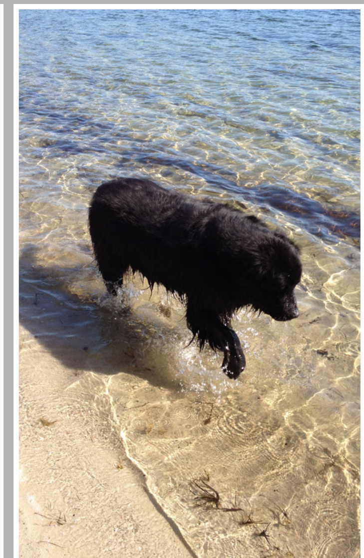
REPORT

TOWN OF BARNSTABLE
NEW SOURCES ALTERNATIVES EVALUATION REPORT

MARCH 2019



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March 12, 2019

Mr. Hans Keijser
Supervisor
Hyannis Water Supply Division
Department of Public Works
47 Old Yarmouth Rd.
Hyannis, MA 02601

Re: New Source Exploration Study for New Public Drinking Sources for the Hyannis Water System
New Source Alternatives Evaluation Report

Dear Mr. Keijser:

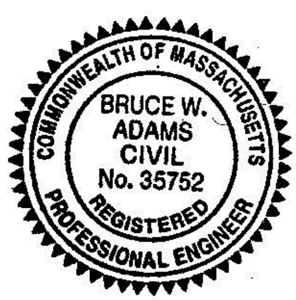
We are pleased to submit to the Town of Barnstable, Hyannis Water Supply Division the attached New Source Alternatives Evaluation Report. This document presents the results of the first phase of the new source exploration study for the Hyannis Water System, focusing on alternatives to obtain additional water supply.

We wish to acknowledge the assistance of Mr. Michael Gorenstein, Project Manager, who assisted the project team in gathering and evaluating background information for this project. Blake Martin, Joe McGinn and Kevin McKinnon of Weston & Sampson worked on the project. We thank you for this opportunity to be of assistance.

Very truly yours,

WESTON & SAMPSON,

Bruce W. Adams, PE
Vice President



EXECUTIVE SUMMARY

The Town of Barnstable Hyannis Water System sources of supply consist of ten (10) active and two (2) inactive wells. These ground water resources rely on yield from a permeable sole source aquifer, the Sagamore Lens. The wells are susceptible to water quality threats from land uses and commercial/industrial practices in their recharge zones. In addition, iron and manganese in the groundwater may require treatment. These conditions are aggravated by the fact that the wells are located in clusters.

The existing water sources cannot provide adequate supply for all demand conditions. This is a result of the shutdown or reduced pumpage from existing wells because of the existence of known contaminants in the groundwater. If treatment was provided for these wells and their full pumpage was restored, the supplies would be nearly sufficient to meet current demand conditions. Additionally, new supplies should be developed to replace contaminated supplies, provide redundancy and to provide for future population and water demand increases.

This recommendation is based on the identified need to supplement the capacity of currently operating groundwater sources by approximately 2.5 MGD in ten years. The projected supply deficit is 1.87 MGD (6.19 – 4.32) in 2020 and will grow to 3.23 MGD (7.55 - 4.32) in 2040. The volume of additional supply is recommended to meet the projected maximum day demand deficit assuming the loss of the largest well field or treatment plant.

Weston & Sampson recommends that the Town of Barnstable should immediately initiate the investigation and development of additional sources of groundwater supply, which will take years to bring on line. In order to take advantage of existing supplies that are available but off-line, upgrading facilities and adding treatment should be prioritized in the near term.

The Town should continue with implementation of current planned water system improvements to immediately restore the operating capacity of the water system, including:

- Reactivation of Straightway Well No. 1; estimated cost approximately $140,000;
- Replacement of Mary Dunn Well No. 4; estimated cost approximately $724,000;
- Implementation of Advanced Water Treatment at the Maher Water Treatment Plant to include filtration for Manganese and Iron Removal, advanced oxidation plus UV for 1, 4 Dioxane removal, and GAC filtration for PFOS removal; estimated cost approximately $11.5 million.

Additional evaluation, conceptual design and cost analysis are required for the following improvements to confirm treatment needs and cost estimates.

- Initiate a feasibility study to create a better understanding of modernizing and upgrading the Mary Dunn Treatment Plant, providing greensand filtration for iron and manganese control from the Airport Well with consideration of two treatment plants or independent dual treatment systems; estimated cost range approximately $10 million.
- Initiate a feasibility study to modernize and upgrade the Straightway Treatment Plant to include installation of greensand filtration; GAC for removal of PFC's; advanced oxidation

plus UV to remove 1,4 Dioxane; and consider additional treatment for nitrogen removal from the Hyannisport Well; estimated approximately $11.5 million.

For the development of new water supplies, we recommend the initiation of hydrogeologic and water quality investigations for development of new groundwater sources in six areas, prioritized in order A through F, as shown on Figure ES-1. Estimated costs for development of new supplies are tabulated below and assume a total capacity of 2.5 MGD per site. The inclusion of greensand filtration would add approximately $7.5 million per site.

Table ES-1: New Groundwater Supply Development Cost Estimate – 2.5 MGD

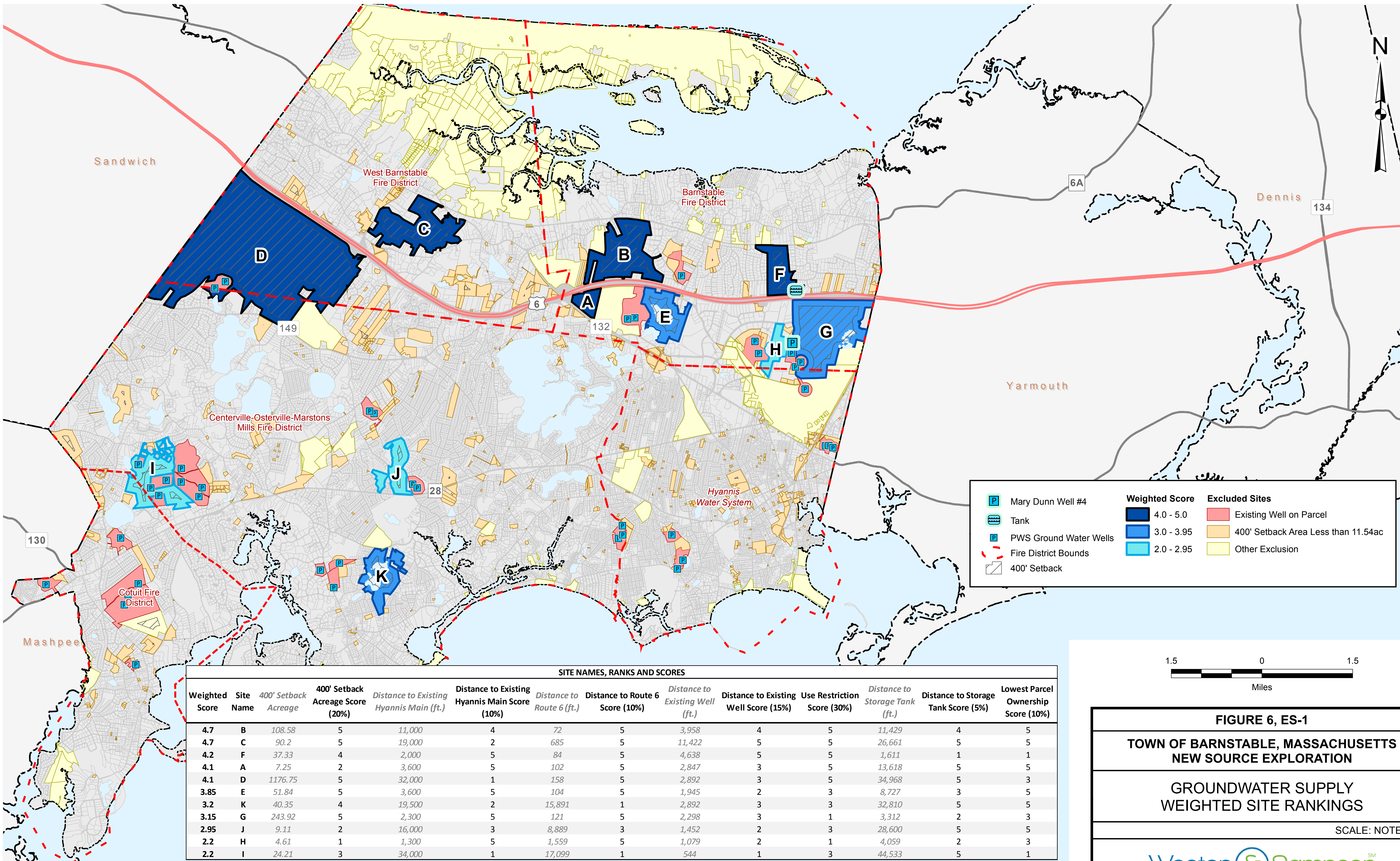
New GW Source	Preliminary Site Studies	Wells & Treatment	Transmission Mains	Engineering 18%	Contingency 15%	Total Cost
Site B	$150,000	$3,000,000	$1,100,000	$765,000	$637,500	$5,652,500
Site A	$100,000	$3,000,000	$360,000	$622,800	$519,000	$4,601,800
Site C	$150,000	$3,000,000	$1,900,000	$909 ,000	$757,500	$6,716,500
Site D	$200,000	$3,000,000	$3,200,000	$1,152,000	$960,000	$8,512,000
Site F	$120,000	$3,000,000	$200,000	$597,600	$498,000	$4,415,600
Site E	$120,000	$3,000,000	$360,000	$626,400	$522,000	$4,628,400

The suggested schedule to implement the recommended improvements to existing sources of supply and the development of new supplies is shown on the table below. A second round of new supply development beginning in 2028 is recommended to provide additional capacity to keep pace with growth and/or to replace existing lost capacity of existing sources.

Table ES-2: Preliminary Schedule of Water Source Improvements

Preliminary Schedule of Water Source Improvements

	Start Date	End Date
Existing Supplies		
Reactivate SW#1	2018	2019
Relocate MD#4	2018	2020
Upgrade Maher Water Treatment	2019	2020
Continue Purchase of Yarmouth Water	2018	2020
Evaluate & Upgrade Mary Dunn Water	2020	2024
Evaluate & upgrade Straightway Water	2020	2024
New Supply Development Phase 1		
GW Exploration, Testing & Permitting	2019	2021
Preliminary Well & Treatment Design	2020	2022
New Source Approval, Design & Permitting	2021	2024
Construct New Wells with Treatment	2025	2029
New Supply Development Phase 2		
GW Exploration, Testing & Permitting	2028	2030
Preliminary Well & Treatment Design	2029	2031
New Source Approval, Design & Permitting	2030	2033
Construct New Wells with Treatment	2034	2038



SITE NAMES, RANKS AND SCORES

Weighted Score	Site Name	*400' Setback Acreage*	400' Setback Acreage Score (20%)	*Distance to Existing Hyannis Main (ft.)*	Distance to Existing Hyannis Main Score (10%)	*Distance to Route 6 (ft.)*	Distance to Route 6 Score (10%)	*Distance to Existing Well (ft.)*	Distance to Existing Well Score (15%)	Use Restriction Score (30%)	*Distance to Storage Tank (ft.)*	Distance to Storage Tank Score (5%)	Lowest Parcel Ownership Score (10%)
4.7	B	*108.58*	5	*11,000*	4	*72*	5	*3,958*	4	5	*11,429*	4	5
4.7	C	*90.2*	5	*19,000*	2	*685*	5	*11,422*	5	5	*26,661*	5	5
4.2	F	*37.33*	4	*2,000*	5	*84*	5	*4,638*	5	5	*1,611*	1	1
4.1	A	*7.25*	2	*3,600*	5	*102*	5	*2,847*	3	5	*13,618*	5	5
4.1	D	*1176.75*	5	*32,000*	1	*158*	5	*2,892*	3	5	*34,968*	5	3
3.85	E	*51.84*	5	*3,600*	5	*104*	5	*1,945*	2	3	*8,727*	3	5
3.2	K	*40.35*	4	*19,500*	2	*15,891*	1	*2,892*	3	3	*32,810*	5	5
3.15	G	*243.92*	5	*2,300*	5	*121*	5	*2,298*	3	1	*3,312*	2	3
2.95	J	*9.11*	2	*16,000*	3	*8,889*	3	*1,452*	2	3	*28,600*	5	5
2.2	H	*4.61*	1	*1,300*	5	*1,559*	5	*1,079*	2	1	*4,059*	2	3
2.2	I	*24.21*	3	*34,000*	1	*17,099*	1	*544*	1	3	*44,533*	5	1

FIGURE 6, ES-1

TOWN OF BARNSTABLE, MASSACHUSETTS
NEW SOURCE EXPLORATION

GROUNDWATER SUPPLY
WEIGHTED SITE RANKINGS

SCALE: NOTED

Weston & Sampson

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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1.0 INTRODUCTION

1.1 Study Objective

The New Sources Alternatives Evaluation Report for the Hyannis Water System (HWS) was initiated to evaluate water supply needs and additional supply options. The study comes at a critical point in time as it has become clear that impairments to groundwater quality and new water quality regulations have reduced the volume of water available from the currently active and previously active wells. The resulting reductions in capacity have created strains on the system that impact the ability to meet maximum day water demands despite successful efforts to conserve water and reduce unaccounted for water throughout the system. The reduction of available supplies has resulted in the need to purchase water from Yarmouth and COMM in each of the last two years. This shortfall in water supply is expected to continue in the absence of new sources of supply and additional treatment of existing sources to comply with new regulations. It is clear that the HWS must increase available water supply to meet both short and long-term demands.

The first phase of this evaluation, and the subject of this report, is to conduct a comprehensive review of a variety of possibilities for new public drinking water sources for the HWS. The HWS's drinking water supply sources are derived from a sole source aquifer that has a long history of water quality threats and resulting impacts to the potability of the supply from a variety of contaminants, both regulated and unregulated. As a response to these impacts, the HWS seeks to evaluate all potential options for meeting the current and future demands of its customers with high quality drinking water. This study seeks to provide an understanding of the current water quality and quantity challenges and recommend a variety of options to resolve these challenges. The options will be evaluated and ranked with respect to the short term and long-term feasibility as well as capital cost, operating cost, personnel needs, safety, complexity of operation, speed of implementation, reliability, and regulatory approvals.

Future water supply options must be evaluated not only against cost, but operational challenges, vulnerability and reliability. A variety of options are available, from additional ground water resource development, additional treatment, water purchase, desalination and water reuse/recharge. A comparative matrix of alternatives scored against multiple criteria and ranked in order of favorability will allow for comparison of viable alternatives.

Although purchase of water is feasible in the short term, efforts are best focused on new well source development. Issues associated with the purchase of water from other systems include the lack of control over such issues as water quality or interruptions in service due to problems in the host water system, such as drought restrictions, main breaks, power outages, source contamination, or treatment plant disruptions. Problems may also arise in relation to Water Management Act Permit limits applicable to the host system. Costs of purchase of finished water from other systems are also beyond the control of the buyer. Treatment, desalination, and reuse options are costly and complex to operate and should be pursued if new, relatively pristine groundwater sources, that require minimal treatment, cannot be developed.

Although new well source development provides for future improvement in system resiliency and reliability, long-term objectives to reduce demand, create or improve protection strategies, emphasize source monitoring, and develop reliable, sustainable re-charge and reuse strategies should be part of any community's water resource management.

1.2 Existing Water Supply System

As of the time of this writing, there are currently ten active wells operating and two inactive wells serving the HWS. A generalized map showing the locations of these public water supply wells is provided as Figure 1. Straightway Well No. 1 was taken offline in 1996 due to odor issues and is currently being reactivated. The Mary Dunn 4 Well was found to be under the influence of surface water and has been inactive for several years. Currently, it is in working condition and sampling is regularly conducted to keep it available for an emergency. A test well investigation is on-going to replace the Mary Dunn 4 Well.

Pumping records for all wells were provided by the HWS for the period 2010 to 2016 and are summarized in Table 1 and Figure 2. As shown in Figure 2, Hyannis and the associated water system experiences the influence of seasonal population and tourism that drastically increase water demand during the peak summer months of June, July and August. September pumping tends to reflect a transition between the summer and fall periods annually. Based on the data for this seven-year period, the average day demand of the system is 2.32 MGD, with a maximum day demand of 5.5 MGD. Monthly and annual total pumping volumes for each well in service compiled over the last seven years are shown in Figure 2.

