including those protected by automatic sprinklers, is considered when determining the number of needed ladder companies. Response areas not needing a ladder company should have a service company. Ladders, tools and equipment normally carried on ladder trucks are needed not only for ladder operations but also for forcible entry, ventilation, salvage, overhaul, lighting and utility control.

The number of ladder or service companies, the height of the aerial ladder, aerial ladder testing and the equipment carried on the in-service ladder trucks and service trucks is compared with the number of needed ladder trucks and service trucks and an FSRS equipment list. Ladder trucks must meet the general criteria of NFPA 1901, *Standard for Automotive Fire Apparatus* to be recognized.

The number of needed ladder-service trucks is dependent upon the number of buildings 3 stories or 35 feet or more in height, buildings with a Needed Fire Flow greater than 3,500 gpm, and the method of operation.

The FSRS recognizes that there are **4 ladder companies** in service. These companies are needed to provide fire suppression services to areas to meet NFPA 1710 criteria or within 2½ miles and the number of buildings with a Needed Fire Flow over 3,500 gpm or 3 stories or more in height, or the method of operation.

The FSRS recognizes that there are **1 service companies** in service.

Item 549 "Credit for Ladder Service (CLS)" = 2.24 points

Item 553 – Credit for Reserve Ladder and Service Trucks (0.50 points)

The next item reviewed is Item 553 "Credit for Reserve Ladder and Service Trucks (CRLS)". This item considers the adequacy of ladder and service apparatus when one (or more in larger communities) of these apparatus are out of service. The number of needed reserve ladder and service trucks is 1 for each 8 needed ladder and service companies that were determined to be needed in Item 540, or any fraction thereof.

Item 553 "Credit for Reserve Ladder and Service Trucks (CRLS)" = 0.19 points

Item 561 – Deployment Analysis (10 points)

Next, Item 561 "Deployment Analysis (DA)" is reviewed. This Item examines the number and adequacy of existing engine and ladder-service companies to cover built-upon areas of the city.

To determine the Credit for Distribution, first the Existing Engine Company (EC) points and the Existing Engine Companies (EE) determined in Item 513 are considered along with Ladder Company Equipment (LCE) points, Service Company Equipment (SCE) points, Engine-Ladder Company Equipment (ELCE) points, and Engine-Service Company Equipment (ESCE) points determined in Item 549.

Secondly, as an alternative to determining the number of needed engine and ladder/service companies through the road-mile analysis, a fire protection area may use the results of a systematic performance evaluation. This type of evaluation analyzes computer-aided dispatch (CAD) history to demonstrate that, with its current deployment of companies, the fire department meets the time constraints for initial arriving engine and initial full alarm assignment in accordance with the general criteria of in NFPA 1710, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments.*

A determination is made of the percentage of built upon area within 1½ miles of a first-due engine company and within 2½ miles of a first-due ladder-service company.

Item 561 "Credit Deployment Analysis (DA)" = 5.12 points

Item 571 – Credit for Company Personnel (15 points)

Item 571 "Credit for Company Personnel (CCP)" reviews the average number of existing firefighters and company officers available to respond to reported first alarm structure fires in the city.

The on-duty strength is determined by the yearly average of total firefighters and company officers on-duty considering vacations, sick leave, holidays, "Kelley" days and other absences. When a fire department operates under a minimum staffing policy, this may be used in lieu of determining the yearly average of on-duty company personnel.

Firefighters on apparatus not credited under Items 513 and 549 that regularly respond to reported first alarms to aid engine, ladder, and service companies are included in this item as increasing the total company strength.

Firefighters staffing ambulances or other units serving the general public are credited if they participate in fire-fighting operations, the number depending upon the extent to which they are available and are used for response to first alarms of fire.

On-Call members are credited on the basis of the average number staffing apparatus on first alarms. Off-shift career firefighters and company officers responding on first alarms are considered on the same basis as on-call personnel. For personnel not normally at the fire station, the number of responding firefighters and company officers is divided by 3 to reflect the time needed to assemble at the fire scene and the reduced ability to act as a team due to the various arrival times at the fire location when compared to the personnel on-duty at the fire station during the receipt of an alarm.

The number of Public Safety Officers who are positioned in emergency vehicles within the jurisdiction boundaries may be credited based on availability to respond to first alarm structure fires. In recognition of this increased response capability the number of responding Public Safety Officers is divided by 2.

The average number of firefighters and company officers responding with those companies credited as Automatic Aid under Items 513 and 549 are considered for either on-duty or on-call company personnel as is appropriate. The actual number is calculated as the average number of company personnel responding multiplied by the value of AA Plan determined in Item 512.D.

The maximum creditable response of on-duty and on-call firefighters is 12, including company officers, for each existing engine and ladder company and 6 for each existing service company.

Chief Officers are not creditable except when more than one chief officer responds to alarms; then extra chief officers may be credited as firefighters if they perform company duties.

The FSRS recognizes **32.00 on-duty personnel** and an average of **0.00 on-call personnel** responding on first alarm structure fires.

Item 571 "Credit for Company Personnel (CCP)" = 7.62 points

Item 581 – Credit for Training (9 points)

Training	Earned Credit	Credit Available
A. Facilities, and Use For maximum credit, each firefighter should receive 18 hours per year in structure fire related subjects as outlined in NFPA 1001.	7.12	35
B. Company Training For maximum credit, each firefighter should receive 16 hours per month in structure fire related subjects as outlined in NFPA 1001.	14.06	25
C. Classes for Officers For maximum credit, each officer should be certified in accordance with the general criteria of NFPA 1021. Additionally, each officer should receive 12 hours of continuing education on or off site.	7.48	12
D. New Driver and Operator Training For maximum credit, each new driver and operator should receive 60 hours of driver/operator training per year in accordance with NFPA 1002 and NFPA 1451.	3.33	5
E. Existing Driver and Operator Training For maximum credit, each existing driver and operator should receive 12 hours of driver/operator training per year in accordance with NFPA 1002 and NFPA 1451.	3.75	5
F. Training on Hazardous Materials For maximum credit, each firefighter should receive 6 hours of training for incidents involving hazardous materials in accordance with NFPA 472.	1.00	1
G. Recruit Training For maximum credit, each firefighter should receive 240 hours of structure fire related training in accordance with NFPA 1001 within the first year of employment or tenure.	5.00	5
H. Pre-Fire Planning Inspections For maximum credit, pre-fire planning inspections of each commercial, industrial, institutional, and other similar type building (all buildings except 1-4 family dwellings) should be made annually by company members. Records of inspections should include up-to date notes and sketches.	9.60	12

Item 580 "Credit for Training (CT)" = 4.62 points

Item 730 – Operational Considerations (2 points)

Item 730 "Credit for Operational Considerations (COC)" evaluates fire department standard operating procedures and incident management systems for emergency operations involving structure fires.

Operational Considerations	Earned Credit	Credit Available
Standard Operating Procedures The department should have established SOPs for fire department general emergency operations	**50**	**50**
Incident Management Systems The department should use an established incident management system (IMS)	**50**	**50**
Operational Considerations total:	**100**	**100**

Item 730 "Credit for Operational Considerations (COC)" = 2.00 points

Water Supply

Forty percent of a community's overall score is based on the adequacy of the water supply system. The ISO field representative evaluated:

- the capability of the water distribution system to meet the Needed Fire Flows at selected locations up to 3,500 gpm.
- size, type and installation of fire hydrants.
- inspection and flow testing of fire hydrants.

	Earned Credit	Credit Available
616. Credit for Supply System	**22.95**	30
621. Credit for Hydrants	**3.00**	3
631. Credit for Inspection and Flow Testing	**3.40**	7
Item 640. Credit for Water Supply:	**29.35**	**40**

Item 616 – Credit for Supply System (30 points)

The first item reviewed is Item 616 "Credit for Supply System (CSS)". This item reviews the rate of flow that can be credited at each of the Needed Fire Flow test locations considering the supply works capacity, the main capacity and the hydrant distribution. The lowest flow rate of these items is credited for each representative location. A water system capable of delivering 250 gpm or more for a period of two hours plus consumption at the maximum daily rate at the fire location is considered minimum in the ISO review.

Where there are 2 or more systems or services distributing water at the same location, credit is given on the basis of the joint protection provided by all systems and services available.

The supply works capacity is calculated for each representative Needed Fire Flow test location, considering a variety of water supply sources. These include public water supplies, emergency supplies (usually accessed from neighboring water systems), suction supplies (usually evidenced by dry hydrant installations near a river, lake or other body of water), and supplies developed by a fire department using large diameter hose or vehicles to shuttle water from a source of supply to a fire site. The result is expressed in gallons per minute (gpm).

The normal ability of the distribution system to deliver Needed Fire Flows at the selected building locations is reviewed. The results of a flow test at a representative test location will indicate the ability of the water mains (or fire department in the case of fire department supplies) to carry water to that location.

The hydrant distribution is reviewed within 1,000 feet of representative test locations measured as hose can be laid by apparatus.

For maximum credit, the Needed Fire Flows should be available at each location in the district. Needed Fire Flows of 2,500 gpm or less should be available for 2 hours; and Needed Fire Flows of 3,000 and 3,500 gpm should be obtainable for 3 hours.

Item 616 "Credit for Supply System (CSS)" = 22.95 points

Item 621 – Credit for Hydrants (3 points)

The second item reviewed is Item 621 "Credit for Hydrants (CH)". This item reviews the number of fire hydrants of each type compared with the total number of hydrants.

There are a total of 2846 hydrants in the graded area.

620. Hydrants, - Size, Type and Installation	Number of Hydrants
A. With a 6 -inch or larger branch and a pumper outlet with or without 2½ -inch outlets	2846
B. With a 6 -inch or larger branch and no pumper outlet but two or more 2½ -inch outlets, or with a small foot valve, or with a small barrel	0
C./D. With only a 2½ -inch outlet or with less than a 6 -inch branch	0
E./F. Flush Type, Cistern, or Suction Point	0

Item 621 "Credit for Hydrants (CH)" = 3.00 points

Item 630 – Credit for Inspection and Flow Testing (7 points)

The third item reviewed is Item 630 "Credit for Inspection and Flow Testing (CIT)". This item reviews the fire hydrant inspection frequency, and the completeness of the inspections. Inspection of hydrants should be in accordance with AWWA M-17, *Installation, Field Testing and Maintenance of Fire Hydrants.*

Frequency of Inspection (FI): Average interval between the 3 most recent inspections.

Frequency	Points
1 year	30
2 years	20
3 years	10
4 years	5
5 years or more	No Credit

Note: The points for inspection frequency are reduced by 10 points if the inspections are incomplete or do not include a flushing program. An additional reduction of 10 points are made if hydrants are not subjected to full system pressure during inspections. If the inspection of cisterns or suction points does not include actual drafting with a pumper, or back-flushing for dry hydrants, 20 points are deducted.

Total points for Inspections = 3.40 points

Frequency of Fire Flow Testing (FF): Average interval between the 3 most recent inspections.

Frequency	Points
5 years	40
6 years	30
7 years	20
8 years	10
9 years	5
10 years or more	No Credit

Total points for Fire Flow Testing = 0.00 points

Item 631 "Credit for Inspection and Fire Flow Testing (CIT)" = 3.40 points

Divergence = -2.51

The Divergence factor mathematically reduces the score based upon the relative difference between the fire department and water supply scores. The factor is introduced in the final equation.

Community Risk Reduction

	Earned Credit	Credit Available
1025. Credit for Fire Prevention and Code Enforcement (CPCE)	**2.16**	2.2
1033. Credit for Public Fire Safety Education (CFSE)	**1.68**	2.2
1044. Credit for Fire Investigation Programs (CIP)	**0.63**	1.1
Item 1050. Credit for Community Risk Reduction	**4.47**	**5.50**

Item 1025 – Credit for Fire Prevention Code Adoption and Enforcement (2.2 points)	Earned Credit	Credit Available
Fire Prevention Code Regulations (PCR) Evaluation of fire prevention code regulations in effect.	10.00	10
Fire Prevention Staffing (PS) Evaluation of staffing for fire prevention activities.	7.82	8
Fire Prevention Certification and Training (PCT) Evaluation of the certification and training of fire prevention code enforcement personnel.	5.50	6
Fire Prevention Programs (PCP) Evaluation of fire prevention programs.	16.00	16
Review of Fire Prevention Code and Enforcement (CPCE) subtotal:	39.32	40

Item 1033 – Credit for Public Fire Safety Education (2.2 points)	Earned Credit	Credit Available
Public Fire Safety Educators Qualifications and Training (FSQT) Evaluation of public fire safety education personnel training and qualification as specified by the authority having jurisdiction.	10.00	10
Public Fire Safety Education Programs (FSP) Evaluation of programs for public fire safety education.	20.50	30
Review of Public Safety Education Programs (CFSE) subtotal:	30.50	40

Item 1044 – Credit for Fire Investigation Programs (1.1 points)	Earned Credit	Credit Available
Fire Investigation Organization and Staffing (IOS) Evaluation of organization and staffing for fire investigations.	4.00	8
Fire Investigator Certification and Training (IQT) Evaluation of fire investigator certification and training.	1.50	6
Use of National Fire Incident Reporting System (IRS) Evaluation of the use of the National Fire Incident Reporting System (NFIRS) for the 3 years before the evaluation.	6.00	6
Review of Fire Investigation Programs (CIP) subtotal:	11.50	20

Summary of PPC Review

for

Plymouth

FSRS Item	Earned Credit	Credit Available
Emergency Communications		
414. Credit for Emergency Reporting	3.00	3
422. Credit for Telecommunicators	4.00	4
432. Credit for Dispatch Circuits	2.91	3
440. Credit for Emergency Communications	9.91	10
Fire Department		
513. Credit for Engine Companies	5.13	6
523. Credit for Reserve Pumpers	0.50	0.5
532. Credit for Pumper Capacity	3.00	3
549. Credit for Ladder Service	2.24	4
553. Credit for Reserve Ladder and Service Trucks	0.19	0.5
561. Credit for Deployment Analysis	5.12	10
571. Credit for Company Personnel	7.62	15
581. Credit for Training	4.62	9
730. Credit for Operational Considerations	2.00	2
590. Credit for Fire Department	30.42	50
Water Supply		
616. Credit for Supply System	22.95	30
621. Credit for Hydrants	3.00	3
631. Credit for Inspection and Flow Testing	3.40	7
640. Credit for Water Supply	29.35	40
Divergence	-2.51	--
1050. Community Risk Reduction	4.47	5.50
Total Credit	71.64	105.5

Final Community Classification = 03/3Y

INSURANCE SERVICES OFFICE, INC.

HYDRANT FLOW DATA SUMMARY

City Plymouth

County Massachusetts(Plymouth), State MASSACHUSETTS (20) Witnessed by: Insurance Services Office Date: Feb 21, 2019

TEST NO.	TYPE DIST.*	TEST LOCATION	SERVICE	FLOW - GPM Q=(29.83(C(d²)p^0.5)) INDIVIDUAL HYDRANTS			TOTAL	PRESSURE PSI STATIC	RESID.	FLOW - AT 20 PSI NEEDED **	AVAIL.	REMARKS***	MODEL TYPE
1		Court Street @ Hedge Road	Plymouth Town of, Plymouth Center	1910	0	0	1910	66	36	7000	2400	(D)-(5648 gpm)	
1.1		Cordage Park	Plymouth Town of, Plymouth Center	1910	0	0	1910	66	36	3000	2400		
1.2		Cordage Park	Plymouth Town of, Plymouth Center	1910	0	0	1910	66	36	6000	2400	(A)-(2250.0 gpm)(D)-(5648 gpm)	
1.3		Cordage Park	Plymouth Town of, Plymouth Center	1910	0	0	1910	66	36	6000	2400	(A)-(2250.0 gpm)(D)-(5648 gpm)	
10		Bay Shore Drive @ Tower Road	Plymouth Town of, Pine Hills Booster	1150	0	0	1150	83	25	1000	1200		
11		Manomet Point Road @ School	Plymouth Town of, Manomet	1430	0	0	1430	55	32	3000	1800		
12		Warren Avenue @ Sunrise Ave.	Plymouth Town of, Plymouth Center	2020	0	0	2020	57	42	3000	3300		
13		P'Town View Road @ Manomet Beach Rd.	Plymouth Town of, Manomet	1860	0	0	1860	73	42	1000	2500		
14		State Road @ Indian Brook Elem. School	Plymouth Town of, Manomet	1350	0	0	1350	70	30	3000	1500		
15		Hillside and Shore Drives	Plymouth Town of, Manomet	1560	0	0	1560	58	40	1000	2300		
16		State Road @ Ellisville Road	Plymouth Town of, Cedarville	2850	0	0	2850	98	72	750	5200		
17		State Road @ Old Country Road	Plymouth Town of, Cedarville	1500	0	0	1500	45	25	3500	1700		
18		Federal Furnace Road @ School	Plymouth Town of, West	1350	0	0	1350	65	36	3000	1700	(A)-(2250.0 gpm)	
19		South Meadow Road @ Airport Plaza	Plymouth Town of, West	1210	0	0	1210	60	18	4500	1200		
19.1		South Meadow Road @ Airport Plaza	Plymouth Town of, West	1210	0	0	1210	60	18	2250	1200		
2		Court Street @ Savory Lane	Plymouth Town of, Plymouth Center	1810	0	0	1810	56	34	3500	2400		