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Figure 1: Hyannis Water System - Public Drinking Water Supply Wells

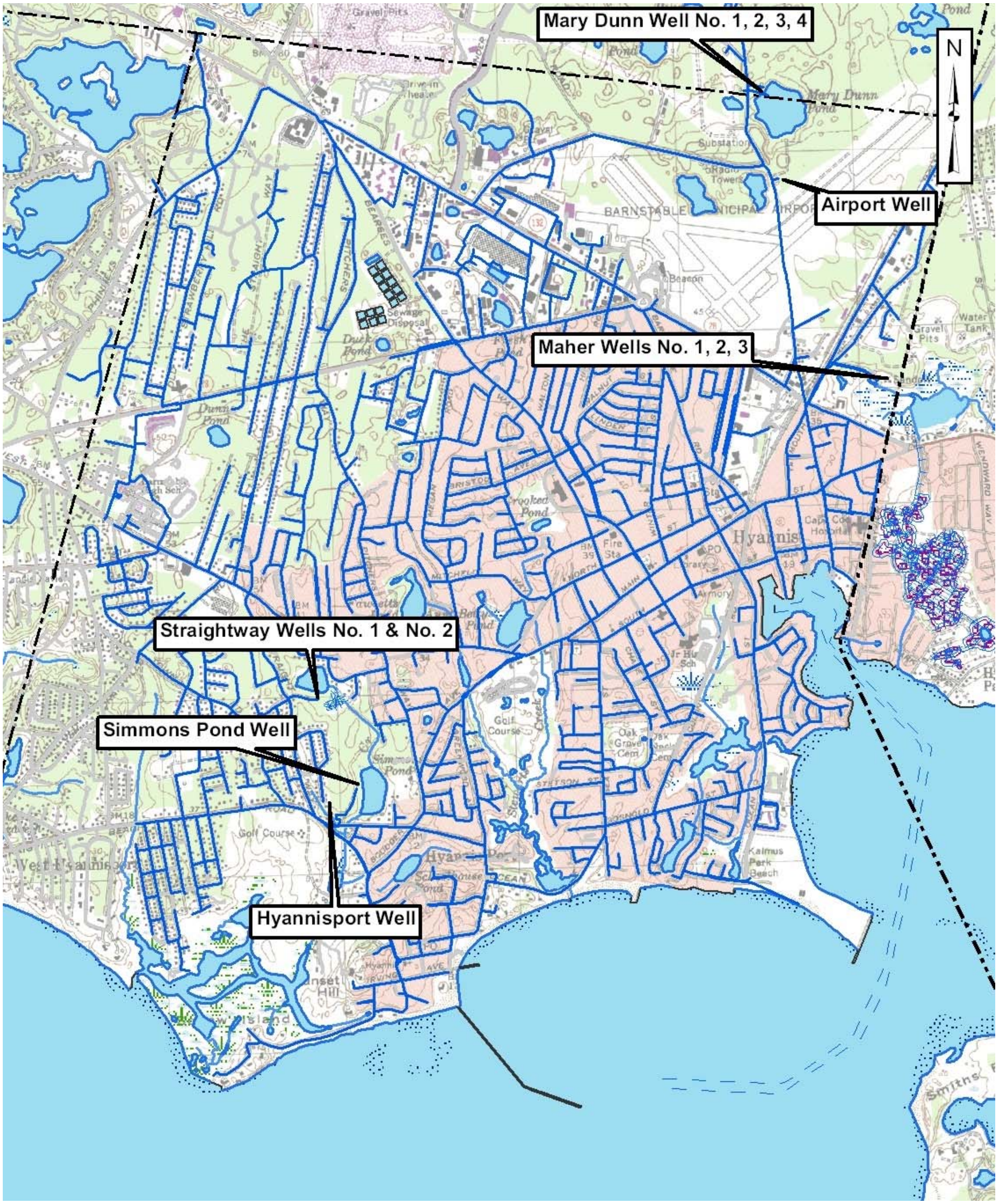
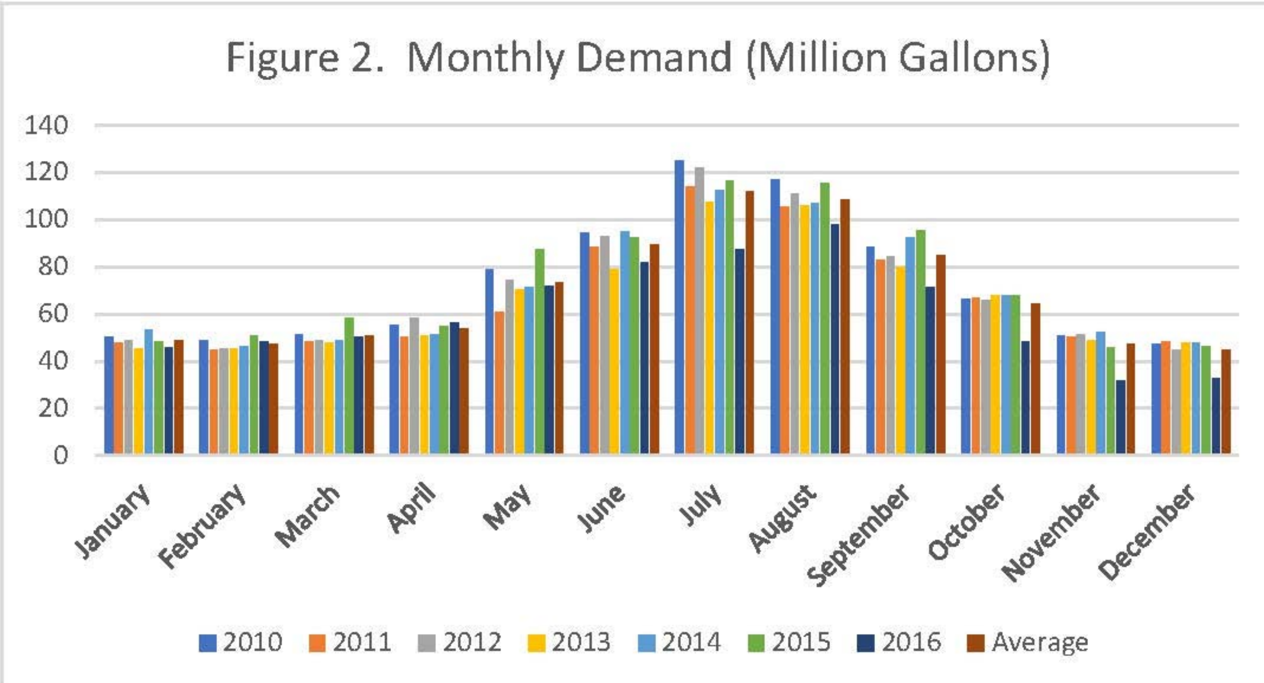


Table 1: Well Data Summary (2010 - 2017)

Existing Wells HWS ID 402004	Well ID	Status	Year Constructed	Age (years as of 2018)	DEP Approved Daily Pumping Volume (MGD)	Safe Yield (gpm)	Safe Yield (MGD)	Actual Yield (gpm)	Well Depth (ft)	Diameter (inches)	Screen Interval (ft)	Pump Type	Motor (HP)
Maher No. 1	07G	Active	1971	47	1.008	972	1.4	525	80	24	37 - 47; 70 - 80	2-Stage	25
Maher No. 2	02G	Active	1975	43	1.008	869	1.25	504	54	24	10	1 Stage Submers.	15
Maher No. 3	11G	Active	1976	42	1.008	663	0.95	391	48.7	18	10	1 Stage Submers.	20
Mary Dunn No. 1	04G	Active	1976	42	0.72	534	0.77	315	54.6	24	10	3 Stage Submers.	40
Mary Dunn No. 2	05G	Active	1975	43	1.01	567	0.82	329	50	24	10	6 Stage VT	50
Mary Dunn No. 3	08G	Active	1975	43	0.72	442	0.64	256	54	10	10	5 Stage Submers.	40
Mary Dunn No. 4	09G	Emergency Use Only	1976	42	0.72	296	0.43	175	51	24	10	VT	40
Airport	10G	Active	1971	47	1.44	459	0.66	248	63	24	10	4 Stage VT	100
Hyannisport	03G	Active	1975	43	0.72	715	1.03	415	75		15	7 Stage, VT	40
Simmons Pond	06G	Active	1975	43	1.01	792	1.14	459	74	18	15	6 Stage VT	50
Straightway No. 1	01G	Inactive	1969	49	0.72			0	62	24/16	15	None	
Straightway No. 2	12G	Active	1988	30	1.584	1530	2.2	1086	187	24	25	5 Stage Submers.	125
Total Authorized Withdrawal Volume (MGD)					11.668		11.29						
total Potential Safe Yield - Active Wells (MGD)							11.29	6.77					

Figure 2: Monthly & Annual Demand (Million Gallons)



As noted in the 2007 Hyannis Water System Master Plan, the estimated safe yield of the ten active wells serving the system is 11.29 MGD. The total DEP approved maximum daily pumping rate or production volume for the ten active wells is 10.948 MGD. This is based on the sum of each well's approved Zone II pumping rate under the Water Management Act. The total authorized average daily withdrawal volume for the HWS is 3.42 MGD. This lower value represents an allocation for withdrawal of "the waters of the Commonwealth" based on the sum of the permitted volume of all well sources (0.71 MGD) plus the original WMA registered volume (2.71 MGD). These values are reported and summarized in the Annual Statistical Reports (ASR's) for the HWS. The average daily withdrawal is 2.32 MGD.

Thus, it would appear that the quantities of water available from existing sources are adequate to meet the current demands of the system. Although these wells can theoretically produce these volumes, the actual yield is much lower due to the age and loss in capacity of most wells. Routine cleaning and rehabilitation of all wells is necessary to maintain rated capacity. But, even with routine maintenance, most wells continue to decline in capacity until they must eventually be replaced.

Continued water quality concerns have also impacted Hyannis Water System's ability to fully utilize all well sources. These limitations are discussed in subsequent chapters in this report. Water quality concerns will likely continue to impact source and treatment decisions for the Hyannis Water System, both in terms of continuing reliance on existing sources and as new sources are further investigated.

In addition, the MassDEP "Guidelines and Policies for Public Water Systems" require that the Town be able to supply the maximum daily pumping demand of the system with the largest source out of service. Compliance with these requirements is required by MassDEP so that water suppliers can provide for needed redundancy. Any interruption in a supply well or treatment would put HWS out of compliance with these DEP requirements and put the system at risk to not meet customer demands.

2.0 CURRENT AND PROJECTED WATER DEMAND

2.1 Current Water Demands

Average daily and maximum day demands over the period 2010 to 2016 are presented in Table 2. Daily demand over this period averaged 2.32 MGD. The average Maximum Day Demand for the same period was 4.84 MGD. This results in a ratio of Maximum Day Demand to Average Daily Demand of 2.09. In the Water System Plan produced by Weston & Sampson for the HWS in 2007, the ten-year average daily demand for the period 1996 to 2005 was reported to be 2.65 MGD; an average maximum day demand of 5.14 and a ratio of Maximum to Average Demand of 1.94. The decrease in demand since that time can be attributed to conservation efforts; decreases in population and residential gallons per capita per day (rgpcd) usage within the HWS; and reduction in the amount of Unaccounted for Water (UAW) as reported by the HWS in the Annual Statistical Reports (ASR's) submitted annually to DEP.

Table 2: Average Day Maximum Day Demand (MGD) - Hyannis Water System

Year	Average Day Demand	Maximum Day Demand	Ratio of Maximum to Average Day Demand
2010	2.39	5.09	2.13
2011	2.21	4.55	2.06
2012	2.32	4.62	1.99
2013	2.18	4.89	2.24
2014	2.32	4.59	1.98
2015	2.41	5.49	2.28
2016	2.43	4.66	1.92
Average	2.32	4.84	2.09

2.2 Population Trends

Population figures for the Town of Barnstable reported by the U.S. Census Bureau are presented in Table 3. The data are presented in five-year increments for the period 1980 – 2015. Population figures for Hyannis Village are also provided in Table 3 for the same period. The estimates of Hyannis Village population are based on prior determination concluding that Hyannis Village population historically averaged 31% of the total population of Barnstable.
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Table 3: Population Variation Over Time (Hyannis Water System)

Year	Town of Barnstable	Hyannis Village
1980	31,334	9,714
1985	33,479	10,378
1990	31,439	9,746
1995	43,184	13,387
2000	47,821	14,824
2005	39,690	12,304
2010	45,193	14,010
2015	44,542	13,808

Population plays an important role both in accounting for current and historic water use and as a basis for projecting future water demand. As a Cape Cod community that historically experiences significant variation in seasonal population due to summer vacation and tourism populations, Barnstable and Hyannis Village need to respond to seasonal variations in water demand. This is clearly shown in Figure 2 in Chapter 1 where graphs of the monthly variation of water demand are shown for each of the years 2010 through 2016.

Projected population estimates for the Town of Barnstable were obtained from the UMASS Donahue Institute (UMDI) and the MassDOT 2000 – 2040 EEA published sources and are presented in Table 4. Projected population estimates for the Hyannis Water System based on both sets of town wide projections are presented in Table 5. These projections are based on the expectation that the population of Hyannis will continue to represent about 31% of the total town population. Also, provided in Table 5 are projections through 2040 based on use of a conservative 35% ratio of Hyannis service area to total Barnstable population. Finally, service area population projections developed by DCR for the Water Needs Forecasts (DCR, 2015) are also provided in Table 5.

Table 4: Projected Population – Barnstable, MA

Year	UMDI	MA DOT 2000 – 2040
2020	42,119	43,573
2025	40,332	
2030	38,781	40,210
2035	37,366	
2040		37,530

Table 5: Projected Population - Hyannis Water System

Year	DCR 2015	Weston & Sampson 2007	35% UMDI	35% MA DOT
2020	22,552	15,780	14,742	15,250
2025	23,217	16,500	14,116	
2030	24,044	18,000	13,573	14,074
2035		19,000	13,078	
2040				13,136

2.3 Water Use

Water use statistics reported for the past four years (2013 – 2016) are summarized in Table 6. Residential use represents about 46% of the total annual usage. Commercial/business uses represents about 44%. All residential and commercial service connections are metered. Another 4.6% of the total reported water use falls within the category of Confidently Estimated Municipal Use. Other, unaccounted water use is typically on the order of 5.4%, well within the DEP permit requirements for a system of this size.

Table 6: Hyannis Water System Annual Water Use 2013-2016

Year	Residential Water Use (MG)	Commercial Water Use (MG)	Confidently Est. Municipal Use (MG)	Unaccounted (MG)	Total (MG)
2013	360.98	365.02	28.46	42.1	796.58
2014	372.36	362.81	30.34	79.9	845.45
2015	407.38	392.05	39.77	43.3	882.52
2016	406.31	373.98	40.71	45.3	866.30

2.4 Projected Water Demands

Water demand projections are presented in Table 7 were developed by DCR (WNF, 2015); W&S (Master Plan, 2007); and current projections (W&S, 2017). This HWS average day water demand projection is based on projections of Barnstable population and represent a conservative 35% of the populations projected by UMDI and MassDOT from Table 5. These demand projections include some anticipated increase in population but do not necessarily reflect recent regional goals that could increase housing density in Hyannis, which could increase population and HWS water demands.

Table 7: Hyannis Water System Recent and Projected Average Day Demand

YEAR	DCR WNF	Weston & Sampson 2007	Weston & Sampson 2017
2020	3.18	2.76	2.71
2025	3.23	2.89	2.84
2030	3.3	3.15	3.09
2035		3.33	3.31
2040			3.31

Water demand projections for the current study have been produced using the population projections developed by W&S in 2017. Projected population estimates are adjusted to account for the seasonal population distributed over the year using the historic average increase of 3,800 persons, distributed monthly over an entire year (Note: This is the same process used by DCR in its WNF methodology). Residential water demands were calculated using a residential gallon per capita per day (rgpcd) use rate of 60 rgpcd. Water demand for the commercial/industrial sector was estimated using a multiplication factor ranging from 1.1 to 1.25 over the period from 2020 to 2040. This distribution range is based on the potential for the Growth Incentive Zone adopted within the commercial zoned area within the distribution system service area. A factor of ten percent (10%) was then added to account for municipal accounted-for and otherwise unaccounted for water use, consistent with use in these two categories reported in Table 5. Table 8 displays the results of this projection process for both average day and maximum day demand over the project planning horizon.

Factors that should be noted in considering future demand projections include the consistent projections of declining population; continued expectation for management of residential demand and continued efforts to control unaccounted for water. This declining population projection is countered by current CCC focus on increasing housing density in Hyannis, which would result in reversal of past trends by increasing water demands. The potential for increases in demand in the commercial and industrial sectors of the service area must also be considered in projecting future demands. Barnstable has established a Growth Incentive Zone along major commercially zoned transportation corridors and interchanges which include several currently vacant parcels as well as existing but unoccupied buildings within the Growth Incentive Zone area. While the ratio of residential to commercial/industrial water consumption is expected to remain fairly even, the potential for additional demands in this sector, and possible expansion of the growth incentive zone, could increase over the planning period of this study. Factors have been chosen to account for such increases in the projections shown in Table 8. The Maximum Day to Average Day demand of 2.28 ratio was used to project future Maximum Day demand. This ratio of 2.28 was chosen as it is the worst-case ratio experienced recently (in 2015), and slightly exceeds the seven-year average of 2.09. The results of the DCR WNF, 2007 and current projected demands are displayed graphically in Figure 3.

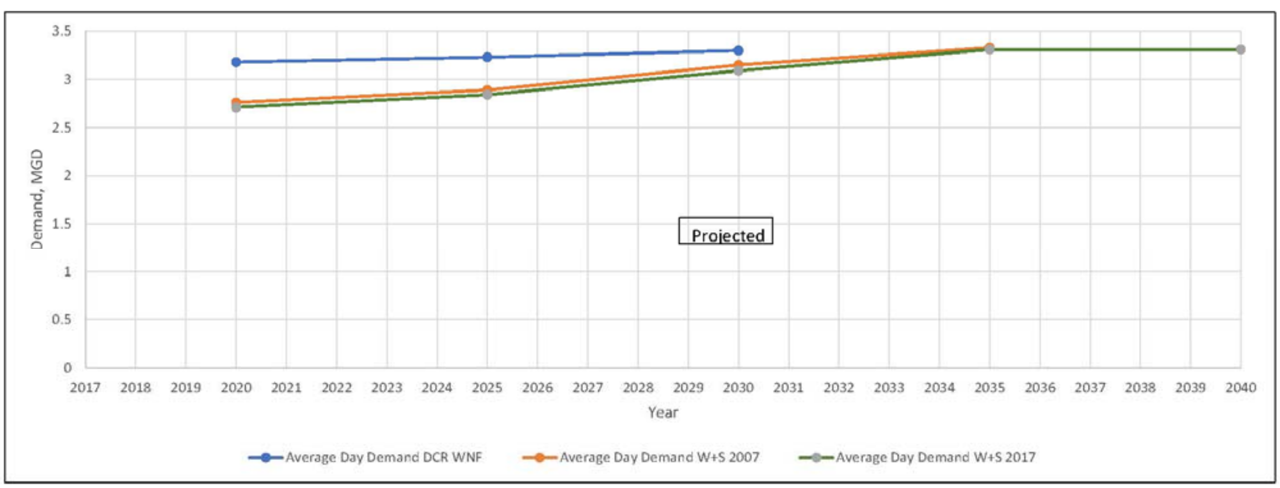
Table 8: Average and Maximum Water Demand Projections, 2020 - 2040

Year	Population*	Average Day Demand (@ 60 rgpcd) (MGD)	Commercial /Industrial ADD %	Commercial /Industrial ADD (MGD)	ADD Sub Total (MGD)	Other Use @10% (MGD)	Total Projected ADD (MGD)	Total Projected Maximum Day Demand (@ 2.28 ratio) (MGD)**
2020	19,580	1.18	110	1.29	2.47	0.25	2.71	6.19
2025	20,300	1.22	112	1.36	2.58	0.26	2.84	6.48
2030	21,800	1.31	115	1.50	2.81	0.28	3.09	7.04
2035	22,800	1.37	120	1.64	3.01	0.30	3.31	7.55
2040	22,300	1.34	125	1.67	3.01	0.30	3.31	7.55

*Adjusted for seasonal population, and includes an average increase of 3,800 persons in summer

** The ratio of 2.28 was chosen as it is the worst-case ratio experienced recently, as discussed above

Figure 3: Hyannis Water System Recent and Projected Average Day Demand



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2.5 Conclusion

The total projected maximum day demand in years 2020 and 2040 is 6.19 and 7.55 MGD, respectively. HWS cannot currently pump enough water from its wells to meet these demands, which occur during the summer months. Several issues prohibit pumping the full available supply from several wells. These issues include multiple contaminants in the groundwater and decreased yield from individual wells. Subsequent sections of this report will discuss and evaluate options to restore capacity of existing supplies, to develop new supplies, and to minimize the risk of catastrophic loss of well and/or treatment capacity.

The MassDEP "Guidelines and Policies for Public Water Systems" state that the Town shall be able to supply the maximum daily pumping demand of the system with the largest source out of service. There are three critical points of finished water production in the HWS including the Mary Dunn WTP (1925 gpm), Maher WTP (1500 gpm) and Straightway WTP (1500 gpm). The total water production that can be supplied from these three WTP's operating at current fully capacity is 4,925 gpm (7.09 MGD). The single largest source in the Hyannis Water System is the Mary Dunn Treatment Plant (1925 gpm/2.77 MGD). With this source offline, the available maximum daily output from the Hyannis system is reduced to 3000 gpm or 4.32 MGD.

With the Mary Dunn Wellfield offline, and 4.32 MGD supply available, the Hyannis system cannot meet its current or future Maximum Day Demand (MDD). The supply deficit under this scenario would be 1.87 MGD in 2020, growing to 3.23 MGD in 2040, as shown in Table 9 below. The projected supply deficit will be approximately 2.5 MGD in 2028, ten years from now.