THE ABOVE LISTED NEEDED FIRE FLOWS ARE FOR PROPERTY INSURANCE PREMIUM CALCULATIONS ONLY AND ARE *NOT* INTENDED TO PREDICT THE MAXIMUM AMOUNT OF WATER REQUIRED FOR A LARGE SCALE FIRE CONDITION.

THE AVAILABLE FLOWS ONLY INDICATE THE CONDITIONS THAT EXISTED AT THE TIME AND AT THE LOCATION WHERE TESTS WERE WITNESSED.

***Comm = Commercial; Res = Residential.**

****Needed is the rate of flow for a specific duration for a full credit condition. Needed Fire Flows greater than 3,500 gpm are not considered in determining the classification of the city when using the Fire Suppression Rating Schedule.**

***** (A)-Limited by available hydrants to gpm shown. Available facilities limit flow to gpm shown plus consumption for the needed duration of (B)-2 hours, (C)-3 hours or (D)-4 hours.**

INSURANCE SERVICES OFFICE, INC.

HYDRANT FLOW DATA SUMMARY

City Plymouth

County Massachusetts(Plymouth), State MASSACHUSETTS (20) Witnessed by: Insurance Services Office Date: Feb 21, 2019

TEST NO.	TYPE DIST.*	TEST LOCATION	SERVICE	FLOW - GPM				PRESSURE PSI		FLOW -AT 20 PSI		REMARKS***	MODEL TYPE
				INDIVIDUAL HYDRANTS			TOTAL	STATIC	RESID.	NEEDED **	AVAIL.		
20		Lantern Lane @ Flint Locke Lane	Plymouth Town of, West	1970	0	0	1970	52	50	750	8800		
21		Esta Road @ Dartmouth Road	Plymouth Town of, West	2020	0	0	2020	57	45	1000	3700		
22		Plympton Road @ West Elem. School	Plymouth Town of, West	1350	0	0	1350	48	34	3000	2000		
23		Aldrin Road @ Armstrong Road	Plymouth Town of, West	1910	0	0	1910	58	52	2250	5200		
25		Great Island Road @ Champlain Circle	Plymouth-Pinehills, Main	700	0	0	700	72	56	1500	1300		
26		Clubhouse Drive @ Clark Road	Plymouth-Pinehills, Main	830	0	0	830	90	80	500	2400		
27		Peter Brown Cartway @ Winslows View	Plymouth-Pinehills, Main	550	0	0	550	46	35	2000	900		
28		Lunns Way @ Dickson Drive	Plymouth-The Ponds, Main	740	0	0	740	75	67	750	2100		
29		Welton Drive @ Lunns Way	Plymouth-The Ponds, Main	660	0	0	660	65	50	750	1200		
3		Water Street @ Lothrop Street	Plymouth Town of, Plymouth Center	1970	0	0	1970	70	47	4500	3000		
3.1		Water Street @ Lothrop Street	Plymouth Town of, Plymouth Center	1970	0	0	1970	70	47	1750	3000		
3.2		Water Street @ Lothrop Street	Plymouth Town of, Plymouth Center	1970	0	0	1970	70	47	4500	3000		
30		Wareham Road @ River Run Way	Plymouth-Agawam Springs Water Co, Redbrook	1140	0	0	1140	50	46	2000	3400		
4		Court Street @ Main Street	Plymouth Town of, Plymouth Center	960	960	0	1920	57	47	3000	3900		
5		Billington Street @ #100	Plymouth Town of, Plymouth Center	2020	0	0	2020	44	34	4500	3200		
5.1		Billington Street @ #100	Plymouth Town of, Plymouth Center	2020	0	0	2020	44	34	1000	3200		

THE ABOVE LISTED NEEDED FIRE FLOWS ARE FOR PROPERTY INSURANCE PREMIUM CALCULATIONS ONLY AND ARE *NOT* INTENDED TO PREDICT THE MAXIMUM AMOUNT OF WATER REQUIRED FOR A LARGE SCALE FIRE CONDITION.

THE AVAILABLE FLOWS ONLY INDICATE THE CONDITIONS THAT EXISTED AT THE TIME AND AT THE LOCATION WHERE TESTS WERE WITNESSED.

*Comm = Commercial; Res = Residential.

**Needed is the rate of flow for a specific duration for a full credit condition. Needed Fire Flows greater than 3,500 gpm are not considered in determining the classification of the city when using the Fire Suppression Rating Schedule.

*** (A)-Limited by available hydrants to gpm shown. Available facilities limit flow to gpm shown plus consumption for the needed duration of (B)-2 hours, (C)-3 hours or (D)-4 hours.

INSURANCE SERVICES OFFICE, INC.

HYDRANT FLOW DATA SUMMARY

City Plymouth

County Massachusetts(Plymouth), State MASSACHUSETTS (20) Witnessed by: Insurance Services Office Date: Feb 21, 2019

TEST NO.	TYPE DIST.*	TEST LOCATION	SERVICE	FLOW - GPM				PRESSURE PSI		FLOW -AT 20 PSI		REMARKS***	MODEL TYPE
				INDIVIDUAL HYDRANTS			TOTAL	STATIC	RESID.	NEEDED **	AVAIL.		
6		Union Street @ Lincoln Street	Plymouth Town of, Plymouth Center	2390	0	0	2390	70	48	5000	3700		
7		Obery Street @ High School	Plymouth Town of, Bradford	2020	0	0	2020	63	45	5000	3200		
7.1		Obery Street @ High School	Plymouth Town of, Bradford	2020	0	0	2020	63	45	750	3200		
8		Long Pond Road @ Camelot Drive	Plymouth Town of, Bradford	1560	0	0	1560	65	35	3500	1900		
9		Russell Mills Road @ Sandwich Road	Plymouth Town of, Plymouth Center	1210	0	0	1210	48	19	500	1200		

THE ABOVE LISTED NEEDED FIRE FLOWS ARE FOR PROPERTY INSURANCE PREMIUM CALCULATIONS ONLY AND ARE *NOT* INTENDED TO PREDICT THE MAXIMUM AMOUNT OF WATER REQUIRED FOR A LARGE SCALE FIRE CONDITION.

THE AVAILABLE FLOWS ONLY INDICATE THE CONDITIONS THAT EXISTED AT THE TIME AND AT THE LOCATION WHERE TESTS WERE WITNESSED.