Table 9: Projected Supply Deficit, 2020 - 2040

Year	Average Day Demand (MGD)	Maximum Day Demand (MGD)	Supply Available (MGD)	Projected Supply Deficit (MGD)
2020	1.18	6.19	4.32	1.87
2025	1.22	6.48	4.32	2.16
2030	1.31	7.04	4.32	2.73
2035	1.37	7.55	4.32	3.23
2040	1.34	7.55	4.32	3.23

3.0 WATER QUALITY CONDITIONS

Understanding the quality characteristics of the sources tapped for drinking water is essential for the protection of public health and decisions relating to the treatment and distribution of a finished drinking water supply. Monitoring of water quality at the source or sources and at specific points in the process of treating water is an important function of the water supplier. Changes in water quality often reflect changes in the hydrogeology and land uses within the contributing areas to both surface and groundwater sources. Changes in source water quality often require adjustments to treatment systems to reliably deliver a finished water with consistent quality characteristics acceptable to consumers.

Water quality standards for drinking water are set by the U.S. Environmental Protection Agency (EPA) pursuant to the authority created by the Safe Drinking Water Act. EPA has established primary drinking water standards for Microbial Contaminants, Regulated Inorganic and Organic Contaminants, and Stage 2 Disinfection and Disinfection Byproducts (DBP's). Primary drinking water standards are set based on the protection of public health. A Maximum Contaminant Level (MCL) is set for each constituent. In some cases, a Maximum Contaminant Goal (MCLG) is also prescribed pending further evaluation of potential human health effects associated with that contaminant. Both the EPA and Massachusetts Drinking Water Standards are published at 320 CMR 22.00 et seq. Monitoring requirements for community water systems are described in 320 CMR 22.05 and 06 for microbiological and inorganic chemicals, respectively.

Secondary standards have also been set for certain contaminants. Secondary standards are often associated with the aesthetic effects associated with each regulated chemical that are not associated with human health impacts. Action levels are descriptive and typically relate to communication of the concentration measured to the consumer or other action related to treatment or other response are specified in the secondary standards.

The sampling requirements for both primary and secondary contaminants are set by EPA and DEP regulation based on the size of the water system and population. Other constituents may be required to be sampled on a monthly or quarterly basis, depending on the Sampling Plan for the community water system as approved by the DEP.

Results of water quality sampling are published annually in the Annual Water Quality Report for the Hyannis Water System. The results as provided in the annual reports for the years 2013 – 2016 are summarized in Table 10. The results are displayed as ranges of the results for each biological and chemical constituent analyzed at all well locations during the year represented. There were no violations of any regulated contaminant during the four-year period represented. The Hyannis Water System meets all primary Water Quality Standards set by the EPA and DEP.

Under the Safe Drinking Water Act (SDWA) Amendments of 1996, EPA is required under the Unregulated Contaminant Monitoring Rule (UCMR) to publish a list of contaminants of emerging concern every five years. The most recent list was released by EPA as of December 20, 2016. Known as UMCR 4, the new list includes monitoring for a total of 30 chemical contaminants including two metals, eight pesticides plus one pesticide manufacturing byproduct, three alcohols, and three semivolatile organic chemicals (SVOC's). Groundwater systems are only required to monitor for twenty (20) specified chemicals. Sampling is required to take place twice over the course of twelve months for a total of two sampling events five to seven months apart. Samples are required to be drawn from an Entry Point to the Distribution System (EPTDS), or, in the case of large groundwater systems, at representative sampling locations. Samples must be analyzed by EPA UCMR approved laboratories.

The most persistent water quality concerns requiring treatment in the HWS are elevated levels of iron and manganese. These issues are discussed in more detail in Chapter 5 of this Report.

Water quality is the primary indicator of the condition of a water supply source. It is not however the only important factor in assessing the condition and vulnerability of a water supply source to potential contamination. DEP has established two zones for the protection of groundwater sources of water supply including Zone I and Zone II. Zone I is a mandatory radius of 400 feet (for wells with a yield greater than 100,000 gpd) around the center of the well itself. Zone I is required to be owned and/or controlled by the water supplier and is intended to be secure from impacts by land uses which could result in release of contaminants which might impact water quality in that well. Based on the most recent available Sanitary Survey for the HWS performed by DEP in 2015, and the information provided by HWS in the mandatory Annual Statistical Report's (ASR's) for the last four years, HWS owns or controls 100% of the Zone I's for Mary Dunn Well 2 and the Airport Well. Zone I areas for other wells are partially owned by HWS. DEP identified non-water supply related activities within these Zone I delineated areas including local roads and unauthorized access (potential for accidental spills and releases), and an electrical power line right-of-way (concerns relate to herbicide use Mary Dunn Wells 1, 3 and 4). While there may not be any specific threats to water quality in any of these wells associated with such activities within the Zone I 400-foot radius, it is an issue that may warrant continued heightened scrutiny of activities within these areas to assure adequate protection of the water source.
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Table 10: Water Quality Data Summary (Hyannis Water System Wells)

Microbial

Year	Total Coliform (%)*	Fecal Coliform (%)**
MCL	5	0
2013	0 - 1	0
2014	0 - 1	0
2015	0 - 1	0
2016	0 - 2.7	0

Lead & Copper (90th Percentile)

Year	Lead (ppm)	Copper (ppm)
AL	0.015	1.3
2013	4	0.32
2014	4	0.32
2015	4	0.32
2016	0	0.23

Regulated Inorganic Contaminants

Year	Arsenic (ppm)	Barium (ppm)	Nitrate measured as N (ppm)	Perchlorate (ppb)	Selenium (ppm)
MCL	0.01	2	10	0.002	0.05
2013	ND - 0.004	ND - 0.066	0.11 - 5.1	ND - 0.20	NR
2014	ND - 0.004	ND - 0.066	ND - 4.7	0.06 - .022	NR
2015	ND - 0.004	0.014 - 0.019	.22 - 4.5	0.06 - 0.23	NR
2016	ND - 0.004	0.014 - 0.019	.24 - 4.5	0.07 - 0.27	ND - 0.004

Regulated Organic Contaminants

Year	Perchloro-ethylene (PCE)(ppb)
MCL	5
2013	ND - 1.1
2014	ND - 2.8
2015	ND - 1.1
2016	ND - 1.1

Stage 2 Disinfection

Year	Chlorine (ppm)
MRDL	4
2013	0.20 - 1.42
2014	0.20 - 1.51
2015	0.23 - 1.21
2016	0.12 - 1.2

Stage 2 Disinfection By Products (DBP's)

Year	HAA5 (ppb)	TTHM's (ppb)	Four TTHM Components ======>	Bromodichloro-methane (ppb)	Chlorodibromo-methane (ppb)	Bromoform (ppb)	Chloroform (ppb)
LRAA	60	80		N/A	N/A	N/A	N/A
2013	0.50 - 2.9	2.4 - 13.0		ND - 1.1	ND - 8.3	ND - 2.4	ND - 10
2014	1.0 - 4.9	3.3 - 11.9		ND - 0.9	ND - 1.6	ND - 1.2	ND - 5
2015	1.0 - 1.5	1.0 - 9.3		ND - 1.0	ND - 1.7	ND - 1.0	ND - 4.8
2016	ND - 2.8	ND - 11.9		ND - 1.1	ND - -1.7	ND - 1.0	ND - 1.4

Secondary Contaminants

Year	Aluminum (ppb)	Calcium (ppm)	Chloride (ppm)	Magnesium (ppm)	Potassium (ppm)	Sulfate (ppm)	Zinc (ppm)
SMCL	50 - 200	N/A	250	N/A	N/A	250	5
2013	11 - 200	NR	15 - 54	NR	NR	6.9 - 19	0.08 - 0.52
2014	NR	1.89 - 14.8	16 - 56	1.51 - 4.29	ND - 2.7	6.6 - 18	0.04 - 0.28
2015	ND - 0.1	1.74 - 16.2	19 - 58	2.10 - 4.68	ND - 3.3	6.3 - 17	0.11 - 0.41
2016	NR	1.87 - 16.1	24 - 54	1.75 - 4.77	1.4 - 14	6.5 - 17	0.182 - 0.495

Secondary Contaminants

Year	Iron (ppm)	Manganese (ppm)***	Sodium (ppm)****
SMCL	0.3	0.05	20
2013	ND - 2.6	0.05 - 0.150	9.8 - 24
2014	ND - 3.13	0.014 - 0.117	9.8 - 24
2015	ND - 2.54	0.022 - 0.604	22 - 37
2016	ND - 2.28	0.029 - 0.312	22 - 37

* 5% per month or if < 40 samples, no more than 1 positive plus additional sampling required
** Repeat samples required after Fecal Coliform positive
*** Manganese Health Advisory is 0.3 ppm
**** Massachusetts Guideline
AL = Action Level
MCL = Maximum Contaminant Level
SMCL = Secondary Maximum Contaminant Level
MRDL = Maximum Residual Disinfectant Limit
LRAA = Locational Running Annual Average

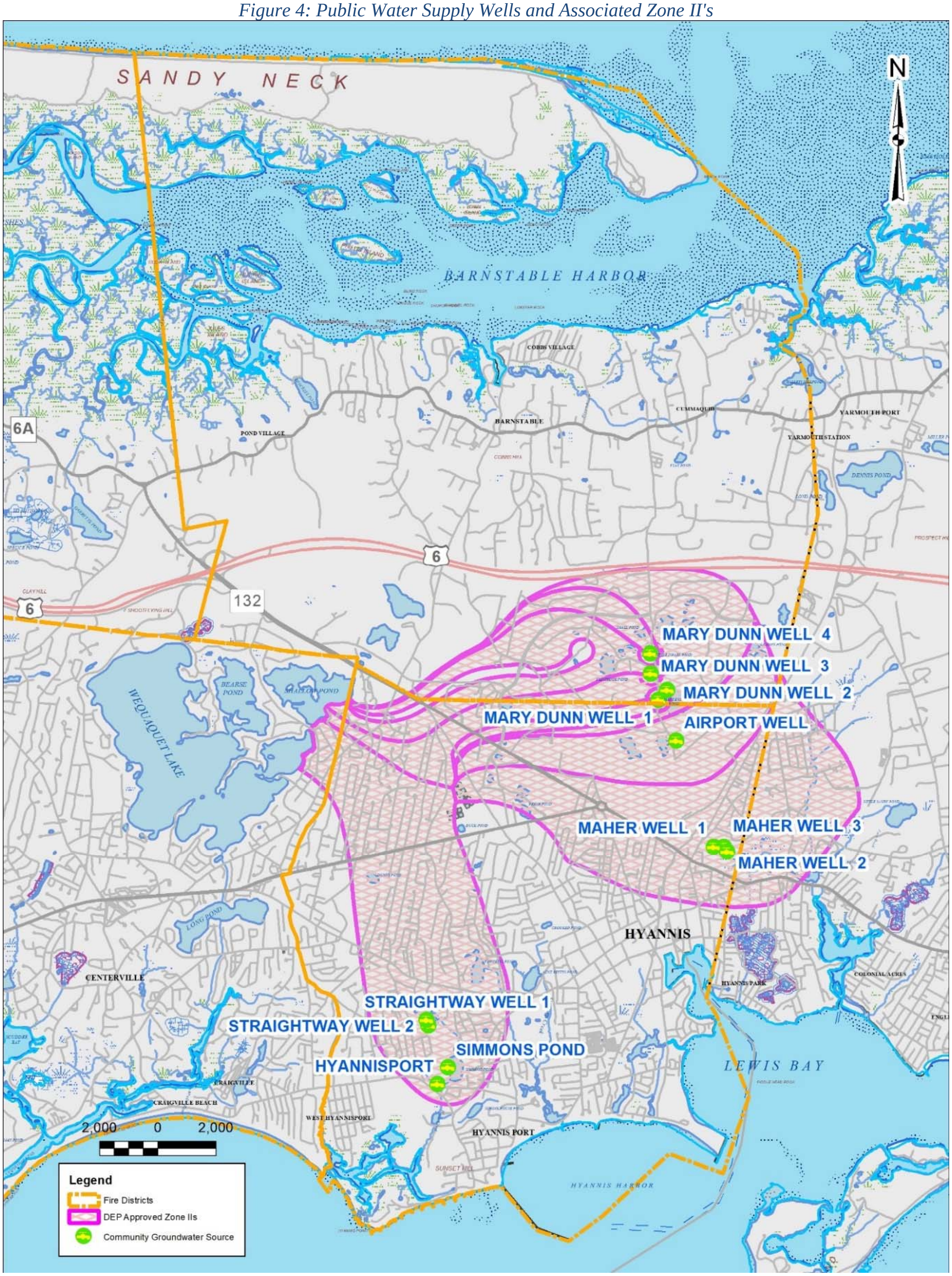
Zone II is defined as the area which constitutes the zone of contribution to the well under pumping conditions. Depending on the aquifer characteristics and the geology and topography of the contributing drainage area, Zone II's can extend considerable distances from the well location. Barnstable sits atop a sole source aquifer. As shown on Figure 4, the Zone II areas for each well extend upgradient several miles from each existing well. The Zone II associated with the Maher wells extends into the adjacent town of Yarmouth. While zoning and other land use protection measures for the protection of wells and well fields located within the town of Barnstable can be employed and monitored, Barnstable cannot easily control land use practices in adjacent towns.

The potential for plumes of suspected or known contaminants that originate in one area to migrate along the general path of the flow of groundwater through the aquifer represents a significant concern. Chemical plumes have the potential to impact multiple wells in the same well field or wells in successively impacted well fields, Chemical plume migration must be considered in assessing the susceptibility of groundwater wells to interruptions in service, treatment decisions or abandonment.

When such occurrences have threatened the water supply, decisions on taking threatened wells out of service on a temporary basis have been made when necessary. Select wells have remained offline until the threat has been abated or remediated or when treatment is implemented to ensure the protection and continued reliability of the water supply.

Based on the documented occurrences of impairments to multiple wells within the HWS from groundwater contamination events; the varying degrees of protection available for Zone I's for each well; and the type and intensity of land uses within Zone II's; the groundwater resources are determined to be susceptible to potential contamination. This susceptibility is compounded by the lack of hydrogeological separation in such a large sole source aquifer. Although continued efforts should be made to manage land use activities in the Zone I and Zone II protection areas, existing and future development will continue to pose a threat to groundwater quality. As the HWS has experienced multiple well impairments, the potential for catastrophic loss of multiple wells is rated as moderate to high. This level of risk warrants immediate attention as a high priority for the HWS.

Figure 4: Public Water Supply Wells and Associated Zone II's



4.0 VULNERABILITY TO CONTAMINATION

4.1 Introduction

The evaluation of current and future water supply sources requires an assessment of vulnerability to water quantity and quality impacts. In recent years, the use of the term "vulnerability" has been used in the regulatory arena to refer to potential for serious consequences from adverse actions such as vandalism, insider sabotage, terrorist attacks and other malevolent, security related acts (e.g. cyber-attacks). The Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (Public Law 107-188) requires community water systems to conduct vulnerability assessments directed at the range of security related threats listed.

For the purposes of this New Sources Alternatives Evaluation Report, the term vulnerability is used synonymously with the term susceptibility, referring to the potential for a water supply source to be impacted by contamination by physical, chemical or biological contaminants.

4.2 Source Water Assessment and Protection (SWAP) Report

Susceptibility to contamination is the approach embodied in the DEP Source Water Assessment and Protection (SWAP) Report process. Susceptibility is defined as a "measure of a water supply's potential to become contaminated due to land uses and activities within its recharge area." As described in the DEP SWAP report for Barnstable Water Company (DEP, April 2003), "(A) sources susceptibility to contamination does not imply poor water quality".

The SWAP report examines land uses within the protection areas defined for both surface and groundwater supply sources. Each land use type is rated based on the potential sources of contamination (PSC's) typically associated with a specific land use. Based on the range of land uses identified within defined protection areas (i.e. Zone I and Zone II for groundwater wells; Zone A and Zone B for surface water sources), DEP determines and rates the potential risk of contamination as Low, Medium or High. Table 11 presents a representative list of the types of contaminants associated with various land uses based on published literature. The associated threat ranking for each identified water quality impact would be based on a variety of factors like density of activity, hydrogeologic conditions, groundwater flow patterns and distance from source water supplies.

Table 11: Contaminant Threats and Land Uses

Land Use	Potential Sources of Contamination (PSC's)	Threat Rank
Agriculture	Fertilizers, Pesticides – Use, application, leaks, spills	M, H
Residential	Septic Systems, Lawn Care, Gardening – Microbial contaminants, household chemicals, medical pass-throughs, pesticides, fertilizers – Improper application, storage or disposal, inadequate or improper maintenance,	L, M, H
Commercial	Wide ranges depending on use – fuels, soaps, paint, solvents, maintenance chemicals, deicing chemicals, hazardous materials – Improper use, storage, disposal	L, M, H
Industrial	Wide ranges depending on purpose and product lines – Solvents and other chemicals, industrial chemicals, metals, metal tailings – Improper use, storage, handling or disposal	H
Other – Examples include Airports, Transportation Corridors, Utility Rights of Way, Fire Training Facilities, Wastewater Treatment Facilities, Hospitals and Medical Facilities	Fuels and other chemicals; deicing chemicals and compounds; Hazardous chemicals; Treatment chemicals; Microbiological contaminants; Herbicides, Pesticides and Fertilizers; pharmaceuticals; others	L, M, H

Based on the identification of land uses within the Zone II's for each of the wells serving the Hyannis water system (formerly the Barnstable Water Company), DEP rated the susceptibility as HIGH. This ranking is based on the presence of at least one high threat land use within the water supply protection areas noted in Barnstable.

Key land use and protection issues identified in the 2003 DEP SWAP Report included:

1. *Inappropriate Activities in Zone I's*
   Zone I consists of the mandatory 400-foot radius around each wellhead. Massachusetts regulations require Zone I to be owned or controlled by a conservation restriction or other

acceptable restrictive covenant approved by DEP (310 CMR 22.00 Drinking Water). Only water supply activities are permitted within a Zone I. DEP acknowledges that many water supplies were developed prior to the regulations and may include non-water supply activities within Zone I's. Such pre-existing activities can include residential house lots, public roads, and utility rights of way.

Specific to the Zone I's for wells in the Hyannis Water System, DEP found the following:

- Local Roads within Zone I's for the Hyannis Port Well, Mary Dunn Well #1, Mary Dunn Well #3, Mary Dunn Well #4.
- Unauthorized Access within Zone I's for Maher Well #2, Mary Dunn Well #1, Maher Well #1. (These Zone I's have since all been fenced.)
- Power Line Rights of Way within Zone I's for Mary Dunn Well #1, Mary Dunn Well #3, Mary Dunn Well #4.

While these issues may not directly cause a water quality impact, they often increase the susceptibility of the source to hazards associated with the activities or conditions listed.

2. *Residential Land Uses*

Residential land uses can pose a threat to groundwater quality through both intentional and unintentional spills, releases or improper management of chemicals. In an effort to characterize these threats and provide a perspective for relative vulnerability, DEP addressed residential land uses in the SWAP program.

Potential sources of contamination in Zone II areas listed by DEP included:

- Septic Systems – While 60 – 70 % of homes in the Zone II areas were found to be connected to sewers, improper disposal of household hazardous chemicals was identified as a potential source of contamination associated with homes reliant on septic systems.
- Household Hazardous Materials – Potential contaminants listed include automotive wastes, paints, solvents, pesticides, fertilizers, and other substances. Improper use, storage, and disposal of chemical products used in homes are considered potential sources of contamination.

- Heating Oil Storage – Leaks or spills from Underground and Above Ground Storage Tanks (UST and AST's) can be potential sources of contamination if managed improperly.
- Stormwater – Stormwater can transport contaminants from lawns, driveways and streets. Potential contaminants include lawn chemicals, pet waste, and automotive activities (e.g. leaks, maintenance, washing or accidents).

Ongoing aquifer monitoring along with notification requirements for spills and releases are generally recommended practices for reducing the threats listed above. However, long-term, fail-safe protections cannot be put in place for residential land uses where activities cannot be monitored or restricted.

3. *Transportation Corridors*

   Major transportation corridors identified by DEP within Zone II areas of existing wells included Routes 132 and 28. DEP also acknowledged local roads as common throughout the Zone II areas. Potential sources of contamination identified included construction, maintenance and typical highway use. Potential contaminants include deicing salts, automotive chemicals, fuels, potentially dangerous transported chemicals and hazardous materials and wastes.

   Railroad tracks were also listed by DEP as there are tracks running through water supply protection areas. Potential sources of contamination identified include chemicals released during normal operation, track maintenance, and accidents. Rail accidents can result in spills and releases of train engine fluids and commercially transported chemicals.

   Again, with the exception of road salt applications, most transportation related water quality threats can be linked to catastrophic spills or events. Emergency response capabilities represent the best defense but do not automatically guarantee protection of ground or surface water supplies.

4. *Hazardous Materials Storage and Use*

   Commercial and industrial land uses were identified within Zone II areas. Potential sources of contamination associated with these land use categories can include hazardous materials, produce hazardous waste products or store hazardous materials in UST/AST's. Improper use, storage or disposal of hazardous materials can result in releases of contaminants associated with such materials. Appendix B of the SWAP Report listed 37 facilities classified as Small, Very Small or Large Quantity Generators of Hazardous Wastes, including 9 Air Quality Permits and one fuel dispenser.

5. *Oil or Hazardous Material Contamination Sites*
   A total of nineteen (19) DEP Tier Classified Oil and/or Hazardous Material Release Sites were identified by DEP as of April 2003. DEP recommended education of local businesses on Best Management Practices (BMP's) for water supply protection; registering facilities generating hazardous waste or waste oil; and educating businesses regarding Massachusetts floor drain requirements.

6. *Comprehensive Wellhead Protection Planning*
   In its 2003 SWAP Report, DEP acknowledged that Barnstable has in place water supply protection controls that meet DEP's Wellhead Protection Regulations 310 CMR 22.21(2). A Wellhead Protection Plan protects drinking water by managing the land area that supplies water to a well. The Wellhead Protection Plan includes provisions to coordinate community efforts, identify protection strategies, establish time frames for implementation and provides a forum for public participation.

4.3 Experiences with Vulnerability of Existing Wells to Chemical Contamination

Contamination of groundwater by 1,4 dioxane and Perfluorinated Compounds (PFC's, including PFOS and PFOA) has occurred at all three well fields within the Hyannis Water System. As a result of testing mandated by the U.S. Environmental Protection Agency under the Unregulated Contaminants Monitoring Rule 3 (UCMR3) program in 2013, 1,4 dioxane was found in the Straightway 2 and Maher Wells in excess of the health goal of 0.3 micrograms per liter (parts per billion, or ppb) set by the DEP Office of Research and Standards.

PFOS was found in Mary Dunn Wells 1 and 2 that exceeded the EPA Health Advisory guideline of 0.2 micrograms per liter (ppb). Additional sampling in 2014 and 2015 confirmed the exceedances of these chemicals in Maher 1, 2, and 3 and Straightway 2 wells. In 2016 EPA further reduced the lifetime Health Advisory Limits for PFOS and PFOA to 70 parts per trillion (ppt). This limit is for each compound or a combined concentration. As a result, the Mary Dunn Well 3 and all Maher wells were impacted and needed to be shut down. At Straightway 2, PFC levels are above Health Advisory Limit values. At Hyannis Port and Simmons Pond Wells, PFC levels continue to be present but below Health Advisory Limit values.

In response to these instances of contamination, a connection with the Yarmouth Water Department was established for blending of waters at the Maher Treatment facility resulting in the dilution of 1,4 Dioxane and PFC's. Currently, only one of the Maher wells is being blended with Yarmouth supplied water to produce finished water consistently below the EPA Health Advisory Limits. Granular activated carbon filtration treatment systems were installed at the Mary Dunn Treatment plant for the removal of PFC's.

The suspected sources of the 1,4 dioxane found in the Maher wells were likely to be associated with chemicals frequently used in the deicing of aircraft as occurs at the Barnstable Municipal Airport in Hyannis.

Contamination of groundwater by PFC's is believed to have occurred because of the use of PFC compounds (PFOS and PFOA) in firefighting foams and associated equipment. The use of these materials at the Barnstable County Fire Fighting Training Facility located to the northwest of the Mary Dunn Well field and subsequent modeling of the suspected contamination plume associated with this facility has been identified as the most likely source of the contamination of the Mary Dunn Wells.

In both cases, the response of the HWS and its contract operator (Suez) has been to immediately remove the wells from service until appropriate treatment systems can be installed.

4.4 Vulnerability Considerations for New Source Alternatives

HWS has experienced contamination of existing wells from accidental releases and/or land uses within the protective zones of groundwater supplies. Any new groundwater source within the Sagamore Lens sole source aquifer will also be susceptible to contamination associated with land use.

The same potential for contamination exists with respect to surface water bodies within the same hydrogeographic area. The presence of the same land uses within the surface drainage basins tributary to streams, lakes and ponds and the interaction of groundwater with surface water contributing to the same lakes and ponds presents similar risks of contamination. Thus, any new groundwater or surface water identified for use as drinking water within Cape Cod should include consideration for water treatment systems capable of removing or reducing contaminant levels to meet established health advisory or other governing safe drinking water standard. Only those sources where upgradient recharge areas have limited or minimal land development can be considered to have a reduced susceptibility to degradation.

Recognition of the significant potential for interaction of surface and groundwater within the hydrogeographic landscape of the Sagamore Lens and its function as a sole source aquifer highlights the importance of adherence to a multiple-barrier approach to the development and protection of new sources of supply. The multi-barrier approach to public health protection is described in publications by both EPA and MA DEP and includes the following four barriers:

- Risk Prevention
- Risk Management
- Monitoring and Compliance
- Individual Action

Risk prevention begins with the identification of potential sources that represent the least probability or risk of contamination from land uses within the zones of contribution. In the case of potential groundwater sources, this translates to ensuring complete ownership and control of the Zone I radius associated with the wellhead itself. Developing an understanding of the extent of the Zone II within the aquifer contributing to the well including current and past land use practices, and the zoning that will determine the potential for new or expanded land uses within Zone II. *This approach also suggests that initial site selection might be guided by the identification of potential sites that are and have been open and undeveloped.* A second site selection criterion might consider identification of sites that are geographically diverse, rather than concentrating multiple sources within too close proximity to one another resulting in an increased system vulnerability to potential contamination. Through careful source selection and protection, the need for and reliance on treatment can be reduced, increasing the reliability of the source in terms of both water quality and quantity resilience.

Water quality testing must be undertaken in association with the development of any proposed new water source in advance of the design and submission of new source approval requests to the DEP. Review and updating of the town’s Wellhead Protection Plan, Stormwater Management Plan, along with zoning analysis of land uses within the zones of contribution to any proposed new water source need to be considered in concert with any proposal to develop a new surface or groundwater source of supply.

Risk management barriers focus on the protection provided by water treatment and system operations. Treatment removes and inactivates contaminants including microbial, physical and chemical constituents and represents a critical barrier of protection for the health of the consumer; the reliability and longevity of the distribution system and to demonstrate compliance with all applicable regulatory requirements. The provision of treatment ensures the delivery of consistent and reliable finished water quality throughout the distribution system.

Based on the history and experience of Barnstable and other water suppliers reliant on groundwater on Cape Cod, long-term provisions for treatment of groundwater to remove or sequester iron and manganese and disinfection are recommended for any groundwater source of supply. Depending on initial source water quality testing, additional treatment for the control of excessive manganese levels may be necessary, including provision of filtration facilities. Modeling of groundwater known or suspected of transmitting contaminant plumes associated with releases of particular contaminants will, in addition to water quality monitoring, dictate the need for additional levels of treatment appropriate to reduce or remove confirmed or suspected contaminants. The examples of blending of Yarmouth water with the Maher well in response to contamination by 1,4 dioxane and PFC's and the provision of granular activated carbon filtration at the Mary Dunn Treatment Plant in response to PFC contamination highlight both the effectiveness of advanced treatment technologies and the protection of public health gained by the barrier of protection provided by the installation of appropriate treatment technology.

Through the monitoring and compliance barrier, the water system reduces the risk of new or suspected contamination by detection and remediation of source water threats as early as possible. Monitoring of water quality at the source and within the distribution system provides protection by alerting operators of the need to adjust treatment processes or to act to prevent contaminants from being released into the distribution system.

Water systems are also required to monitor water quality in the distribution system to prevent the formation of disinfection byproducts and the leaching of lead and copper from household plumbing. Monitoring distribution system water quality can also be a useful tool to optimize the useful life of the distribution system, including pumping stations, piping, meters and service connections.

Individual action as a protection barrier embraces the concepts of consumer awareness and participation. Community water systems are required to publish annual Water Quality Reports including the condition of the source water and the levels of contaminants present in the system. Water systems are also required to issue public notification of any violations of drinking water standards. These requirements are intended to ensure that consumers are informed of any potential health risks in a timely manner and to enable water systems to build trust with consumers through open sharing of information.

In support of these ideas, the Hyannis Water System publishes an Annual Water Quality Report which conforms to the requirements of the Consumer Confidence Report specified by regulations. Water quality reflected in the WQR's for the years 2013 through 2016 are presented in Table 9 in Section 3 of this Report.

5.0 TREATMENT ISSUES IN THE HYANNIS WATER SYSTEM SOURCE WATER

5.1 Regulatory Framework for Water Treatment of Existing Sources

Drinking water regulations have been established to protect the health of customers consuming the public water supply. Surface water supplies are typically obligated to meet more regulations and follow more guidelines than groundwater sources. The following list summarizes the major drinking water rules and the major components included in each rule.

Surface Water Treatment Rule (SWTR) and Interim Enhanced Surface Water Treatment Rule (IESWTR)

- Applies to public water systems supplied by surface water or groundwater under the direct 5.2 Conventional Water Treatment
- IESWTR is an amendment to the SWTR that applies to systems that serve at least 10,000 people.
- WTP must achieve a 99 percent (2-log) removal of Cryptosporidium, 99.9 percent (3-log) removal of Giardia cysts and 99.99 percent (4-log) removal of viruses.
- Disinfectant residuals entering the distribution system have to be monitored continuously and cannot be less than 0.2 mg/L for more than 4 hours.
- Combined filter effluent turbidity must be measured at least once every four hours, and turbidity levels must be less than or equal to 0.3 NTU for at least 95 percent of the measurements per month with no turbidity samples exceeding 1 NTU at any time.
- Established disinfection contact time (CT) requirements based on water temperature, pH, and inactivation requirements for various disinfectants including ozone, chlorine, chlorine dioxide, and chloramines.
- Requires that disinfection profiling be conducted by any system whose one year running annual average of TTHMs or HAA5 levels are greater than or equal to 80 percent of the MCLs. The 80 percent thresholds for TTHMs and HAA5 are 64 μg/L and 48 μg/L, respectively.

Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)

- Applies to public water systems supplied by surface water or groundwater under the direct influence (GWUDI) of surface water.

- Rule provided additional public health protection from Cryptosporidium requiring systems to monitor their source water to determine potential additional treatment requirements for Cryptosporidium.
- Systems serving greater than 10,000 people must conduct two years of sampling for Cryptosporidium, turbidity, and E. Coli. Sampling is used to classify water system into one of four different treatment categories called bins. Additional treatment may be required based on which bin a system is assigned.

Stage 1 Disinfection Byproduct Rule (Stage 1 DBPR)

- Applies to all public water systems.
- Set the MCL for TTHM at 80 μg/L and for HAA5 at 60 μg/L based on the running annual average (RAA) of quarterly samples.
- At least 25 percent of samples must be taken at locations with a maximum residence time within the distribution system; the remaining 75 percent of samples are collected at locations with an average residence time.
- Established requirements for Total Organic Carbon (TOC) removal from surface water and GWUDI systems using conventional treatment based on the RAA monthly raw water alkalinity and percent removals.

Stage 2 Disinfection Byproduct Rule (Stage 2 DBPR)

- Applies to all public water systems, but the number of required sampling locations is greater for surface water or GWUDI public water supplies.
- Requires water systems to meet "locational" running annual averages (LRAA) of 80 μg/L for TTHM and 60 μg/L for HAA5.
- Requires water system suppliers to conduct Initial Distribution System Evaluations (IDSE) to select new Stage 2 DBPR compliance monitoring locations that more accurately represent peak disinfection byproducts in the distribution system.

Total Coliform Rule (TCR)

- Applies to all public water systems.
- Established MCLs for the presence of total coliform in drinking water. Systems must not find coliform in more than five percent of the samples collected each month.
- The number of monthly samples collected is based on the population served.
- Each total coliform positive routine sample must be tested for the presence of fecal coliform or E. coli.

- If any routine sample is total coliform positive, at least three repeat samples must be collected and analyzed for total coliform. Repeat samples follow the same requirements of the initial routine samples.

Lead and Copper Rule

- Applies to all public water systems.
- Requires sampling from customer's faucets.
- Established action levels for lead of 15 ppb and copper of 1.3 ppm. If the action levels are exceeded in more than 10% of customer taps sampled, the system must undertake a number of additional actions to control corrosion.
- Requires water suppliers to optimize their treatment system to control corrosion in customer's plumbing;
- Requires sampling of sources to rule out the source water as a significant source of lead or copper.
- If lead action levels are exceeded, suppliers are required to educate their customers about lead and suggest actions they can take to reduce their exposure to lead through public notices and public education programs and may have to replace lead service lines under their control.

Groundwater Rule

- Applies to a public water system supplied by groundwater or to a system that has both groundwater and surface water sources if water from groundwater sources is added to the distribution system directly without treatment.
- For a system that provides at least 99.99 percent (4-log) inactivation and/or removal of viruses from the groundwater source(s), the system is required to conduct compliance monitoring to show the effectiveness of their treatment process. For systems using chemical disinfection, compliance monitoring consists of continuously monitoring disinfectant residual to maintain the minimum required concentration.
- For a system that does not provide 4-log removal of viruses, the system is required to sample each groundwater source for E. coli if a routine TCR sample tests positive for total coliform. If the groundwater source tests positive for E. coli, five additional samples from the same source shall be collected. If a repeat sample tests positive for E. coli, then the system must take corrective action.
- Corrective action can include correcting the deficiency if possible, eliminating the water source, providing an alternate source of water, or providing new treatment that achieves 4-log inactivation and/or removal of viruses.

As detailed in the previous summary, there are several rules and regulations governing drinking water for public water supplies. However, due to the various contaminants typically present in surface water, the regulations are more extensive for a surface water or GWUDI supply compared to a groundwater supply. The requirements of the rules and regulations were considered when evaluating the Town's future water supply alternatives as some regulations may make certain alternatives more difficult to implement.

5.2 Water Treatment Process Overview

Included in this section of the report is a summary of processes that could be employed to treat water in the future from the existing groundwater supplies or from future surface and groundwater sources, for which a water treatment plant (WTP) may be necessary. Presented below is a review of treatment options for the Town's potential surface water and groundwater sources. These options include pressure filtration, upflow clarification followed by filtration, membrane filtration, and conventional treatment. These filtration options should allow the Town to meet the required primary and secondary water quality standards and regulations. However, any filtration option will need to be pilot tested to confirm that it provides the necessary treatment for the particular source of water.

<u>Conventional Treatment</u>
Conventional treatment consists of chemical addition followed by rapid mix, flocculation, sedimentation, and filtration. Typical chemicals added for conventional treatment include, but are not limited to, aluminum sulfate (alum), ferric chloride, polyaluminum chloride, powdered activated carbon and sodium or potassium hydroxide. The alum, ferric chloride or polyaluminum chloride will coagulate suspended particles into a settleable floc. The powdered activated carbon will reduce dissolved organic material such as taste, odor and color compounds, and will be removed during the sedimentation stage. Hydroxide (or a similar pH adjustment chemical) is added to adjust pH for coagulation.

Rapid mixing after chemical addition provides an initial interaction period between the chemicals and the targeted constituents. Typically, rapid mixing consists of a short detention time (approximately 30 seconds) and a high-energy mixing process.
After rapid mixing, flocculation allows for continued interaction between the chemicals and the targeted constituents. Detention times are greater than rapid mixing but less than sedimentation (approximately 15 to 30 minutes). Mechanical processes used during this stage

add a predetermined amount of energy to the water that promotes the formation of floc. Floc formation is essential to achieve settling during the sedimentation stage.

The sedimentation process allows the floc to settle. Sedimentation basins are typically long, rectangular basins that are designed based on the settling velocity of a targeted particle size. The maximum flow entering the basin is determined and the critical settling velocity is calculated. Once these two values are known, the area of the basins can be sized with typical detention times being two to four hours. To enhance the settling efficiency, settling devices such as tube settlers or plate settlers can be installed to maintain a comparable water quality entering the filtration stage while also allowing for smaller sedimentation basins.

Residuals that are effectively settled in the sedimentation basins need to be removed from the bottom of the basin periodically. The method that is used needs to ensure that disturbances are minimized so that settled particles do not become re-suspended. A flight and chain system or a suction system is a common method used for residuals disposal. For a flight and chain system, the operation is most efficient if the direction of travel of the flights is in the opposite direction of the flow through the basin. The residuals are transported away from the outlet zone thereby reducing the solids loading on the filters. The sumps should be located in the inlet zone for this form of residuals management. As an alternate to a flight and chain system, a residuals suction system can be used. This operation employs a roving vacuum installed on tracks on the bottom of the basin for the removal of residuals.

After settling, a filtration stage is necessary to physically remove particles that have not been removed prior to this step. Different forms of media exist to achieve the desired level of filtration. A combination of one or more different granular media sizes, known as mono-, dual-, or multi-media filtration may be used. Anthracite coal, garnet, and sand are often used. The media is placed over an underdrain system. A gravel bed may be used to disperse the water before being collected by underdrain piping. However, new underdrain technology may be considered that eliminates the need for a gravel bed as part of the collection system. During backwashing, an air scour system should be used. The addition of air aids in the scouring of filter media granules and the removal of particulates trapped in the filter bed. Replacement of filter media is typically required every 10 to 15 years.

Conventional treatment is a proven water treatment technology that has been used with New England surface and groundwaters. It provides good water treatment capabilities with variable raw water quality. Generally, conventional treatment provides more flexibility than other treatment technologies. However, the building footprint for conventional treatment is the largest of the alternatives often resulting in a higher capital cost.