***Comm = Commercial; Res = Residential.**

****Needed is the rate of flow for a specific duration for a full credit condition. Needed Fire Flows greater than 3,500 gpm are not considered in determining the classification of the city when using the Fire Suppression Rating Schedule.**

***** (A)-Limited by available hydrants to gpm shown. Available facilities limit flow to gpm shown plus consumption for the needed duration of (B)-2 hours, (C)-3 hours or (D)-4 hours.**

Appendix E

Hydrant Flow Test Reports

TEST 1

Environmental Partners GROUP

Project:	Water System Master Plan Update	Date:	August 14, 2019
Client:	Town of Plymouth	Time:	8:44 AM
Job No:	196-1710	SCADA Time:	8:36 AM

LOCATION: ***Warren Avenue west of Pine Hills BPS***

No. of Outlets:	1
Diameter Outlet (in.):	4.5
Coefficient:	N/A
Pitot (psi):	10
Static (psi):	44
Residual (psi):	36

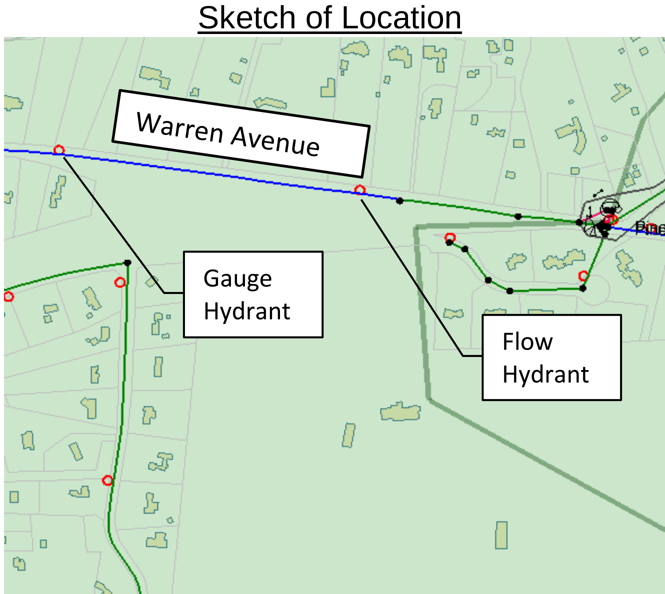
Flow

$29.83 \times D^2 \times \sqrt{Pitot} \times Coeff.$

Flow Available at 20 psi

$Flow \times (Static - 20)^{.54} / (Static - Residual)^{.54}$

Sketch of Location



Calculations

1,211 gpm

Flow Available at 20 psi

$1211 \times (44 - 20)^{0.54} / (44 - 36)^{0.54} =$

2,192 gpm

Source Status

	Flow	Pressure
South Pond No. 1	792.3	33.8
South Pond No. 2	1077	
Lout Pond	0	
Nook Road Actuator Valve	0	

	Flow	Pressure
Nook Road BP 1	0	
Nook Road BP 2	0	
Deep Water BP 1	0	
Deep Water BP 2	0	
Pine Hills BP 1	unknown	
Pine Hills BP 2	unknown	

Tank Status:

	Level	Elevation
Lout Pond	33.7	
Chiltonville	52	

Personnel Conducting Test:

Lauren Underwood	EP
Marcus Brunelle	EP
Josh	Plymouth
Drew	Plymouth

TEST 2

Environmental Partners GROUP

Project: Water System Master Plan Update
Date: August 14, 2019

Client: Town of Plymouth
Time: 9:32 AM

Job No: 196-1710
SCADA Time: 9:24 AM

LOCATION: ***Rocky Hill Road east of Gate Road***

No. of Outlets: 1

Diameter Outlet (in.): 4.5

Coefficient: N/A

Pitot (psi): 4

Static (psi): 65

Residual (psi): 64

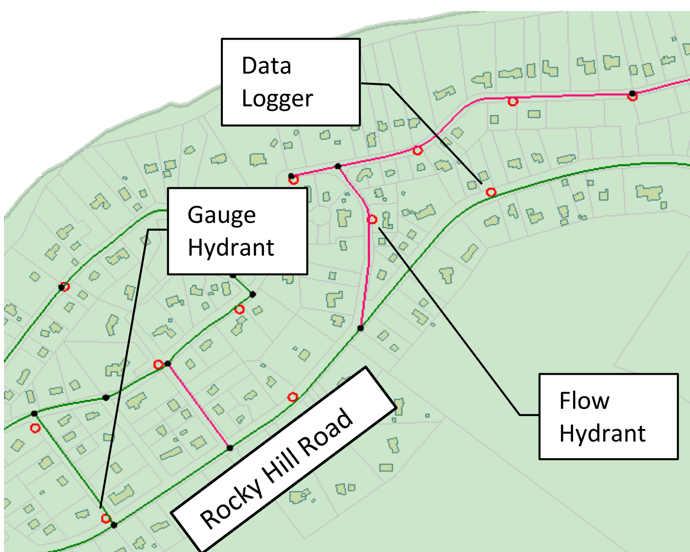
Flow

$29.83 \times D^2 \times \sqrt{Pitot} \times Coeff.$

Flow Available at 20 psi

$Flow \times (Static - 20)^{.54} / (Static - Residual)^{.54}$

Sketch of Location



Calculations

750 gpm

Flow Available at 20 psi

$750 \times (65 - 20)^{0.54} / (65 - 64)^{0.54} =$

5,859 gpm

Source Status

	Flow	Pressure
Pine Hills BP 1	unknown	
Pine Hills BP 2	unknown	

Tank Status:

	Level	Elevation
North Pine Hills	24.2	

Personnel Conducting Test:

Lauren Underwood	EP
Marcus Brunelle	EP
Josh	Plymouth
Drew	Plymouth

TEST 2

Environmental Partners GROUP

Project: Water System Master Plan Update

Date: August 14, 2019

Client: Town of Plymouth

Time: 1:35 PM

Job No: 196-1710

SCADA Time: 1:27 PM

LOCATION: ***Rocky Hill Road east of Gate Road***

No. of Outlets:	1
Diameter Outlet (in.):	4.5
Coefficient:	N/A
Pitot (psi):	4
Static (psi):	77
Residual (psi):	43

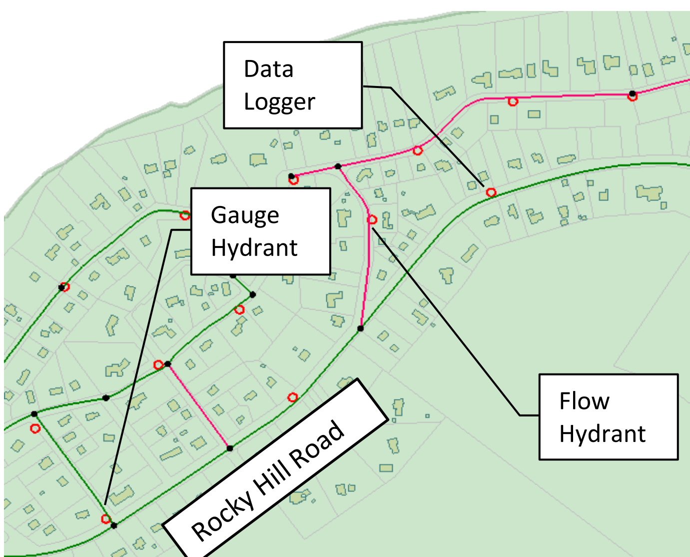
Flow

$29.83 \times D^2 \times \sqrt{Pitot} \times Coeff.$

Flow Available at 20 psi

$Flow \times (Static - 20)^{.54} / (Static - Residual)^{.54}$

Sketch of Location



Calculations

766 gpm

Flow Available at 20 psi

$766 \times (77 - 20)^{0.54} / (77 - 43)^{0.54} =$

1,013 gpm

Source Status

	Flow	Pressure
Pine Hills BP 1	unknown	
Pine Hills BP 2	unknown	

Tank Status:

	Level	Elevation
North Pine Hills	23.7	

Personnel Conducting Test:

Lauren Underwood	EP
Marcus Brunelle	EP
Josh	Plymouth
Drew	Plymouth

TEST 3

Environmental Partners GROUP

Project: Water System Master Plan Update
Date: August 14, 2019
Client: Town of Plymouth
Time: 10:00 AM
Job No: 196-1710
SCADA Time: 9:52 AM

LOCATION: ***Entergy Nuclear Facility***

No. of Outlets:	1
Diameter Outlet (in.):	4.5
Coefficient:	N/A
Pitot (psi):	4
Static (psi):	54
Residual (psi):	20