Pressure Filtration

Pressure filtration is commonly used in New England to treat groundwater with elevated levels of iron and manganese. Generally, pressure filtration is not used to treat surface water. The media used in pressure filtration typically includes an upper layer of anthracite for rough particulate removal followed by a layer of catalytic media specifically designed for iron and manganese removal. The lower level of the filter is usually equipped with a gravel support media above the underdrain system. Three viable media options include GreensandPlus, LayneOx, and Pureflow. The filter vessels are either vertical or horizontal cylindrical steel tanks.

The influent water supply is pre-chlorinated for oxidation of the dissolved iron and manganese in preparation for removal through the pressure filters. In some applications, the media also requires the addition of potassium permanganate for the oxidation of manganese and continuous media regeneration. The typical filter loading rate ranges from 3 to 10 gpm/ft^2, depending on water quality. The filters are equipped with a backwash system. Some manufacturers also employ an air scour system. Replacement of filter media is typically required every 10 to 15 years.

If there are elevated color and organic levels, the addition of a small amount of coagulant prior to filtration, such as alum, may help to remove the organics during filtration. The use of alum is not necessary for most groundwater sources with low levels of color and organics, but for certain groundwaters which can have elevated levels of color and organics depending on the season, a coagulant may be necessary. The potential need for a coagulant can be determined by sampling for and evaluating color and total organic carbon levels and verified during pilot testing.

Pressure filtration is a proven technology for treating groundwater with elevated levels of iron and manganese. Pressure filtration can be used for treating water with elevated levels of TOC and color, but a coagulant may be needed to help remove the additional organics during filtration. The additional organics and coagulant added will increase residuals and potentially shorten filter run times. For waters known to have higher levels of organics, a clarification step prior to pressure filtration may provide an advantage over direct pressure filtration.

Upflow Clarification Followed by Filtration

Upflow clarification through a naturally buoyant media is a package plant technology that does not rely on the formation of a settleable floc. This treatment process is typically used for surface waters. As a result, the footprint can be reduced to as low as 20 percent of the footprint of a conventional treatment system. The upflow clarification and filtration system is provided as a package unit. Chemical addition similar to conventional treatment, including the addition of a coagulant and possibly a polymer, occurs prior to the package unit and contact time occurs in the area of the tank beneath the buoyant media. Water is forced upward through the clarifier where the buoyant media removes small floc formations from the water before being sent to the filter side of the treatment unit.

Following upflow clarification, a multi-media filter is used to treat the water depending on the water quality. Removing small floc through the upflow clarifiers will reduce the strain on the filters. This will potentially increase the run length of the filters and cut down on the backwash frequency. Less coagulant and polymer are used than would be needed for conventional treatment.

Upflow clarification/filtration units typically have a clarifier flush cycle for cleaning the clarifiers including an air scour followed by a water flush. A separate filter backwash cycle for cleaning the filters typically includes an air scour and water backwash depending on the type of media and filtration system used. The clarifier flush cycle occurs independently and more frequently than the filter backwash. However, the treatment unit has to be removed from treatment operations altogether during either a clarifier flush or filter backwash as both processes are needed to properly treat the water.

A typical upflow clarifier unit operates at a loading rate of 10 gpm/ft^2. The typical filter loading rate is 5 gpm/ft^2. Upflow clarification does not typically perform well at removing TOC. Therefore, we do not recommend this process for waters with elevated levels of organics.

Pressure and Vacuum Membrane Filtration

Membranes separate particles from water using a simple sieving process. The pore openings of the various available membrane media determine which application the membranes will be used for. In drinking water treatment in New England, ultrafiltration and microfiltration membranes are common.

Membrane filtration can either be a pressure driven or vacuum driven process. The way in which a membrane separates solids will also define the type of membrane process. Raw water can flow inside the membrane media and be forced out via pressure for what is known as an inside-out process. Target particles are trapped on the inside of the membrane. Raw water can also flow on the outside of the membrane media and be forced into the hollow structure. This is known as the outside-in process and causes particles to be trapped on the outside of the membrane. Pressure membranes can employ either method. Vacuum membrane filtration uses the outside-in process.

Membrane designs are based on a parameter known as the flux rate. The flux rate is the rate of finished water produced per square foot of membrane area. Once the flux rate is determined, the required membrane area can be calculated. If the quality of the water is poor, a lower flux rate is used, thereby increasing the required membrane area and increasing the footprint of the process. The same membrane area footprint is typically required for either the pressure or the vacuum membrane alternatives.

One of the major differences between the vacuum and pressure alternatives is the housing. Pressure membranes are housed in a pressure vessel (canister). Vacuum membranes are housed in an open tank. Pressure membrane housing is generally long and tubular in structure. The system arrangement includes piping and valving connecting a number of individual membrane bundles within canisters. Vacuum membranes are setup on a rack with no piping or valving separating the membrane filters and are immersed in a tank.

The energy requirements of the two systems may vary. A closed pressure vessel is needed in pressure membrane filtration to support the higher-pressure conditions during operation. In vacuum membrane filtration, the membranes are in a tank open to the atmosphere and operate under suction. The difference in operating conditions may be seen in power costs. Operating a system with suction may require less power than operating a system with pressure. It should be noted that a vacuum membrane system also employs an air-blower system during normal operation. The power costs associated with the blowers may make the overall power costs of the two alternatives comparable.

Backwashing of the membrane alternatives differ also. Both alternatives utilize a back-pulsing technique that reverses the flow of water to clean the surface of the membrane. The transport of the residual produced is what differs between the two systems. In a pressure membrane system, the residual flow exits the membrane canister through a separate residual line and is pumped to the residuals management system. In a vacuum membrane system, the residuals are pulsed off the membrane surface and fall to the bottom of the water tank that houses the membrane units. Once the concentration of residuals at the bottom of the tank reaches a certain level, the residuals are pumped out.

For water sources with elevated levels of iron and manganese and possibly color/TOC, an initial clarification step may be needed prior to membrane filtration for best removal results. Coagulation and flocculation may occur in the same basin as the membranes if used in conjunction with vacuum membrane filtration. The coagulation and flocculation processes would be similar to those detailed for conventional treatment. Chemicals are added just prior to a rapid mix stage and allowed to coagulate within a designated flocculation basin. A pin floc need only be formed due to the small pore size of the membrane media. As long as the pin floc is larger than the pore opening (0.1 micron), removal will occur through the membrane, eliminating the need for a settling stage. This is a form of direct filtration (without settling) using membrane filter technology. Membrane filtration is a proven water treatment technology that provides high level water treatment capabilities for surface and groundwater with variable raw water quality.

Summary of Advantages and Disadvantages

Presented in Table 12 is a summary of advantages and disadvantages for the filtration alternatives discussed in this report.

Table 12: Summary of Filtration Options – Advantages and Disadvantages

Treatment Type	Advantages	Disadvantages	Typical Source Water
Conventional Treatment	• Multi-barrier approach • Proven water treatment technology • Effective for treating various raw water quality • Effective for organic and iron and manganese removal	• High capital cost • High operational cost • Requires largest building footprint • Coagulant required • Higher residuals production due to coagulant addition	Surface Water and Ground-water
Pressure Filtration	• Low capital cost • Low operational cost • Most effective for iron and manganese removal • Lower residuals production	• Not as effective for organic removal • Filter media replacement can be more difficult in tanks	Ground-water

Upflow Clarification	• Multi-barrier approach • Moderate operational cost	• Moderate capital cost • Requires larger building footprint than pressure filtration alone • Coagulant required • Not very effective for TOC removal • Higher residuals production due to coagulant addition	Surface Water
Membrane Filtration	• Multi-barrier approach • Excellent effluent quality • Effective for organic and iron and manganese removal	• High capital cost • High operational cost • Requires larger building footprint than pressure filtration • Operations atypical from standard filtration (greater complexity) • Upstream clarification and coagulant may be needed • Higher residuals production if coagulant required	Surface Water and Ground-water

5.3 Current Treatment Provided for Existing Wells

Water treatment is provided at four locations including the Maher Treatment Plant, the Mary Dunn Treatment Plant, the Hyannis Port Treatment Plant and the Straightway Treatment Plant. Basic treatment systems common to each of the treatment systems serving the system include chemical addition for pH adjustment and corrosion control to comply with the Lead and Copper Rule; sequestration of iron and manganese to address the SMCL's for these chemicals; and disinfection.

The Maher Treatment Plant treats water from the three Maher wells plus water purchased from Yarmouth. In addition to the basic treatment described above, packed tower aeration has been installed for the removal of volatile organic compounds. Following treatment, water is stored in a baffled, two-compartment 800,000-gallon ground level storage tank. A booster pumping station delivers water from the storage tank to the distribution system.

The Mary Dunn Treatment Plant treats water from the three active Mary Dunn wells plus the Airport Well. Granular Activated Carbon filters have been installed on Mary Dunn Wells 1, 2 and 3 to remove Perfluorinated chemicals (PFOS and PFOA) resulting from groundwater contamination by firefighting chemicals. Treated water is pumped directly into the distribution system.

The Hyannisport Treatment Plant treats water from the Hyannisport and Simmons Pond wells. Treated water is pumped to a baffled 400,000-gallon ground level storage tank located at the Straightway Treatment location.

The Straightway Treatment Plant treats water from the Straightway 2 Well and will include the Straightway 1 Well in the future. Treated water from the Straightway wells is pumped to the same storage tank which receives treated water from the Hyannisport Treatment Plant. A booster pump station pumps water from the storage tank to the distribution system.

5.4 Water Quality Regulation and Change Impacts

Chemical treatment for iron and manganese through sequestration is provided for each of the wells in the HWS. Iron levels in finished water which, at the high end of the range reported annually, are on the order of 2.3 – 3.1 parts per million (ppm). The Secondary Maximum Contaminant Level (SMCL) for iron is 0.3 ppm.

Manganese is observed to be present over a range from under 0.1 to near 1 ppm over the four years for which data were provided. The SMCL for Manganese is 0.05 ppm. The Health Advisory limit is 0.3 ppm. The DEP maximum allowable limit is 0.2 mg/l. In recent years, high manganese concentrations in Straightway Well No. 2 was one of the triggers prompting the review of options to maximize available supply. The short-term solution included reactivation of Straightway Well No. 1 and blending of water from four wells - Straightway No. 1, Straightway No. 2, Simons Pond and Hyannisport, to reduce the total manganese concentrations of the blended flow to below 0.2 mg/l. This has resulted in the maximum flow rate from Straightway Well No. 2 flow being set at 150 gpm maximum, well below its original yield of near 1,000 gpm. Reactivation of Straightway Well No. 1 supply at about 450 gpm is under design with installation anticipated in 2019.

Past and current land use practices are impacting wells used in the HWS. Releases of chemicals subject to hazardous waste clean-up requirements have been reported at a variety of locations within the town over the past twenty or more years. Releases of 1,4 dioxane have impacted the Maher Wells and the Hyannisport area wells.

Perfluorinated compounds (PFC's) released due to the use of firefighting foams (AFFF) at the Barnstable County Fire Training Academy have impacted Mary Dunn Wells No. 1, 2 and 3. Granular activated carbon filters have been installed and remain in operation at this location.

PFC's have been detected at Maher and Hyannisport wells. At the Maher wells, the detects were above the Health Advisory levels and two of the wells were shut down. One well is producing water and is being mixed with Yarmouth water to produce finished water under the Health Advisory level.

5.5 Treatment Considerations for Existing Sources of Supply

As mentioned in the preceding section, concerns have been expressed by DEP regarding increases in manganese levels reported at Straightway No. 2. While blending is feasible to result in a source that produces water that meets the DEP set maximum concentration of 0.2 mg/l for manganese, this has seriously reduced the capacity of Straightway No. 2. To regain capacity from Straightway No. 2, treatment for manganese removal will be needed. The typical treatment option would include greensand filtration at the Straightway site. This location might at some point be considered as a central site for treatment of Simmons Pond, Hyannisport and both Straightway wells. Levels of 1, 4 Dioxane, PFOS/PFOA and Nitrate in the Straightway 2, Simmons Pond and Hyannisport wells may also result in a need for additional treatment.

Although below regulatory action levels, VOC's, Nitrate, PFOS, 1,4 dioxane, iron and manganese have been identified as potential future issues at both the Simmons Pond and Hyannisport wells. Flows from these two wells, Straightway 2 and the flows projected to become available upon completion of the reactivated Straightway 1 are estimated to achieve a combined capacity of 2 MGD. Continued monitoring will determine the need for future additional treatment to address these contaminants of concern.

As previously noted, the Maher wells have been impacted by VOC's, PFOS/PFOA, 1,4 dioxane, iron and manganese. An air stripper was installed to remove VOC's. Treatment considerations at the Maher Treatment Plant include the use of advanced oxidation plus Ultraviolet light (UV), GAC, and the addition of greensand filtration for removal of iron and manganese. Implementation of these treatment components would optimize water quality and realize operating cost benefits by extending the life of the GAC filters, reduce flushing efforts and decrease water quality complaints.

The Mary Dunn Treatment Plant includes GAC filters which are presently set up to treat influent streams from Wells 1, 2 and 3. They will also eventually treat water from replacement Well 4. In the future, the installation of greensand filtration or other treatment to handle iron and manganese levels from these wells and the Airport Well is advisable. If treatment is added, the units should be arranged in separate pairs much like the current GAC units are set up.

Crossover capability would allow for redundancy and continued and uninterrupted operation in the event of failure of a single component.

5.6 Treatment Considerations for Potential New Sources of Supply

As it is highly unlikely that any groundwater withdrawn from any location within the Sagamore Lens will ever be considered "pure" or "pristine" based on the mix of land uses and waste disposal systems which impact the raw water quality of this groundwater resource, the development of any new source(s) of groundwater can be expected to require, at a minimum, the same levels of basic treatment associated with any of the existing wells. Such minimum treatment can be anticipated to include pH adjustment and chemical addition for corrosion control; disinfection; and sequestration for iron and manganese. Where water quality testing confirms the presence of higher levels of iron, manganese or both, consideration for greensand filtration treatment will be warranted.

In the event that source water quality testing or modeling suggest that there is susceptibility to contamination by organic or other contaminants, higher levels of treatment will need to be considered. Such advanced treatment will likely vary depending on the nature of the contaminants of concern but will typically consist of any one or combinations of processes including packed tower aeration, granular activated carbon (GAC) or other process such as Advanced Oxidation Process (AOP) technology. As sites are evaluated as potential new groundwater sources the main goal is to locate wells on parcels where water quality conditions will not require the use of advanced treatment such as GAC or AOP.

For the purposes of evaluating costs for development of new groundwater wells in the HWS, we recommend basing costs on treatment including basic treatment processes plus greensand filtration.

6.0 PRELIMINARY IDENTIFICATION OF NEW SOURCE OPTIONS

6.1 Introduction

An initial analysis to identify options for new sources of supply requires multiple factors and multiple scenarios. Several scenarios were evaluated to meet the future demands of the system and to respond to the potential of catastrophic loss of existing sources of supply. The following represents a preliminary list of new source options considered for further review and exploration in this study:

1. Groundwater Wells
    a. New Wells
    b. Augmentation of Existing Wells
    c. Treatment of Groundwater - Existing and New Wells
2. Surface Water Sources
3. Purchase of Water from Other Systems
4. Desalination
5. Optimize GW Recharge within Zone II's of Existing Wells
6. Water Reuse/Recycling
7. Water Harvesting
8. Conservation Based Strategies
9. Integrated Water Resource Management
10. Vulnerability Based Strategy to Develop System Resilience & Redundancy

6.2 New Source Development Criteria

To begin the process of identifying and analyzing new source options, a useful first step involves establishing some baseline criteria to determine the quantity of water that needs to be provided. The analysis of water quantity and permitted withdrawals has determined that although permitted withdrawal volumes associated with existing wells are adequate to meet the system demands through 2035, reductions in the available yield from existing wells result in the need to increase and/or develop additional supply, subject to appropriate permit revisions. The issue of the vulnerability of the existing wells to catastrophic loss due to contamination, drought or other failure scenario is also a reason to identify target volumes for new or additional sources of supply to serve the future needs of the HWS. Ensuring an additional level of flexibility and redundancy for buffering both seasonal demand issues and responding to sudden changes in water quality regulations are equally compelling criteria for the consideration of additional reliable sources of water supply.

The MassDEP “Guidelines and Policies for Public Water Systems” require that the Town be able to supply the maximum daily pumping demand of the system with the largest source out of service. There are three critical points of finished water production in the HWS including the Mary Dunn WTP (1925 gpm), Maher WTP (1500 gpm) and Straightway WTP (1500 gpm). The total water production that can be supplied from these three WTP’s operating at current full capacity is 4,925 gpm (7.09 MGD). The single largest source in the Hyannis Water System is the Mary Dunn Treatment Plant (1925 gpm/2.77 MGD). With this source offline, the available maximum daily output from the Hyannis system is reduced to 3000 gpm or 4.32 MGD. With the Mary Dunn Wellfield offline, the Hyannis system cannot meet its current or future Maximum Day Demand (MDD). The supply deficit under this scenario would be 1.87 MGD (6.19 – 4.32) in 2020. This would grow to 3.23 MGD (7.55 - 4.32) in 2040.

Similarly, the loss of either the Maher, Straightway or Hyannisport well fields or the loss of any of the other water treatment plants, would produce a significant loss of system capacity under MDD conditions.

The Town water supply sources must also meet water quality requirements from the source through to the customer tap. This can require multiple levels of treatment from chemical addition to filtration. Treatment provided at each of the sources was discussed in detail in Chapter 4. Recently changes in water quality requirements have been enacted at the federal level by EPA as well as on a state level by DEP. As a result of these more stringent standards, HWS is looking at increasing levels of treatment involving filtration at most of the supply sources to remove one or more of the following compounds - manganese, iron, VOC’s, PFOS, 1,4 dioxane, and nitrates.

For the purpose of identifying and screening options for new sources of supply, we recommend a target level of 2.5 MGD of installed capacity to augment and supplement the existing groundwater sources of supply and development of a separate treatment facility at a geographical diverse location. This will provide enough water to meet the near-term projected supply shortfall (1.87 MGD in 2020 and 2.5 MGD in 2028). We also recommend an additional installed capacity of at least 1.0 MGD be developed by 2040 to meet the longer-term projected shortfall of 3.23 MGD.

In addition, the following long-term goals for the resilience of the system are proposed for consideration by the HWS and the Town of Barnstable:

- HWS should work to increase source capacity to an amount greater than the projected maximum day demands for the entire water system (with the largest source out of service) but within the DEP permitted withdrawal limits (under the Water Management Act).
- Optimize system resilience against drought, disaster, contamination, climate change, and competing withdrawals.
- Incorporate redundancy as a critical infrastructure prioritization criterion. This includes locating wells and treatment systems at distant locations to ensure against contamination and/or failure of single centralized facilities.

6.3 Alternatives Evaluated

Evaluations of each of the alternatives identified for consideration as potential new sources of water supply for the HWS are presented in the following sections.

6.3.1 New Groundwater Wells

The process of identifying potential sites for the development of new groundwater wells began with a review of the groundwater favorability of the sole source aquifer underlying and serving as the primary source of water supply for Barnstable and several other towns on Cape Cod. A study of potential water supply property tracts completed in 2008 by the town in cooperation with the Cape Cod Commission in a project referred to as the "Priority Land Acquisition Assessment Project (PLAAP) resulted in the production of a map entitled "Water Supply Development Potential of Priority Property Tracts Based upon Existing Conditions – Town of Barnstable". This map is reproduced here for informational purposes as Figure 5.

W&S examined the general areas highlighted on Figure 5 relative to the identified parcels which may be worthy of further on-site exploration in subsequent phases of this study. The mapping of the Zone II's for all the HWS existing wells was overlaid on the towns parcel data map. For the purposes of this analysis, the boundary delineations associated with the other water and fire districts within Barnstable were not treated as a constraint for the initial identification of potential new well sites. Initially all parcels were reviewed for size, use and ownership. Of particular interest are potential parcels or groups of parcels that fall within publicly owned land and would be capable of ensuring 100% ownership or control of the mandatory 400-foot Zone

I Radius by the HWS. For initial screening purposes, areas considered included a parcel or contiguous parcels with an area of at least 11.54 acres (area within the 400' Zone 1 radius) that would allow construction of a well with the full 400' protective radius. Many parcels were eliminated from consideration for the reasons described below.

- Developed commercial, industrial, school and other parcels.
- Known contamination that would require excessive permitting and/or cost to treat. E.g. Airport and DPW properties.
- Expected low yields and/or brackish water concerns (parcels north of Route 6A).
- Existing public water supply properties.

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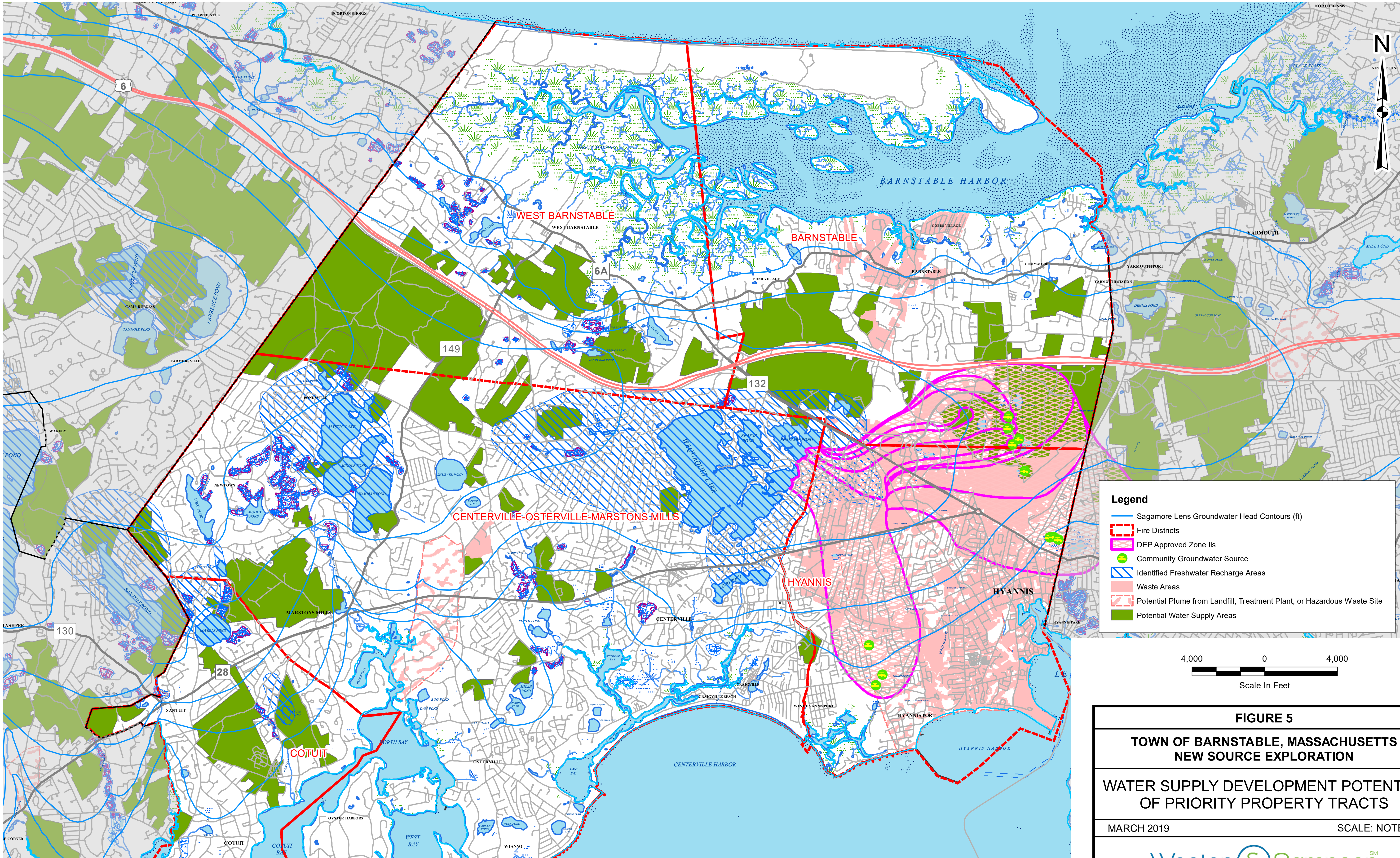

4,000 0 4,000

Scale In Feet

FIGURE 5

TOWN OF BARNSTABLE, MASSACHUSETTS
NEW SOURCE EXPLORATION

WATER SUPPLY DEVELOPMENT POTENTIAL OF PRIORITY PROPERTY TRACTS

MARCH 2019 SCALE: NOTED

Weston & Sampson

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As discussed, the remaining identified parcels were aggregated together where they were contiguous with one another, and each received a site designation. A total of 11 sites were identified as A through K.

Each site was then scored according to seven criteria. Each criterion was weighted, from 5% to 30% based on relative importance. Scores were assigned for each of the seven criterion which ranged from 1 to 5. A high rating received a 5 and a low rating received a 1. The seven criterion and the scoring range for each is described below.

- Use restrictions can limit the pumping of groundwater when it is needed most. Several sites could have restrictions to protect the resource area, reducing pumping rates during seasons when HWS needs water the most. Sites can also be restricted based on known groundwater contamination nearby. 30% of score.
  - 5 = No known restrictions
  - 4 = Probable minimal restrictions
  - 3 = Restrictions or limits based on nearby contaminated site(s)
  - 2 = Probable significant restrictions
  - 1 = Expected seasonal restrictions

- Acreage of site, after excluding the Zone 1 setback of 400'. Greater acreage will allow for a greater number of wells to be installed in the site. 20% of score.
  - 5 = 50 acres or greater
  - 4 = 25 to 50 acres
  - 3 = 10 to 25 acres
  - 2 = 5 to 10 acres
  - 1 = up to 5 acres

- Distance to an existing HWS, COMM, Cotuit or West Barnstable well. A greater distance to an existing well will allow for greater theoretical yield from a new well or well field. Greater separation also decreases vulnerability to disruption from various causes. 15% of score.
  - 5 = Greater than 4,000'
  - 4 = 3,000' to 4,000'
  - 3 = 2,000' to 3,000'
  - 2 = 1,000' to 2,000'

  - 1 = 0 to 1,000’

- Distance to Hyannis water distribution main, as measured from the approximate center of the site. A shorter distance will require less water main and other infrastructure. 10% of score.
  - 5 = 0 to 6,000’
  - 4 = 6,000 to 12,000’
  - 3 = 12,000’ to 18,000’
  - 2 = 18,000 to 24,000’
  - 1 = Greater than 24,000’

- Distance to Route 6, as measured from the edge of the site. Route 6 generally follows the high ground along the Cape. As such, groundwater generally flows outward (north or south) from Route 6. This should result in greater protection from contamination of the groundwater resource. 10% of score.
  - 5 = 0 to 2,000’
  - 4 = 2,000 to 5000’
  - 3 = 5,000’ to 10,000’
  - 2 = 10,000 to 15,000’
  - 1 = Greater than 15,000’

- Parcel ownership by the Hyannis Water System or the Town of Barnstable should allow for improved control of a site, fewer restrictions on development, and allow for faster implementation. Sites owned by other fire/water districts, county and state agencies were scored lower. 10% of score.
  - 5 = Hyannis Water System or the Town of Barnstable ownership
  - 4 = N/A
  - 3 =County or other fire/water district ownership
  - 2 = N/A
  - 1 = State agencies, including Fish & Wildlife

- Distance to the Hyannis Water System Mary Dunn water storage tanks. A greater distance between the tanks and the water supply wells will allow for improved water quality (via decreased water age), and more reliable service with lower chance of disruption to customers (by separating water source and storage), improved hydraulics and water pressure consistency (and fire flow capability), and lowered vulnerability (from interruption of common pipeline). 5% of score.

- 5 = Greater than 4,000’
- 4 = 3,000’ to 4,000’
- 3 = 2,000’ to 3,000’
- 2 = 1,000’ to 2,000’
- 1 = 0 to 1,000’

Each site was ranked based on the weighted scoring under each of the seven criteria and relative importance. The results of the ranking are shown in Table 13, below. The highest rated sites are B and C at 4.7 and the lowest are H and I at 2.2 points. Sites F, A and D are ranked closely in the low 4’s. Given their close weighted scores, we suggest that sites A, B, C, D and F be investigated first. And sites E, and G would be investigated if the initial sites prove unavailable or unproductive. Sites H, I, J, and K should be deferred.

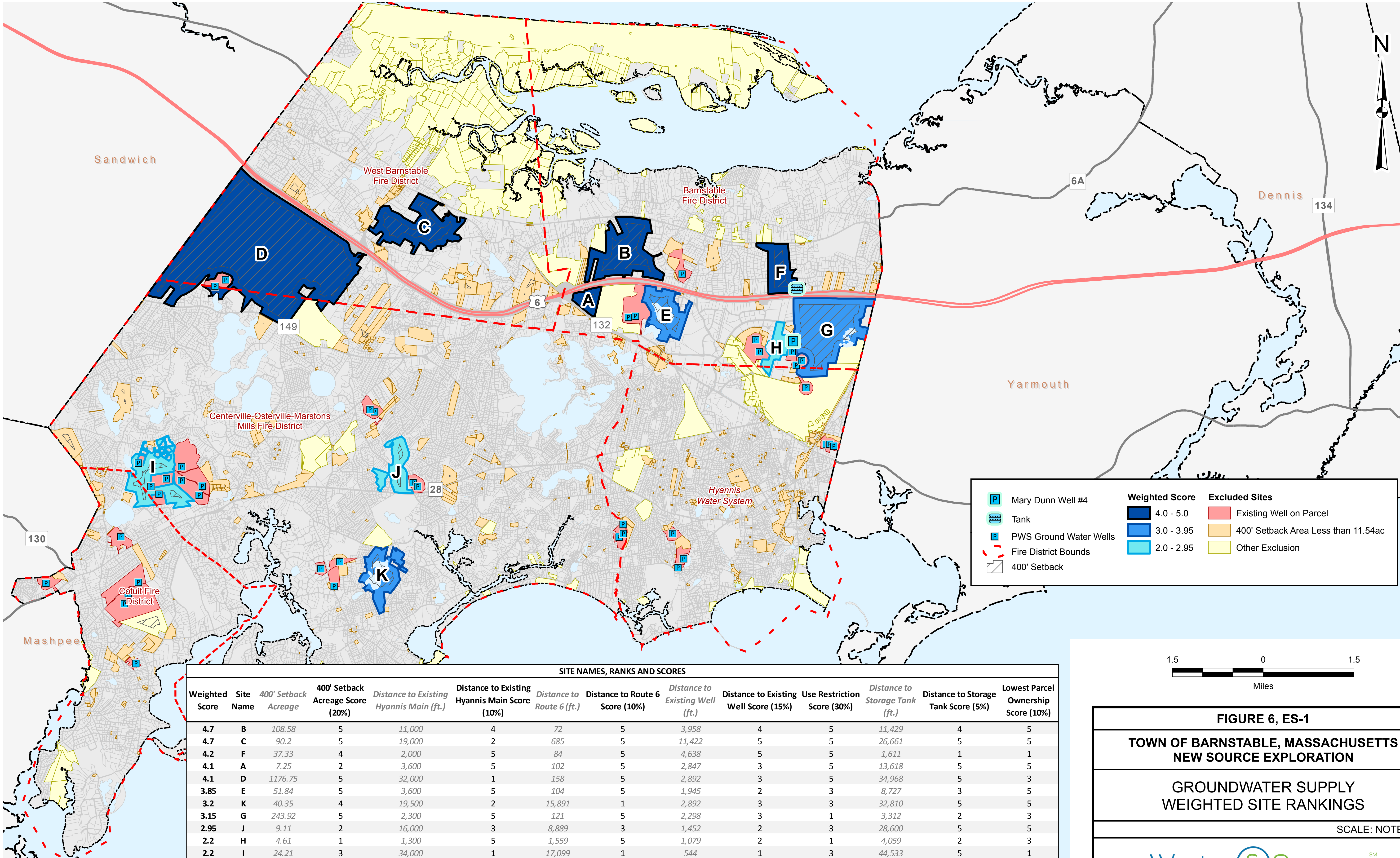
The most potentially productive sites are the largest in area and therefore could support the greatest number of wells. The largest site is site D which could easily support four wells. Sites B, C and G could also likely support four wells. Other sites are less likely to support four or more wells but might support fewer wells with higher yields. Site productivity and individual well yield will be determined through the groundwater exploration program. Site A is along the pipeline route to Hyannis from Sites B, C and D and could be an ideal site for a treatment facility. For this reason, Site A should be evaluated and investigated early in the exploration program.

Pairing of sites, A and B together and C and D together are recommended given proximity and likely combined yield. Site E could be added to Sites A and B if yields require it. And, Sites F and G could be paired if other sites are determined to be less advantageous. Pairing of sites is also advantageous by reducing costs for construction of water transmission mains and treatment facilities. Ultimately, the best locations of wells, water mains and treatment facilities will be confirmed once location of potential wells, their respective yield, and their water quality is known.

Table 13: Highest Ranking Sites for New Wells

Weighted Score	Site Name	Use Restriction Score 30%	400' Setback Acreage (Acres)	Score 20%	Distance to Existing Well (feet)	Score 15%	Distance to Existing Hyannis Main (feet)	Score 10%	Distance to Route 6 (feet)	Score 10%	Parcel Ownership Score 10%	Distance to Storage Tank (feet)	Score 5%
4.7	B	5	*109*	5	*3,958*	4	*11,000*	4	*72*	5	5	*11,429*	4
4.7	C	5	*90*	5	*11,422*	5	*19,000*	2	*685*	5	5	*26,661*	5
4.2	F	5	*37*	4	*4,638*	5	*2,000*	5	*84*	5	1	*1,611*	1
4.1	A	5	*7*	2	*2,847*	3	*3,600*	5	*102*	5	5	*13,618*	5
4.1	D	5	*1177*	5	*2,892*	3	*32,000*	1	*158*	5	3	*34,968*	5
3.85	E	3	*52*	5	*1,945*	2	*3,600*	5	*104*	5	5	*8,727*	3
3.2	K	3	*40*	4	*2,892*	3	*19,500*	2	*15,891*	1	5	*32,810*	5
3.15	G	1	*244*	5	*2,298*	3	*2,300*	5	*121*	5	3	*3,312*	2
2.95	J	3	*9*	2	*1,452*	2	*16,000*	3	*8,889*	3	5	*28,600*	5
2.2	H	1	*5*	1	*1,079*	2	*1,300*	5	*1,559*	5	3	*4,059*	2
2.2	I	3	*24*	3	*544*	1	*34,000*	1	*17,099*	1	1	*44,533*	5

#



SITE NAMES, RANKS AND SCORES

Weighted Score	Site Name	*400' Setback Acreage*	400' Setback Acreage Score (20%)	*Distance to Existing Hyannis Main (ft.)*	Distance to Existing Hyannis Main Score (10%)	*Distance to Route 6 (ft.)*	Distance to Route 6 Score (10%)	*Distance to Existing Well (ft.)*	Distance to Existing Well Score (15%)	Use Restriction Score (30%)	*Distance to Storage Tank (ft.)*	Distance to Storage Tank Score (5%)	Lowest Parcel Ownership Score (10%)
4.7	B	*108.58*	5	*11,000*	4	*72*	5	*3,958*	4	5	*11,429*	4	5
4.7	C	*90.2*	5	*19,000*	2	*685*	5	*11,422*	5	5	*26,661*	5	5
4.2	F	*37.33*	4	*2,000*	5	*84*	5	*4,638*	5	5	*1,611*	1	1
4.1	A	*7.25*	2	*3,600*	5	*102*	5	*2,847*	3	5	*13,618*	5	5
4.1	D	*1176.75*	5	*32,000*	1	*158*	5	*2,892*	3	5	*34,968*	5	3
3.85	E	*51.84*	5	*3,600*	5	*104*	5	*1,945*	2	3	*8,727*	3	5
3.2	K	*40.35*	4	*19,500*	2	*15,891*	1	*2,892*	3	3	*32,810*	5	5
3.15	G	*243.92*	5	*2,300*	5	*121*	5	*2,298*	3	1	*3,312*	2	3
2.95	J	*9.11*	2	*16,000*	3	*8,889*	3	*1,452*	2	3	*28,600*	5	5
2.2	H	*4.61*	1	*1,300*	5	*1,559*	5	*1,079*	2	1	*4,059*	2	3
2.2	I	*24.21*	3	*34,000*	1	*17,099*	1	*544*	1	3	*44,533*	5	1

FIGURE 6, ES-1

TOWN OF BARNSTABLE, MASSACHUSETTS
NEW SOURCE EXPLORATION

GROUNDWATER SUPPLY
WEIGHTED SITE RANKINGS

SCALE: NOTED

Weston & Sampson SM

Path: \\wse03.local\WSE\Projects\MA\Barnstable MA\New Source Exploration Study\GIS\New Source Eval Criteria 11x17.mxd User: OzerekZ Saved: 2/28/2019 5:06:42 PM Opened: 2/28/2019 5:06:55 PM

The next step in the new water source exploration process will include:

- Confirmation of site availability
- Preparation of a plan for site access for test well exploration
- Site and permitting approval for the exploration
- Test well drilling and water quality testing
- Evaluation of results for quantity and quality of groundwater

Consideration of developing wells beyond the corporate boundaries of the Town of Barnstable were not considered as part of this evaluation. Legal and institutional issues associated with the ownership, control and use of land in another community would need to be further analyzed prior to pursuing such options. Also, the increased distance from possible points of connection to the Hyannis Water System (10 miles or more, in some cases) is an impediment. Such distances create significant cost increases relating to the length of transmission mains and the potential need for pumping to maintain hydraulic conditions. Additionally, costs of land in another community can be expected to be in similar ranges to costs for land in Barnstable. Such lands, even if vacant or publicly owned, may be affected by restrictive covenants, prior use restrictions and be subject to protections under Article 97 of the Constitution of the Commonwealth, requiring legislation and MEPA review, in addition to other required permitting and approvals. Acquisition of land in other communities may also require legislative approval, public review and potential intermunicipal legal hurdles. The Hyannis Water System should however seek to keep potential intertown options open for discussion in light of the regional nature of the Sagamore Lens as a sole source aquifer serving the water supply needs of the region.