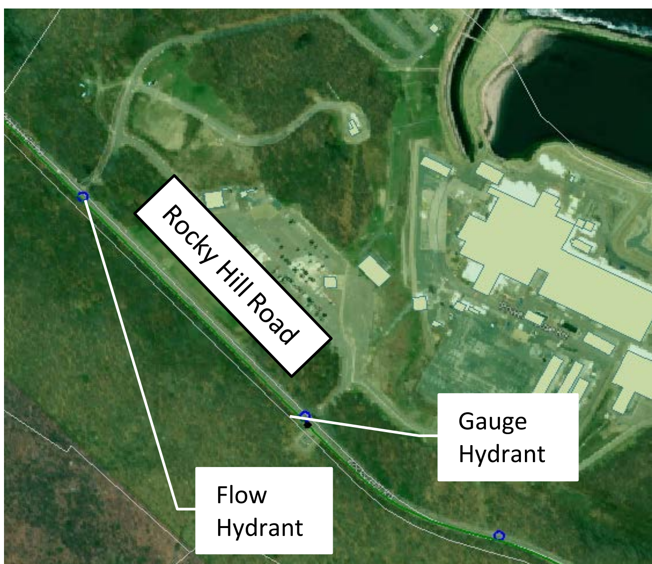
Flow

$29.83 \times D^2 \times \sqrt{Pitot} \times Coeff.$

Flow Available at 20 psi

$Flow \times (Static - 20)^{.54} / (Static - Residual)^{.54}$

Sketch of Location



Calculations

766 gpm

Flow Available at 20 psi

$766 \times (54 - 20)^{0.54} / (54 - 20)^{0.54} =$

766 gpm

Source Status

	Flow	Pressure
Wannos Pond Well	502*	37.6
Ship Pond Well	345	
Ellisville Well	584	
Cedarville Actuator Valve	216	103.2

*Wannos appeared to be ramping up or down

	Flow	Pressure
Cedarville BP 1	209*	103.2*
Cedarville BP 2		

*don't know which pump was running
only one pump runs at a time

Tank Status:

	Level	Elevation
South Pine Hills	34	
Indian Hill	37.6	

Personnel Conducting Test:

Lauren Underwood	EP
Marcus Brunelle	EP
Josh	Plymouth
Drew	Plymouth

TEST 4

Environmental Partners GROUP

Project: Water System Master Plan Update
Date: August 14, 2019
Client: Town of Plymouth
Time: 10:41 AM
Job No: 196-1710
SCADA Time: 10:33 AM

LOCATION: ***Priscilla Beach Road***

No. of Outlets: 1
Diameter Outlet (in.): 4.5
Coefficient: N/A
Pitot (psi): 8
Static (psi): 64
Residual (psi): 40

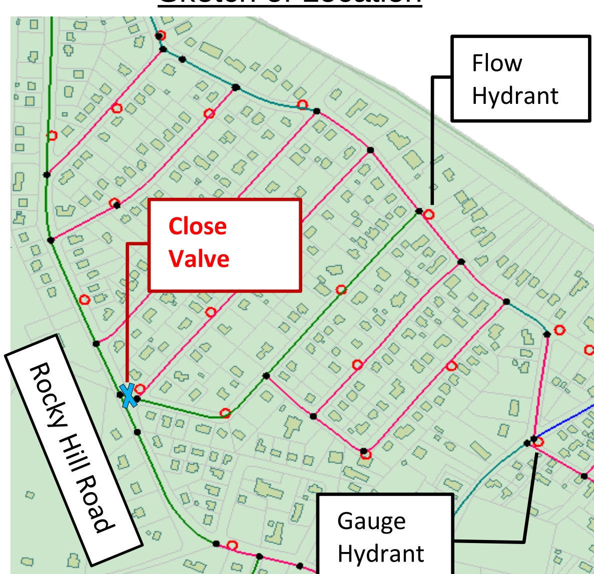
Flow

$29.83 \times D^2 \times \sqrt{Pitot} \times Coeff.$

Flow Available at 20 psi

$Flow \times (Static - 20)^{.54} / (Static - Residual)^{.54}$

Sketch of Location



Calculations

1,100 gpm

Flow Available at 20 psi

$1100 \times (64 - 20)^{0.54} / (64 - 40)^{0.54} =$

1,526 gpm

Source Status

	Flow	Pressure
Wannos Pond Well	502	37.6
Ship Pond Well	326	
Ellisville Well	couldn't read - running	
Cedarville Actuator Valve	197	103.5

	Flow	Pressure
Cedarville BP 1	206*	103.4*
Cedarville BP 2		

*don't know which pump was running
only one pump runs at a time

Tank Status:

	Level	Elevation
South Pine Hills	35.3	
Indian Hill	37.6	

Personnel Conducting Test:

Lauren Underwood	EP
Marcus Brunelle	EP
Josh	Plymouth
Drew	Plymouth

Hyannis:
396 North Street, Hyannis, MA 02601
TL 508.568.5103 • FX 508.568.5125

Headquarters:
1900 Crown Colony Drive, Suite 402, Quincy, MA 02169
TL 617.657.0200 • FX 617.657.0201

Woburn:
18 Commerce Way, Suite 2000, Woburn, MA 01801
TL 781.281.2542 • FX 781.281.2543

www.envpartners.com

TEST 6

Environmental Partners GROUP

Project: Water System Master Plan Update

Date: August 14, 2019

Client: Town of Plymouth

Time: 12:06 PM

Job No: 196-1710

SCADA Time: 11:58 AM

LOCATION: ***Bulrush Lane and Brook Road***

No. of Outlets: 1

Diameter Outlet (in.): 4.5

Coefficient: N/A

Pitot (psi): 14

Static (psi): 73

Residual (psi): 36

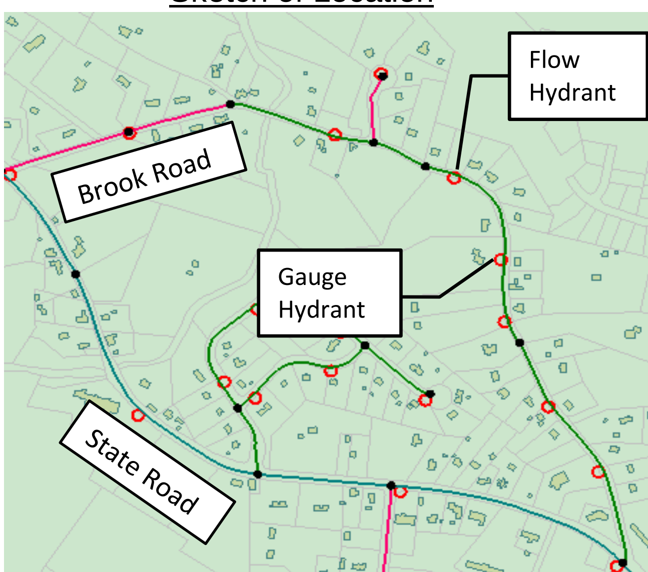
Flow

$29.83 \times D^2 \times \sqrt{Pitot} \times Coeff.$

Flow Available at 20 psi

$Flow \times (Static - 20)^{.54} / (Static - Residual)^{.54}$

Sketch of Location



Calculations

1,375 gpm

Flow Available at 20 psi

$1375 \times (73 - 20)^{0.54} / (73 - 36)^{0.54} =$

1,669 gpm

DRAFT

Source Status

	Flow	Pressure
Wannos Pond Well	502*	37.6
Ship Pond Well	317	
Ellisville Well	couldn't read, running	
Cedarville Actuator Valve	182	104

*Wannos appeared to be ramping up or down

	Flow	Pressure
Cedarville BP 1	205*	103.9*
Cedarville BP 2		

*don't know which pump was running
only one pump runs at a time

Tank Status:

	Level	Elevation
South Pine Hills	37.8	
Indian Hill	37.6	

Personnel Conducting Test:

Lauren Underwood	EP
Marcus Brunelle	EP
Josh	Plymouth
Drew	Plymouth

TEST 5

Environmental Partners GROUP

Project:	Water System Master Plan Update	Date:	August 14, 2019
Client:	Town of Plymouth	Time:	11:35 AM
Job No:	196-1710	SCADA Time:	11:27 AM

LOCATION: ***White Horse Road between State Road and Rocky Hill Road***

No. of Outlets:	1
Diameter Outlet (in.):	4.5
Coefficient:	N/A
Pitot (psi):	16
Static (psi):	66
Residual (psi):	46