6.3.1.1 Augmenting and Maintaining Existing Groundwater Wells

Augmenting and/or maintaining HWS well supplies, whether by pump replacement, well rehabilitation, or installation of a replacement well in close proximity to an existing well, should be continued to ensure that the maximum quantity of water available in the aquifer is withdrawn for use. It is important to also recognize that any potential risks of contamination and/or water quality issue requiring treatment of existing wells can impact efforts to augment and maintain supply from those same sources of supply. Should an existing well or well field become lost due to contamination or other reason, that lost capacity will need to be replaced by a new well or well field. These types of catastrophic loss would be in addition to the development of supplemental water supply capacity recommended. Augmentation was therefore not considered for further analysis as it is not equivalent to a new or additional source of future or replacement water supply.

6.3.1.2 Treatment of Ground Water

Treatment of water is provided for all the existing wells that serve the HWS as described in Chapter 5.0 of this report. The base level of treatment provided at each of the existing water treatment plants includes pH adjustment, sequestration, corrosion control and disinfection. Granular Activated Carbon filters are in operation at the Mary Dunn Treatment plant in response to observed levels of PFOS in source groundwater. Packed tower aeration is provided at the Maher Treatment plant.

As previously noted, the Maher wells have been impacted by VOC's, PFOS, 1,4 dioxane, iron and manganese. Treatment considerations at the Maher Treatment Plant include the use of advanced oxidation plus Ultraviolet light (UV), GAC, and the addition of green sand filtration for control of iron and manganese. VOC's, Nitrate, PFOS, 1,4 dioxane, iron and manganese have been identified as issues at the Straightway, Simmons Pond and Hyannis Port wells. Green sand filtration, GAC, advanced oxidation and UV/peroxide treatment are additional treatment options that could potentially be required in response to water quality conditions or future regulatory requirements. An approach to the estimation of costs for new wells and varying degrees of treatment is presented in Chapter 7.0 of this report.

6.3.2 Surface Water Sources

There are 182 ponds occupying about 1,856 acres within the Town of Barnstable. A report produced by the Cape Cod Commission and the Coastal Systems Group of the School of Marine Science and Technology of the University of Massachusetts Dartmouth in 2008 entitled "Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities, Final Report", July 2008 for the Barnstable Conservation Division (Barnstable Pond Report), served as in important source of information on ponds large enough to consider as possible surface water sources of water supply. Of the 182 ponds in the town, Appendix B of the Pond Report provides orthophoto maps of 19 of the larger ponds, including bathymetric mapping. While the Pond Report provides information on the surface areas of several ponds, the report did not provide any information on pond volumes. Based on the potential of a pond to supply 2.5 MGD on a continual basis, there are six ponds that might be considered for further evaluation as potential sources of water supply. These ponds include Hamblin Pond, Lovells Pond, Middle Pond, Mystic Lake, Shubael Pond and Wequaquet Lake (including the hydraulically linked Bearses Pond). Surface area, depth and volume of these six ponds are summarized in Table 14. Supplemental information on the 19 ponds described in the 2008 report is provided in Appendix A.

Table 14: Potential Surface Water Sources

Pond	Area (Acres)	Average Depth (ft.)	Maximum Depth (ft.)	Volume (MG)
Hamblin Pond	115.4	25'	60'	1,029
Lovells Pond	55.5	20'	30'	336.6
Middle Pond	104.6	15'	30'	589
Mystic Lake	148.4	20'	42'	913
Shubael Pond	55.1	20'	40'	340
Wequaquet + Bearses Ponds	663.1	16'	30'	3,457

Costs associated with the development of any of these ponds for water supply must include consideration of the level of treatment required to comply with the Safe Drinking Water Act Surface Water Treatment Rule, as well as the disinfection and disinfection by-products rules and the long-term enhanced surface water treatment rule. Location and type of intake structure are also considerations with cost implications. The availability of publicly owned land in the proximate vicinity of each of these potential sources is also a key consideration and challenge. Considerations for blending treated surface water with groundwater are important but beyond the scope of this initial screening study.

6.3.3 Purchase of Water from Other Systems

The HWS currently has existing interconnections with the Centerville-Osterville-Marston Mills Water Department (COMM) and the Town of Yarmouth. There are not presently any interconnections with the Barnstable Fire District (BFD).

A new interconnection with the Yarmouth Water District at the Maher WTP was constructed in 2016. Since its activation in May of 2016, the Yarmouth interconnection has provided a total of 142.4 Million Gallons to the HWS. Water is routed into the Maher Treatment Plant for blending and treatment prior to distribution into the HWS distribution system.

A new interconnection with COMM was also constructed in 2016. The interconnection includes two water pumps, disinfection and sequestration so that the incoming supply pressure and water quality closely matches HWS. The system was constructed in a movable steel storage container and can be operated when additional HWS supply is needed and COMM has available supply. A more permanent interconnection is currently under design.

Interconnections with other water systems including Cotuit Fire District, Mashpee, Sandwich and Falmouth were initially considered but dropped from further consideration based on transmission costs, limitations in the amounts of water available for purchase when it is needed most, and the cost to purchase water. Additional water quality concerns include the effect of mixing water from those systems with Hyannis Water System supply.

6.3.4 Desalination

The idea for desalinating sea water to produce drinking water for human consumption has been around for several decades. In a variety of applications in the Middle East, Asia and Africa and a few other fresh-water limited parts of the world, desalination has been in use for many years.

Locally, desalination projects have been constructed in Taunton (2.2 MGD; $20M) and Brockton MA (5 MGD; $75M). A desalination water treatment facility has been proposed in Hull MA with a design flow of 2.5 MGD and an estimated cost of $24 Million.

Water quality is a primary consideration in the selection of the type and source of seawater proposed to be used for desalination. The two principal options are seawater, where levels of Total Dissolved Solids (TDS) are on the order of 35,000 parts per million (ppm); or brackish water, typically withdrawn from groundwater subject to salt water intrusion, where TDS levels are generally on the order of 2,000 ppm. The selection of seawater source can produce significant impacts in terms of the capital and operation and maintenance costs of a desalination facility.

The selection of a source can also be significantly affected by the consistency of source water quality over the life of the desalination facility. Generally, brackish water drawn from sand and gravel deposits in the near coastal area is likely to be more consistent in terms of key water quality parameters than the open ocean environment. This is due to the potential for biota, detritus, wind and tide generated materials, bird droppings and other potential pollutant sources to be introduced and even concentrated at open water intake locations, even when screens and backwash facilities are incorporated into intake designs. Brackish water can be pumped using the same or similar methods of well design and construction used for other groundwater applications. Consideration needs to be made for the potential corrosion and screen clogging that can occur due to the nature of the brackish water and the typically sandy soils associated with the potential brackish water portion of coastal aquifers.

Among the critical design considerations for desalination of seawater are:

- Choice of Intake Location
- Type of Intake
- Pumping requirements from Intake to Treatment Facility
- Treatment Facility siting and design
- Pumping requirements to deliver treated water into the distribution system
- Residuals disposal

The choice of intake location is critical to ensure consistency in the water quality drawn for treatment. Based on the location of the HWS within the Town of Barnstable, the intake location would presumably be at a location along the south coast of the town. Important considerations include the availability of publicly owned land to host the pumping station for the intake; ensuring that the intake location would neither interfere with nor be impacted by the usual marine traffic associated with high use harbors and marine facilities; reasonably protected from tidal variation; capable of ensuring consistent water quality and not likely to interfere with regular use and access to the outstanding beaches along the south coast of Barnstable. Location of an intake structure along the north coastline of Barnstable is unlikely as there are several areas of sensitive environmental concern and represent areas that are relatively remote from the HWS service area.

The choice of type of intake is equally important. Essentially, there are two options, including an open water, riser type intake or a below grade, seabed infiltration gallery, constructed under the sand in the near-shore region. Riser type intakes typically consist of a structure located at a depth such that the intake is always inundated, regardless of tidal fluctuation. A riser intake can still be subjected to extreme tidal forces and can also be exposed to impacts from marine water craft, fishing equipment and other activities that could damage the structure.

Seabed infiltration galleries are typically located in a sandy-gravelly benthic material that can act as a pre-filter for keeping out seaweed and other floating and submerged solids in the marine environment and prevent such items from clogging and fouling the intake and pumps. The submerged intakes generally require periodic inspection and can be difficult to access and maintain during severe storm and tide conditions.

Pumping is required to lift seawater from the set elevation of the intake up to the elevation required to provide positive, gravity flow through the treatment facility. Location of the pumping station required for this purpose will need to be carefully considered due to costs of land in addition to potential aesthetic impacts associated with a pumping station located in a denselypopulated neighborhood. Such neighborhood impacts might include exterior appearance, noise, alarms, security devices and fencing, and maintenance activities.

Treatment for desalination of seawater is generally accomplished by reverse osmosis. The process results in the generation of a brine waste which can be difficult to process and, in some cases, will not be permitted to be discharged into a wastewater treatment facility. There are a few notable desalination projects in Massachusetts and elsewhere in the US today whose development and permitting processes can be instructive for the Barnstable community. Brackish water can also be treated using reverse osmosis. In addition, other technologies such as nanofiltration can also be considered for treatment of brackish water.

6.3.5 Optimize GW Recharge within Zone II's of Existing Wells

All water that falls as precipitation including snowmelt contributes to recharging the sole source aquifer from which all groundwater supplies on the Cape are drawn. The concept of optimizing recharge considers taking advantage of topography to direct runoff that might otherwise be lost or rendered unavailable for recharge and redirecting that runoff onto and through infiltration galleries within the Zone II's of the existing wells. Consideration of water harvesting as further described in section 6.3.7 can be incorporated in a System or Town-wide effort directed at aquifer recharge optimization. Consideration of this option will require careful analysis of runoff capture drainage areas and the potential for redirecting that runoff to one or more Zone II areas associated with the well fields serving the existing ten wells in the HWS system. Water quality is also a consideration in that runoff from more urbanized areas could contain road salt and other chemicals potentially injurious to the water supply.

6.3.6 Water Reuse/Recycling

The concept of recycling treated wastewater for reincorporation into drinking water systems has been continually in development since the late 1970's/1980's. While very few systems return treated wastewater directly into a drinking water system, there are a variety of methods for capturing treated wastewater to augment water supply sources prior to treatment and distribution into a public water system. Such methods include injection into source aquifers up gradient from direct zones of contribution; deep well injection well below the intake elevation of source wells; discharge into recharge galleries in areas proximate to surface water bodies impacted by drawdown from pumping wells to stabilize water levels and other variants of such options. Within the Town of Barnstable, and within the Village of Hyannis, many residences continue to rely on septic systems and other on-site wastewater disposal systems for wastewater disposal. Such systems return wastewater to the groundwater system in the localized areas where they are operational. The relatively low degree of treatment afforded by on-site systems presents the potential for both bacterial and other pollutants to be introduced into the groundwater regime.

The existing Hyannis Wastewater Treatment Facility provides treatment for about 4.2 MGD with discharge of effluent to the ground. USGS, the Cape Cod Commission, DEP and others have modeled the plume and mound conditions resulting from the treatment plant discharge. Concerns have been identified for the potential contamination of the Straightway Wells, the Simmons Pond and Hyannisport wells which generally fall within the suspected plume region of the groundwater discharge from the treatment facility. In addition, concerns have been expressed with regard to potential unregulated contaminants including for example pharmaceuticals which can pass through most wastewater treatment systems unaltered.

Consideration for providing additional treatment technologies to the existing wastewater treatment regimen currently in operation at the Hyannis Wastewater Treatment Facility should be evaluated for cost and environmental benefits to sensitive human and ecological receptors and for reintroduction of advanced treated wastewater into the groundwater regime of the active wells in the HWS or for use in non-potable reuse applications.

6.3.7 Water Harvesting

Water harvesting can be described as the capture, diversion and storage of rainfall for use in landscaping and other purposes. Other purposes may include irrigation, aquifer recharge, pond level maintenance among other potential uses. Water harvesting is suitable for application at both small (e.g. household) and large scale (e.g. subdivision, municipal streetscapes, commercial properties, public buildings, parks) applications. Potential benefits can include cost savings for water use, demand reduction on municipal water supplies, reduction of flooding, erosion and sedimentation of surface waters, and efficient use of a valuable resource.

Water harvesting systems can range from simple systems which collect rain as it falls on impervious surfaces and is then routed directly to a designated application site or piped into a storage tank or other device for use at a later time; to complex systems that may store large volumes of water for distribution over a larger area or to an area designated for aquifer recharge. Agricultural systems typically involve taking advantage of the process of condensation and formation of droplets on plant and other ground-level surfaces in the early morning period of the day. The phenomenon of dew formation is the essential operative process. Harvesting that water for storage and use is the goal of water harvesting. Some examples of agricultural water harvesting operations are small to very small scale, involving green house and other similar operations. In such operations, the water harvested is used on-site for watering of plants/crops and related purposes.

While harvesting may not be deemed highly practical as a potential water source for a municipal system, it could become an important component of a larger system for managing water resources for the community as a whole. This is particularly applicable as a seasonal alternative to reliance on municipal sources for high volume, non-potable applications (e.g. golf course irrigation, greenhouse watering, street cleaning uses, etc.). There are several examples of communities around the U.S. which have incorporated water harvesting into zoning and other land use regulations or as an element of local integrated water resource management strategies.

6.3.8 Conservation Based Strategies

It is noted that the system demands experienced in 2016 were considerably reduced from all other years in the period 2010 to 2016. The implementation of the State Water Conservation Plan and education program in the service area as a consequence of the emergency declarations due to extensive drought conditions culminating in 2016 are considered to have been key reasons for this notable demand reduction. At issue is whether and to what extent the continuation of demand management and conservation-based strategies might be able to produce seasonal caps to demand, particularly the summer tourist season as demonstrated by the graphs shown on Figure 2. A public education program inclusive of billing inserts, updated web information to focus on daily and maximum day demand, and a device retrofit program would be potentially effective tools to initiate such a program. At the other end of the spectrum, the HWS could consider instituting a demand management seasonal pricing structure and educate the tourism community and tourists of the importance of eliminating water waste, even while on vacation.

6.3.9 Vulnerability Based Strategy for System Resilience & Redundancy

The Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (Public Law 107-188) was enacted on June 12, 2002. This Act requires community water systems that serve populations greater than 3,300 persons to conduct vulnerability assessments. Systems serving between 3,300 to 50,000 people were required to conduct vulnerability assessments and submit reports to the Environmental Protection Agency by June 30, 2004. EPA has worked with Sandia National Laboratories to produce the Risk Assessment Methodology for Water

Utilities, known as RAM-W™. This material is available to water utilities who demonstrate a need to know and willingness to sign a nondisclosure agreement.

The concept of a vulnerability-based strategy was introduced in the discussion regarding new sources. While it may be possible to meet current and future demands as projected through 2035 with existing sources, it is recommended that HWS begin the planning process for developing additional sources, whether new groundwater, surface water or interconnections with other systems, to ensure that the HWS can reliably supply an additional 2.5 MGD in the event a catastrophic loss of one or multiple sources occurs without warning. While emergency interconnections may carry the system through an initial period of loss of a well source or well field, there are no doubt limitations on the time over which such emergency connections can be employed without imposing impacts on the host source of supply. The combination of new groundwater sources and conservation-based strategies should be considered as a first-step approach to the development of such a strategy.

Vulnerability of a water system can be reduced significantly by incorporating redundancy as a critical infrastructure prioritization criterion. This includes locating wells and treatment systems at distant and/or different locations to ensure against contamination and/or failure of a single centralized facility. The current HWS system includes three distant decentralized well aquifer areas (Maher, Mary Dunn and Straightway) with centralized supplies and facilities located within each area. Future aquifer areas that are developed are recommended to be set up as additional decentralized areas to reduce vulnerability.

6.3.10 Integrated Water Resource Management

Integrated water resource management is a systematic approach to managing the water resources within a given geographic setting on a holistic or integrated approach. This concept is based on the provision, use and recycling of all the water which hydrologically originates in an area (i.e. watershed, district, municipality, etc.) from the time such water falls onto the land by precipitation or condensation; runs off into surface streams, lakes and ponds; permeates into the groundwater and then is used for water supply, irrigation, recreation, fisheries habitat and other purposes; and is finally treated as wastewater and reintroduced into the hydrologic system. This approach treats runoff as an integral component of the sources of surface and groundwater and considers wastewater, particularly treated wastewater, as an integral element of the hydrologic system. This approach can open the door to the development of integrated approaches to rate setting that permit communities to assign values to the water within the system at various times and conditions and to recover the costs of managing water at each stage of its generation, use, treatment and reuse.

7.0 COST ANALYSIS

Cost estimates are presented for those feasible options that involve tapping new potential sources of water supply for which hard engineering design and construction costs are reasonably ascertainable. Those options include new groundwater wells; development of a surface water source of supply with conventional water treatment; desalination, including brackish water and seawater alternatives; and advanced treatment of wastewater effluent to drinking water standards prior to indirect use for aquifer recharge. Other options presented in this report tend to represent "soft" concepts for which cost estimates are highly variable and dependent on both internal and external policy choices that are not easily translatable into a comparative cost framework.

Weston & Sampson follows the American Association of Cost Engineer's guidelines for a cost estimating classification system. Typically, there are three cost estimating stages of water engineering projects, including the conceptual/evaluation estimate, the pre-design estimate and the final design estimate. Table 15 below summarizes the expected range of accuracy for each of the three typical phases of a project.

Table 15: Cost Estimation Classifications

Project Maturity Level	Low Range of Expected Accuracy	High Range of Expected Accuracy
Conceptual	-15% to -30%	+20% to +50%
Pre-Design	-10% to -20%	+10% to +30%
Final Design	-3% to -10%	+3% to + 15%

The costs estimates presented at this conceptual level of project maturity reflect the "best professional judgement" informed by past and present-day project experience in the technologies, regulatory and permitting environment and facilities construction in the water and wastewater industry in the New England region.

7.1 Costs of New Source Options

7.1.1 New Groundwater Wells

Cost estimates for new groundwater wells incorporate major cost items including exploration, development, permitting, transmission and treatment. Land acquisition can represent a significant potential cost associated with a new groundwater source development and is not included. It is assumed that a parcel of a minimum area of twelve (12) acres is required. However, it is important to consider that there are several parcels of land within Barnstable that are owned by the town, county or Commonwealth of at least that size that would not require the expenditure of funds for acquisition.

Five conceptual levels of treatment are considered for cost estimation purposes. Level A, referred to as the "base" treatment level, is based on the premise that at a minimum, any new well supply will require treatment including pH adjustment, sequestration, corrosion control and disinfection as presently provided for all existing wells serving the Hyannis Water System.

Cost estimates for Levels B, C, D and E are then estimated based on the addition of one additional advanced treatment process based including any of the following:

- Greensand Filtration
- Packed Tower Aeration (PTA)
- Granular Activated Carbon (GAC)
- UV/peroxide

Level B would be based on the addition of filtration to the base level treatment systems. Level C might include the addition of Filtration and GAC to the base level treatment system. Level D could include filtration plus PTA plus GAC in addition to the base treatment system. Level E would include all of the advanced treatment options to base level treatment. Table 16 presents the projected costs for each of the alternative treatment levels based on the recommended design flow of 2.5 MGD and a smaller flow of 1.5 MGD.