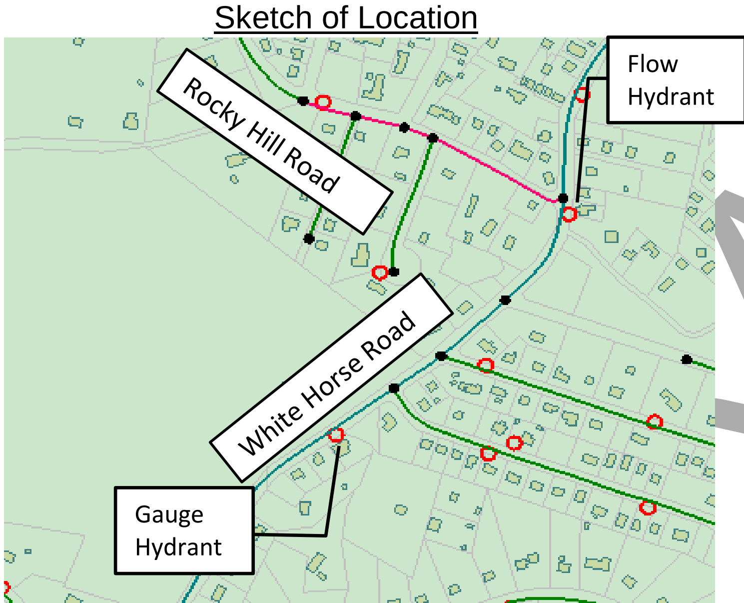
Flow

$29.83 \times D^2 \times \sqrt{Pitot} \times Coeff.$

Flow Available at 20 psi

$Flow \times (Static - 20)^{.54} / (Static - Residual)^{.54}$

Sketch of Location



Calculations

1,504 gpm

Flow Available at 20 psi

$1504 \times (66 - 20)^{0.54} / (66 - 46)^{0.54} =$

2,358 gpm

Source Status

	Flow	Pressure
Wannos Pond Well	502	37.6
Ship Pond Well	327	
Ellisville Well	can't read, running	
Cedarville Actuator Valve	201	103.8

	Flow	Pressure
Cedarville BP 1	201*	103.9*
Cedarville BP 2		

*don't know which pump was running
only one pump runs at a time

Tank Status:

	Level	Elevation
South Pine Hills	37	
Indian Hill	37.6	

Personnel Conducting Test:

Lauren Underwood	EP
Marcus Brunelle	EP
Josh	Plymouth
Drew	Plymouth

TEST 7

Environmental Partners GROUP

Project: Water System Master Plan Update
Date: August 14, 2019

Client: Town of Plymouth
Time: 12:29 PM

Job No: 196-1710
SCADA Time: 12:21 PM

LOCATION: ***Manomet Point Road near Highland Terrace***

No. of Outlets: 1

Diameter Outlet (in.): 4.5

Coefficient: N/A

Pitot (psi): 12

Static (psi): 58

Residual (psi): 27

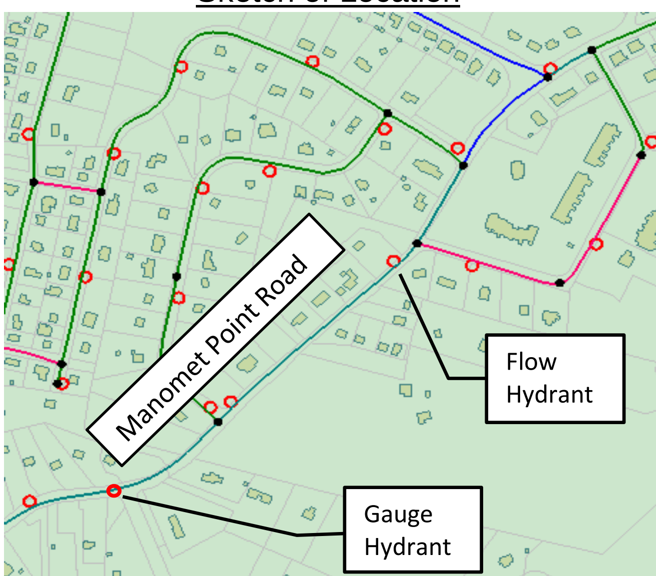
Flow

$29.83 \times D^2 \times \sqrt{Pitot} \times Coeff.$

Flow Available at 20 psi

$Flow \times (Static - 20)^{.54} / (Static - Residual)^{.54}$

Sketch of Location



Calculations

1,303 gpm

Flow Available at 20 psi

$1303 \times (58 - 20)^{0.54} / (58 - 27)^{0.54} =$

1,454 gpm

Source Status

	Flow	Pressure
Wannos Pond Well	0	37.3
Ship Pond Well	0	
Ellisville Well	0	
Cedarville Actuator Valve	0	104.2

	Flow	Pressure
Cedarville BP 1	0	104.3
Cedarville BP 2		

*don't know which pump was running
only one pump runs at a time

Tank Status:

	Level	Elevation
South Pine Hills	37.8	

	Level	Elevation
Indian Hill	37.5	

Personnel Conducting Test:

Lauren Underwood	EP
Marcus Brunelle	EP
Josh	Plymouth
Drew	Plymouth

Environmental Partners GROUP

Project: Water System Master Plan Update | Date: August 14, 2019

Client: Town of Plymouth | Time: 12:55 PM

Job No: 196-1710 | SCADA Time: 12:47 PM

LOCATION: ***State Road near Woodland Avenue***

No. of Outlets: 1

Diameter Outlet (in.): 4.5

Coefficient: N/A

Pitot (psi): 13

Static (psi): 48

Residual (psi): 36

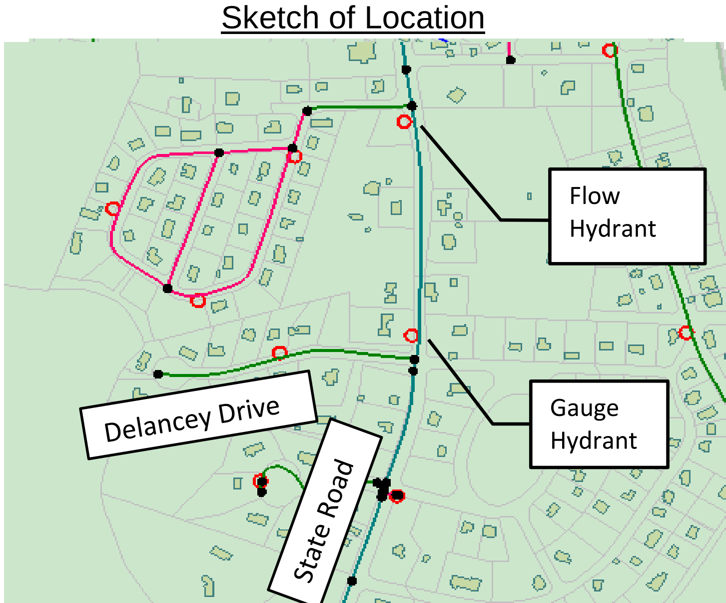
Flow

$29.83 \times D^2 \times \sqrt{Pitot} \times Coeff.$

Flow Available at 20 psi

$Flow \times (Static - 20)^{.54} / (Static - Residual)^{.54}$

Sketch of Location



Calculations

1,356 gpm

Flow Available at 20 psi

$1356 \times (48 - 20)^{0.54} / (48 - 36)^{0.54} =$

2,143 gpm

Source Status

	Flow	Pressure
Wannos Pond Well	0	37.1
Ship Pond Well	0	
Ellisville Well	0	
Cedarville Actuator Valve	0	103.9

	Flow	Pressure
Cedarville BP 1	0	104.3
Cedarville BP 2		

*don't know which pump was running
only one pump runs at a time

Tank Status:

	Level	Elevation
South Pine Hills	37.5	
Indian Hill		

Personnel Conducting Test:

Lauren Underwood	EP
Marcus Brunelle	EP
Josh	Plymouth
Drew	Plymouth

Appendix F

Example Water Balance/Banking Program

TOWN OF ___________WATER SYSTEM
RULES & REGULATIONS

Sample Verbiage for Water Balance Program Bylaw

1. WATER BALANCE PROGRAM

a. Water supplies for new developments and expanding water needs must be offset through a Water Balance Plan in order to manage water withdrawals within the limits established, regulated, and enforced by the Massachusetts Department of Environmental Protection.

b. The Water Balance Program applies to all new and expanded water use projects with the following exceptions:

   1) Residential Development with only a single service connection and;

   2) New and/or expanded water use developments that are expected to require less than 100,000 gallons per year of water.

c. For applicants that do not meet the exceptions listed above, the Water Balance Program provides the following options: Applicant-Directed Conservation, Water Banking, and Supplemental Source of Water Supply.

d. **Applicant-Directed Conservation**:

   1) Applicant shall identify and implement water conservation activities through retrofits approved by the Town.

   2) The Applicant must provide the Town with an estimate of the annual water demand for the proposed new development or expanded water use, and must develop and implement a Conservation Plan that will reduce the existing water usage within the Town system by an amount equal to the estimated demand of the proposed new development. Average day water demands can be estimated by Massachusetts Title 5 regulations (310 CMR 15.203) or by actual data from comparable facilities (upon approval by the Town).

   3) Estimated water usage for a variety of plumbing devices is included in the Water Balance Program Application in Appendix A.

   4) Note that irrigation demand must be estimated separately in each demand projection. Any new irrigation system will be required to use a rain or moisture sensor that is designed to interrupt the cycle of an automatic irrigation system when a specific amount of rainfall has occurred or when the moisture in the soil exceeds a specified limit.

   5) Water demand estimates shall be subject to review and acceptance by the Town.

   6) The Applicant must include a preliminary deposit of $1,000 as part of the application, except for Applicants electing to use Title 5 Design Flows as the basis for water demand projections. Additional cost to review, approve, and audit the project will be billed to the

Applicant on an as needed basis. Any unused funds will be returned to the Applicant.

7) Water service will not be provided to the Applicant's project until the activities described by the approved Water Conservation Plan have been completed.

e. **Water Banking**:

1) Applicant shall provide funding for a Water Bank that will be used by the Town to fund conservation efforts.

2) The Applicant must provide the Town with an estimate of average annual water usage and maximum daily water usage, including all relevant supporting data. Average day water demands can be estimated by Massachusetts Title 5 regulations (310 CMR 15.203) or by actual data from comparable facilities (upon approval by the Town). Upon request, the Town will provide historical water demand data.

3) Note that irrigation demand must be estimated separately in each demand projection. Any new irrigation system will be required to use a rain or moisture sensor that is designed to interrupt the cycle of an automatic irrigation system when a specific amount of rainfall has occurred or when the moisture in the soil exceeds a specified limit.

4) Water demand estimates shall be subject to review and acceptance by the Town.

5) Once the Town has reviewed and accepted the Applicant's estimated water demands, the Applicant must provide funding for the Water Bank at a rate of $10 per gallon per day based on the proposed development's annual average water demand. If the project's estimated average daily water demand is greater than 10,000 gallons per day, the Town has the discretion to modify the Water Bank rate on a case-by-case basis. In such cases, the Water Bank rate will be calculated and determined based on the sum of the actual costs incurred by the Town for completing water conservation work divided by the gallons saved associated with the work.

6) The Applicant must include a preliminary deposit of $1,000 as part of the application, except for Applicants electing to use Title 5 Design Flows as the basis for water demand projections. Additional costs to review, approve, and auit the project will be billed to the Applicant on an as needed basis. Any unused funds will be returned to the Applicant.

7) Water service will not be provided to the Applicant's project until the Applicant has provided the required funds for the Water Bank.

f. **Supplemental Source of Water Supply:**

1) Applicant shall identify and develop a supplemental source of supply for the Town. The Applicant shall finance the development of the supplemental source. The development of a supplemental source of supply is subject to further negotiations and agreement between the

Town and the Applicant.

2) Additional meetings with the Town will be required to review this option upon completing a Water Balance Program Application.

g. A pre-application meeting with the Town is encouraged to explore the above options. The Town will work with the Applicant towards any of the above options.

h. A Water Balance Program Application can be found in Appendix A.

TOWN OF __________ WATER DEPARTMENT

WATER BALANCE PROGRAM APPLICATION

The Applicant should be aware that the withdrawal of the water resources from the Commonwealth of Massachusetts to serve the communities noted above are regulated and limited by the Massachusetts Department of Environmental Protection (DEP). In order to manage these water withdrawals within the limits established, regulated, and enforced by the DEP, water supplies for new developments and expanding water needs must be offset through a Water Balance Plan.

The Water Balance Program applies to all new and expanded water use projects, except (1) residential development with only a single service connection and (2) new and/or expanded water use developments that are expected to require less than 100,000 gallons per year of water. Applicants will have several options including:

1. **Applicant-Directed Conservation** – Applicant identifies and implements water conservation activities through retrofits approved by the Town.

2. **Water Banking** – Applicant provides funding for a Water Bank that will be used by the Town to fund conservation efforts.

3. **Supplemental Source of Water Supply** – (1) The Applicant identifies and develops a supplemental source of supply for the Town and (2) the Applicant finances the development of a supplemental source of supply.

More detailed descriptions and requirements for each of these options are provided within this document. The Town will work with the Applicant towards any of these options. A pre-application meeting is encouraged to explore the options. The development of supplemental source of supply is subject to further negotiations and agreement between the Town and the Applicant.

If the Applicant elects the <u>Applicant-Directed Conservation Option</u> or <u>Water Banking Option,</u> check here ☐, complete Sections 1 and 2 of the Application, and review the application requirements for these options on the following pages.

If the Applicant elects the <u>Supplemental Source of Water Supply Option,</u> check here ☐, complete Sections 1 and 2 of the Application, and additional meetings will be scheduled with the Town to review this option.

TOWN OF __________ WATER DEPARTMENT

WATER BALANCE PROGRAM APPLICATION

Application Date *(mm/dd/yyyy)*:____________________________
Application Number (assigned by the Town): ________________

SECTION 1 – APPLICANT INFORMATION

Applicant's Name: ______________________________________
Street Address: ____
City: ____
State: ____
Zip Code: ____
Primary Contact: ____
Phone Number: ____
Fax Number: ____
E-mail: ____

SECTION 2 – GENERAL PROJECT INFORMATION

Project Name (if applicable): _________________________________
Project address or closest street: ____________________________
Municipal location: _______________________________________
Type of project: ____
Type of water service(s) being requested: (Circle)   Domestic   Irrigation   Fire Hydrants
Number of new domestic services: ____________________________
Number of Irrigation Systems: _______________________________
Number of new fire services: ________________________________
Number of new private fire hydrants: _________________________
Number of new public fire hydrants: __________________________
Applicant's Engineer (if applicable): __________________________
Engineering Contact (Name): ________________________________
Engineer's Street Address: __________________________________
City: ____
State: ____
Zip Code: ____
Engineer's Phone Number: ___________________________________
Engineer's Fax Number: _____________________________________
Engineer's E-mail: ____

PROVIDE A PROJECT NARRATIVE IN THE BELOW SPACE
(Attach additional pages if necessary)

REQUIREMENTS/CHECKLIST FOR APPLICANT-DIRECTED CONSERVATION PROGRAM

With the Applicant-Directed Conservation Option, the Applicant must provide the Town with an estimate of the annual water demand for the proposed new development or expanded water use, and must develop and implement a Conservation Plan that will reduce the existing water usage within the Town system by an amount equal to the estimated demand of the proposed new development. Details are provided below.

☐ **Submit estimate of projected water demands for the proposed development on the attached form**

- The projections must include an estimate of average annual water usage (expressed in MGD – million gallons per day) and maximum daily water usage (in MGD). All relevant, supporting data must be provided. Demands must represent full project build-out. If the project is phased, then the incremental increases in demand must be shown and explained.

- Massachusetts Title 5 regulations (310 CMR 15.203) can be used to project average day water demands.

- Water demands can be projected by using actual data from comparable facilities upon approval by the Town. The Applicant should describe the similarities and differences between the proposed facilities and the facilities generating the demand data.

- Irrigation demand must be estimated separately in each demand projection. Note that any new irrigation system will be required to use a rain or moisture sensor that is designed to interrupt the cycle of an automatic irrigation system when a specific amount of rainfall has occurred or when the moisture in the soil exceeds a specified limit.

- Water demand estimates shall be subject to review and acceptance by the Town.

☐ **Submit a Water Conservation Plan**

The accepted water demand projections must be offset by an equal amount of water savings. Developing and implementing the Water Conservation Plan is the responsibility of the Applicant. A proposed Plan shall be submitted to the Town with this Application. Methods to offset new water demands include:

- Implementing water demand reductions from existing water customers in the same service area as the new development. This can be done by retrofitting existing buildings with water saving fixtures and appliances. Estimated savings from retrofits can be derived from the information shown on Table 1. Higher water savings estimates may be considered with supporting documentation.

- Demand reduction measures (e.g., independent irrigation systems, decreasing commercial and industrial consumptive use) including conducting water audits of significant water users. (Large users will be identified by the Town upon request.)

Table 1 – Estimated Water Usage for Plumbing Devices

Device	Projected Usage
Vintage Toilet (pre-1978)	20.0 gallons per capita per day
Conventional 3.5 gpf Toilet (1978-1993)	17.5 gallons per capita per day
Low Consumption 1.6 gpf (Toilet (after 1993)	10.0 gallons per capita per day
Conventional (3 gpm or more) Showerhead	13 gallons per capita per day
Low Flow (2.5 gpm or less) Showerhead	11 gallons per capita per day
Vintage Urinal (pre-1994) (3.5 gpf) 3 flushes per capita per day	7.5 gallons per capita per day
Standard Urinal (post-1993) (1.0 gpf) 3 flushes per capita per day	3 gallons per capita per day
Waterless Urinal	0 gallons per capita per day
Vintage Faucets (pre-1994) (3 gpm)	12 gallons per capita per day
Standard Faucet (post-1993) (2.2 gpm)	11 gallons per capita per day

gpf = gallons per flush

Sources:

- American Water Works Association Manual M22 – Sizing Water Service Lines and Meters
- Manufacturers Literature

TOWN OF __________ WATER DEPARTMENT

WATER BALANCE PROGRAM APPLICATION

REQUIREMENTS/CHECKLIST FOR WATER BANKING OPTION

Under the Water Banking Option, the Applicant must provide the Town with an estimate of the water demand for their proposed new development of expanded water use, and provide funds for the Town's Water Bank, which will be used by the Town to fund conservation activities with then Town system serving the above-noted towns.

☐ **Submit estimate of projected water demands for the proposed development on the attached form**

- The projections must include an estimate of average annual water usage (expressed in MGD – million gallons per day) and maximum daily water usage (in MGD). All relevant, supporting data must be provided. Demands must represent full project build out. If the project is phased, then the incremental increases in demand must be shown and explained.

- Massachusetts Title 5 regulations (310 CMR 15.203) can be used to project average day water demands.

- Water demands can be projected by using actual data from comparable facilities. The Applicant should describe the similarities and differences between the proposed facilities and the facilities generating the demand data.

- Irrigation demand must be estimated separately in each demand projection. Note that any new irrigation system will be required to use a rain or moisture sensor that is designed to interrupt the cycle of an automatic irrigation system when a specific amount of rainfall has occurred or when the moisture in the soil exceeds a specified limit.

- Upon request, the Town will provide historical water demand data. Water demand estimates shall be subject to review and acceptance by the Town.

☐ **Provide funding for the Water Bank**

Once the Town has reviewed and accepted the Applicant's estimated water demands, the owner/developer must provide funding for the Water Bank at a rate of $10 per gallon per day (gpd) based on the proposed development's annual average water demand. At the exclusion limit of 100,000 gallons per year (or 273 gallons per day), the required funding amount would be $2,730. The $10 unit price is based on the water conservation activities developed in consultation with our engineers. The Town will use the funds at its discretion to fund conservation activities.

If a project's estimated average daily water demand is greater than 10,000 gallons per day, the Town has the discretion on a case-by-case basis to modify the Water Bank Rate.

TOWN OF __________ WATER DEPARTMENT

WATER BALANCE PROGRAM APPLICATION

SECTION 3 – ACKNOWLEDGEMENTS

The Applicant acknowledges (by checking each box) that:

☐ This application must be completed for the Town to complete its review. A complete application should include this form.

☐ The Applicant is responsible for all costs for the Water Balance Plan development and implementation. For the Applicant-Directed Water Conservation Option and Water Banking Option, Applicants must include a preliminary deposit of $1,000 as part of this application, except for Applicants electing to use Title 5 Design Flows as the basis for water demand projection. No initial deposit is required for these applications. Receipt of the $1,000 deposit will be provided. Additional cost to review, approve, and audit the project will be billed to the Applicant on an as needed basis. Any unused funds will be returned to the Applicant.

☐ The Applicant acknowledges that the requirement for a Water Balance is based upon current water withdrawal limits and current plans required by the DEP. Water Balance may or may not be required in the future and the Town reserves the right to alter or discontinue this program at any time.

☐ For the Applicant-Directed Water Conservation Option, water service will not be rendered to the Applicant's project until the activities described by the Applicant's Water Conservation Plan, as approved by the Town, have been completed by the Applicant. A written acknowledgement that the Applicant has complied will be provided. Projects involving expansion of existing water demand requiring either construction or change in use must comply with the plan in order to maintain water service delivery.

☐ For the Water Banking Option, water service will not be provided to the Applicant's project until the Applicant has provided the Town with the required funds for the Water Bank.

☐ The Applicant acknowledges the Town or its designee will routinely review the project's water use. In the event that the actual usage exceeds the estimated usage, the difference will require the applicant to immediately offset the additional usage through another Water Balance Program application under the existing terms and conditions of the program.

TOWN OF __________ WATER DEPARTMENT

WATER BALANCE PROGRAM APPLICATION

Acknowledged by the APPLICANT:

PRINT (TYPE) NAME: ________________________________

TITLE: ____

SIGNATURE: ____ Date of Signature: ___________________

Acknowledgement of Receipt by the Town:

PRINT (TYPE) NAME: ________________________________

TITLE: ____

SIGNATURE: ____ Date of Signature: ___________________

TOWN OF __________ WATER DEPARTMENT

WATER BALANCE PROGRAM APPLICATION

WILL SERVE LETTER APPLICATION
APPLICATION DATE: ________________
PROJECT SITE INFORMATION:

Project Name: ____
Location/Address: ____
____

Proposed Use: ☐ Commercial/Industrial   Building Size (s.f.): _____________
☐ Residential   Building Size (s.f.): _____________
Site Elevations: High: _____________ft   Low: _____________ft
Datum Elevation (USGS): ____
Length/Side (Dia.) or Proposed Service: ___________________________________
Site Plan Attached: ☐ (Must show Elevation Contours)

WATER DEMAND INFORMATION (Determined by the applicant's project plumbing consultant)

Commercial/Industrial Use	**Residential Use**
Commercial/Industrial Demand	Domestic Demand
Projected Facility Usage____________gal/day (310 CMR 15.203)	No. of Units____________ No. of Bedrooms/Units____________ Total No. Bedrooms____________
Projected Irrigation Usage____________gal/day	Projected Residential Usage______________gal/day (110 gpd/bedroom, 310 GMR 15.203)
	Projected Irrigation Usage______________gal/day (1" per week x area, Apr. – Sept.)
Fire Flow Requirements	Fire Flow Requirements
Hydrant____________gal/min	Hydrant____________gal/min
Building Sprinklers: Yes ☐ No ☐	Building Sprinklers: Yes ☐ No ☐
Required Sprinkler Flow:____________gal/min	Required Sprinkler Flow:____________gal/min
Residual Pressure: ________________psi	Residual Pressure: ________________psi

Residential projects with more than 1 service connection and commercial/industrial projects greater than 100,000 gallons per year (273 gallons per day) are subject to the Water Balance Program.

TOWN OF __________ WATER DEPARTMENT

WATER BALANCE PROGRAM APPLICATION

CONTACT INFORMATION

Applicant (or Agent) Name: _________________________________
Address: ____
____
Tel. No.: ____
Email: ____

SIGNATURE: ____________________ **PRINT NAME & TITLE: _________________________**

Environmental Partners GROUP

A partnership for engineering solutions

1900 Crown Colony Drive, Suite 402 Quincy, MA 02169

P: 617.657.0200 F: 617.657.0201 www.envpartners.com

Quincy, MA · Woburn, MA · Hyannis, MA · Middletown, CT

ENVIRONMENTAL PARTNERS GROUP 20 YEARS CELEBRATING 1997 - 2017