Table 16: Projected Costs for New Groundwater Wells with Treatment

	Level of Treatment	Cost (@2.5 MGD Design Flow	Cost (@ 1.5 MGD Design Flow
A.	Base Level	$3M	2M
B.	Base Level Plus One Advanced Treatment Operation	$10.5M	$8M
C.	Base Level Plus Two Advanced Treatment Operations	$13M	$9.4M
D.	Base Level Plus Three Advanced Treatment Operations	$14.5M	$10.8M
E.	Base Level Plus Four Advanced Treatment Operations	$16M	$12.2M

7.1.2 Surface Water Source with Treatment

Cost estimates for development of a surface water source of supply from one out of the six largest ponds within Barnstable range from about $22M to $30M based on the recommended design flow of 2.5 MGD. Land is a significant cost component for this option. We note that there do not appear to be any publicly owned parcels of sufficient size in close proximity to any of the larger ponds in town capable of supporting a water treatment plant, estimated to require a minimum of 5 acres. There is a group of parcels in proximity to Bearse's Pond along Iyannough Road that total about 11 acres. However, the depth of water in that area of the pond is not suitable for the installation of an intake and pumping station of sufficient capacity to withdraw 2.5 MGD from this pond.

Treatment costs are the primary reason for the costs estimated. The permitting required for a new water treatment plant withdrawing water from a previously untapped surface water body is also open to a wide range of costs. Treatment costs are also potentially highly variable based on the source water quality that is expected to vary considerably across the ponds that are of sufficient size to consider for potential sources of drinking water. The treatment process train may require pretreatment including ozone or chlorine addition, followed by flocculation and settling, then rapid sand filtration followed by disinfection by chorine. Depending on source water organic matter concentrations, additional treatment by Biological Activated Carbon (BAC) or Granular Activated Carbon (GAC) with post-treatment ozonation and disinfection may be required in response to algal densities in any particular source water body or other pathogenic organism presence.

In addition, operational difficulties have been reported to occur in systems that mix waters from ground and surface water sources. Surface water bodies can experience significant variations in seasonal temperature, pH and biological and chemical composition that are difficult to manage in combination with ground water sources which are generally more consistent over time.

A significant effort will be required to further evaluate the water quality conditions of any of the possible surface water sources identified within Barnstable to refine the possible treatment alternatives that may be required before a more refined cost estimate is possible to consider.

7.1.3 Desalination Options

Cost estimates have been developed for desalination of two categories of salt water, including brackish water (groundwater with a Total Dissolved Solids (TDS) concentration of about 2,000 parts per million (ppm)); and sea water with a typical TDS concentration of about 35,000 ppm.

In addition, the sea water options include selection of either of two types of intake structure, including an underwater riser and a seafloor infiltration gallery. At this conceptual level of cost analysis however, it is not practicable to distinguish the differences in costs associated with either sea water intake option.

Two categories of land are required. Land is required on which to site an intake well for brackish water source development and intake and pumping station installations for sea water intakes. In addition, land is required for the treatment facilities required to transform salty water to potable water, suitable for drinking. Design and Permitting costs can be highly variable depending on the site(s) selected for intake and pumping station locations as well as the treatment facility site location. Environmental assessment and impact analysis associated with highly sensitive and regulated coastal zone resource areas can require several years of data collection and analysis and near-shore littoral modeling of both coastal hydraulics and water quality.

The location of an intake well or brackish water intake would be located close to the shoreline in an area of water availability. Specific sites were not reviewed in detail, but potential sites include Kalmus Beach (670 Ocean Street). Finding a suitable site will be challenging due to the lack of available land and costs. The location of a treatment plant would be easier to site nearby, possible near Kalmus Beach.

Cost estimates for desalination for a design flow of 2.5 MGD range from about $16M for brackish groundwater sources up to about $30M for a sea water desalination operation. As described in Section 6.3.4, treatment for desalination is based on reliance of reverse osmosis (RO) systems including pre-treatment, flocculation and settling, RO and disinfection prior to distribution to the water supply system. Source water quality will largely dictate the selection of an appropriate treatment process train to produce the highest quality water suitable for use as public drinking water.

7.1.4 Reuse/Recycling of Wastewater for Aquifer Recharge

As discussed in Section 4, Barnstable is entirely dependent on the sole source aquifer that underlies the spine of Cape Cod and that this same aquifer is both the source of both public and private water supplies and the discharge location for on-site wastewater treatment systems and the town's wastewater treatment facility. While questions of public acceptance of even highly treated wastewater as a source of public water supply remain to be formally answered, the reality is that there are already areas where wastewater discharges are integral inputs to the same aquifer from which water supplies are withdrawn. Cost estimates are presented here for the application of advanced treatment technologies that would substantially improve the quality characteristics of the effluent discharged from the wastewater treatment system. Such improved effluent would then be far more suitable for use in aquifer recharge applications than the effluent quality currently discharged into the ground.

The advanced treatment processes that could be employed would include ozone, followed by BAC/GAC filters, followed by membrane/ultra-filtration and finally ultraviolet light (UV) disinfection. The estimated costs of this treatment train are in the range of $4 - $6 per gallon of effluent treated. This yields an estimate range based on the average daily flow of the Barnstable WWTP of about 4 MGD of $16M to $24M. This estimate range at this conceptual level of development could vary significantly based on the effluent quantity considered for treatment to an advanced level (e.g. 1 MGD as opposed to 4 MGD); or whether it may become desirable to pump effluent to multiple discharge locations with lower discharge volumes to distribute treated effluent across multiple recharge areas. The cost for treatment of the groundwater for drinking water purposes as described in Section 7.1.1, would be added to the above costs.

7.2 New Groundwater Supply Estimate of Costs

Cost estimates for new supply development recommendations are presented in Table 17 for each of the six potential new source sites suggested for more detailed hydrogeologic and water quality investigations. The costs estimated for preliminary studies include drilling of three to five test wells on each site, water quality sampling, pump testing to develop aquifer characteristic information and potential yields and identify environmental conditions for permitting. Preliminary design and permitting would only be required for those sites determined to be suitable for final design and permitting and would include site surveys, initial consultation with DEP and local permitting agencies, and other state permitting authorities. Preliminary design would include developing design flow rates, building requirements, pump sizing and treatment recommendations based on water quality conditions specific to each site investigated. Costs estimated for wells and treatment are based on four wells, at an average capacity of approximately 450 gpm each, and one water treatment plant with a design capacity to produce the full 2.5 MGD projected requirement to provide redundancy to meet future MDD. Treatment includes pH adjustment, corrosion control and disinfection. A greensand treatment system to treat 2.5 MGD would add approximately $7.5 million to the costs. The costs of transmission pipes are based on the estimated distances required to connect water produced at any one potential site to the nearest identified point of connection to the HWS distribution system. Engineering services include design, bidding, and services during construction. It should be noted that the costs presented for each site option are not intended to be additive and are offered for comparison purposes only. It is possible that the well and treatment costs for example, while estimated for each site, may be distributed over two or more sites based on the combination of yield and water quality conditions determined through the preliminary detailed investigation and preliminary design stages of new source development.

Table 17: New Groundwater Supply Development Cost Estimate – 2.5 MGD

New GW Source Site	Preliminary Site Studies	Wells & Chemical Treatment	Transmission Mains	Engineering 18%	Contingency 15%	Total Cost*
Site B	$150,000	$3,000,000	$1,100,000	$765,000	$637,500	$5,652,500
Site A	$100,000	$3,000,000	$360,000	$622,800	$519,000	$4,601,800
Site C	$150,000	$3,000,000	$1,900,000	$909 ,000	$757,500	$6,716,500
Site D	$200,000	$3,000,000	$3,200,000	$1,152,000	$960,000	$8,512,000
Site F	$120,000	$3,000,000	$200,000	$597,600	$498,000	$4,415,600
Site E	$120,000	$3,000,000	$360,000	$626,400	$522,000	$4,628,400

* greensand treatment system to treat 2.5 MGD would add approximately $7.5 million to each site cost.

7.3 Existing Supply Improvement Estimate of Costs

Cost estimates for recommendations have been developed for existing supplies and are summarized in Table 18 below. The cost estimates for existing supply projects are based on the best available information from HWS and their consultants currently engaged in active projects. New supply development estimated costs are based on the estimated number of new wells and treatment facilities required to achieve the restoration of pumping capacity lost due to water quality issues and to meet current and future maximum day demands without requiring the purchase of water from Yarmouth.

Table 18: Existing Supply Improvement Estimated Costs

Project	Estimated Cost	Comments
Straightway #1 Reactivation	$140,000	Underway
Mary Dunn #4 Relocation	$724,000	Underway
Upgrade Treatment – Maher WTP	$11.5M	Assumes Advanced Oxidation, GAC and Greensand Filtration
Upgrade Treatment – Mary Dunn	$10M	Assumes Greensand Filtration and Construction of two parallel treatment plants
Upgrade Treatment – Straightway WTP	$11.5M	Assumes Advanced Oxidation, GAC and Greensand Filtration

7.4 Capital Cost Analysis and Comparison

The costs to develop a groundwater supply are lowest of the new source options evaluated. If minimal treatment is required, the cost can be very low, relative to other options. Table 19 below presents the approximate costs to develop and treat a 2.5 MG supply. The four source options evaluated include the cost of the well or supply intake and treatment systems. These costs are also presented in dollars per gallon. It should be noted that the cost per gallon decreases significantly as the total volume of water treated increases. This is due to the base cost of site work, building construction and utilities being a significant initial cost of a project. The additive cost to make the building larger for added treatment capacity or chemical storage is much less.

Table 19: New Source Water Treatment Estimated Costs per Gallon

New Source 2.5 MGD	Project Cost (Million $)	Cost per Gallon*
Groundwater		
Base	$3.0	$1.20
Base +1	$10.5	$4.20
Base +2	$13.0	$5.20
Base +3	$14.5	$5.80
Base +4	$16.0	$6.40
Surface Supply	$25.0	$10.00
Desalination		
Brackish	$24.0	$9.60
Sea Water	$30.0	$12.00
Wastewater Recharge	$27.0	$10.80

*The cost per gallon decreases significantly as the total volume of water treated increases.

Groundwater supplies, even when complex treatment using multiple treatment systems is required, are almost always the least expensive to develop and construct. They are less susceptible to mass disruption, since they include multiple separate wells. They also offer better redundancy, as clusters of several wells are typically located in various locations throughout town. This assists with meeting the DEP requirement to provide water for maximum day demands with the largest supply (well) or treatment plant out of service. Operational costs are also generally lower for groundwater supplies when compared to other options.

The fastest option for HWS to gain supply is to treat existing sources. The costs to treat an existing groundwater supply is generally lower than the cost to develop a new groundwater supply. And, as shown in Table 20 below, the cost to provide additional treatment at the existing Maher, Mary Dunn and/or Straightway sites is on par with the cost to develop a new supply with greensand treatment for iron and manganese. Ideally HWS would do both to provide redundancy, meet future demands and to reduce susceptibility to contamination.

Table 20: Existing Source Improvement Estimated Costs per Gallon

Existing Source	Project Cost (Million $)	Cost per Gallon*
Straightway 1 Reactivation	$0.14	$0.19
Mary Dunn 4 Relocation	$0.724	$0.96
Maher Treatment Upgrade	$11.5	$4.60
Mary Dunn Treatment Upgrade	$10.0	$3.33
Straightway Treatment Upgrade	$11.5	$4.60

*The cost per gallon decreases significantly as the total volume of water treated increases

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The HWS is unable to meet the current and future maximum day demand (MDD) with currently available water supplies. Several existing water supply wells are off line and unavailable due to various contaminants that prevent their use as drinking water without additional treatment. There is a need to replace and/or provide treatment for these off-line wells. These actions will allow HWS to discontinue the purchase of water during summer high demand periods.

Currently plans are underway to restore Straightway 1 to service, followed by the replacement of Mary Dunn 4. Treatment for the removal of various contaminants in the groundwater of well supplies in all three areas, Straightway, Maher, and Mary Dunn, will be needed to fully restore off line capacity. Even with replacement and treatment of off-line wells, the system will remain susceptible to water shortfalls due to the lack of redundancy.

To provide the redundancy required by DEP policy whereby the water system can meet the MDD with the largest source out of service, HWS will need to develop additional water supplies. W&S has identified the need to secure 2.5 MGD of additional water supply. With new supplies on line, additional water will be available to meet current and future maximum day demands during all seasons and conditions.

It is estimated that it may take ten years to complete work required to regain off line capacity and to develop additional capacity for redundancy. If population and water demands continue to increase in the future, more additional water supplies will be required. In addition, the permanent loss of supplies, either by contamination that cannot be cost effectively treated, or through decision of the HWS, would require the development of even more additional supply. If an entire area is permanently lost, such as Straightway or Maher, from 2 to 3 MGD would be needed to replace each area.

8.2 Recommendations

W&S recommends that the HWS should continue to replace off line capacity with the lowest cost alternatives. As wells age, they should be cleaned on a regular basis to maintain capacity, until they reach the end of their useful life, at which point they should be replaced. HWS should continue with plans to treat all supplies that are currently off line due to contamination, provided costs are determined to be reasonable. Those supplies that can be restored at the lowest overall cost should receive priority.

W&S recommends that the HWS should also immediately begin the investigation and exploration to locate additional sources of groundwater supply. The development of additional groundwater sources of 2.5 MGD will provide needed redundancy and help to replace capacity lost or impaired due to water quality degradation and contamination. An additional groundwater source will also provide resilience to failure of a treatment plant, additional well shutdowns, drought, or another catastrophic event.

Specific recommendations are presented in three groups based on the need to recover and increase existing available supplies immediately, to identify additional groundwater sources with sufficient yield and good water quality, and to provide optimal management the sole source aquifer on which the Town relies for water supply and public health. The recommendations are designed to:

1. Provide treatment of existing water supplies to regain lost capacity due to impairments to water quality; and,
2. Investigate and then develop new groundwater sources; and,
3. Provide comprehensive water management practices that will pay dividends into the future including reduced costs, management of consumption and protecting water quality into the future.

<u>Existing Supply Recommendations</u>: HWS should continue short-term implementation of current planned water system improvements to immediately improve and restore the operating capacity of the water system, including:

- Reactivation of Straightway Well No. 1; estimated cost approximately $140,000
- Replacement of Mary Dunn Well No. 4; estimated cost approximately $724,000
- Implementation of Advanced Water Treatment at the Maher Water Treatment Plant to include filtration for Iron and Manganese Removal; and advanced oxidation plus UV for removal of 1, 4 Dioxane; estimated cost approximately $11.5 million.

In addition, it is recommended that HWS evaluate treatment system improvements at the Mary Dunn and Straightway sites. Additional evaluation, conceptual design and cost analysis are required for these improvements.

- Modernize and upgrade the Mary Dunn Treatment Plant to provide flexibility in operation of the GAC filters and provide greensand filtration for iron and manganese control for at least the Airport Well; estimated cost approximately $10 million.
- Modernize and upgrade the Straightway Treatment Plant to include installation of greensand filtration; GAC for removal of PFC's; advanced oxidation plus UV to remove 1,4 Dioxane; and consider additional treatment for nitrogen removal from the Hyannisport Well; estimated cost approximately $11.5 million.

Should Barnstable not modernize the Mary Dunn or Straightway supplies with additional treatment, or choose to discontinue use of these supplies, then additional supplies of 2 to 2.5 MGD would need to be developed to replace each source.

<u>New Supply Development Recommendations</u>: The HWS, should immediately proceed to investigate and explore to locate viable new groundwater sources. Based on a preliminary review of the parcel information presented in the Report at section 6.3.1, including review by the HWS, we recommend the immediate initiation of detailed hydrogeologic and water quality investigations of the following parcels, in the following order of priority:

Site B - North of Route 6: This site is a fairly large contiguous land area north of Route 6 directly north from the golf course located within the Barnstable Fire District. Multiple parcels might be considered for inclusion in this option. The combined area of these parcels totals nearly 300 acres, of which nearly 250 acres are contiguous open land, and 109 acres could support wells. Development of wells and treatment facilities will require crossing under Route 6 but could prove feasible if developed in conjunction with parcel A or in a scenario where combining of water districts becomes feasible. It is estimated that sufficient yield could be developed within this area. This site was grouped with site A for investigation and potential development to support at least four wells. Site E could also be grouped with A and B. Approximately 11,000 linear feet of 12" DI transmission main would be required around Route 6 past Site A and then to the distribution system. Approximately 7,400 linear feet of main would be required if combined with Site A.

Site A - Route 132/Route 6: Combination of several parcels located between the Golf Course, Route 6 and Route 132. These parcels combine to create an area consisting of about 50 acres, of which wells could be located on about seven acres. These parcels are owned by the Town of Barnstable and MassDOT and are located between site B and the distribution system, so should be investigated together. This location is estimated to be able to accommodate at least one new well and associated treatment and transmission facilities. Approximately 3,600 linear feet of 12” DI transmission main would be required within the site and along Route 132 to connect to the distribution system.

Site C – Bridge Street Conservation Area: Multiple parcels were aggregated into Site C. About 90 acres within West Barnstable could support two or three wells. It is a large undeveloped area that sits on high ground on the north side of Route 6 at over three miles from the existing HWS system. This makes it favorable for development of new supplies, but is costly for transmission main construction. Approximately 19,000 linear feet of 12” DI transmission main would be required on and off site to connect to the distribution system This site was grouped with site D for investigation and potential well development.

Site D – West Barnstable Conservation Area: Multiple parcels were aggregated into Site D. It is one of the largest contiguous areas of Barnstable that is undeveloped. Over 1,100 acres mostly within West Barnstable could support many wells. It is on high ground on the south side of Route 6 at over five miles from the existing HWS system. Approximately 32,000 linear feet of 12” DI transmission main would be required to link site D to the distribution system. If Site C is also developed, the length of main would be 19,000 feet less or 13,000 feet.

Site F - County Farm: This area is an assemblage comprised of several individual parcels with a combined area of over 110 acres. Primarily consisting of the County Farm, the area is west of Mary Dunn Road and north of Route 6. The area is close to the existing HWS system, including the Mary Dunn Wells and the Water Storage Tanks, which increases vulnerability. The parcel is crossed by two power lines. The northern half of the area is woodland, a portion of which has been used for farming. A transmission main from the center of the site to Mary Dunn Road would be about 2,000 linear feet.

Site E - Pond Lijah Lane: Parcel 276002 is located on Pond Lijah Lane, west of Phinney’s Lane, south of Route 6. The lot includes about 67 acres. Well development on this parcel would require approximately 3,600 linear feet of transmission main to connect to the HWS distribution system. This area is located within the Barnstable Fire District and may warrant consideration for combining water systems or creating other institutional arrangements with the Barnstable Fire District.

Site G - Fish & Wildlife: The MA Fish and Wildlife land east from Mary Dunn Road and south of Route 6, parcel identification number 347002001, consists of over 330 contiguous acres. The area is located south of Route 6, north of the airport between Mary Dunn Road and

Willow Street. This parcel abuts several Town-owned parcels along Mary Dunn Road along its westerly boundary. Approximately 2,300 linear feet of 12" DI transmission main would be required to connect to the distribution system. Treatment facilities would also be required in the vicinity of the sites selected within this parcel. This site is close to the Mary Dunn wells, and draws water from the same area of the aquifer which increases vulnerability. Seasonal restrictions on water withdrawal could be imposed by DEP for these and all nearby wells.

Site H - Barlaco: A combination of parcels, known locally as the Barlaco land. This land is adjacent to the existing Mary Dunn Well 4. The area of potential combined parcels is 59 acres and would include both the new Mary Dunn Well 4 plus up to two additional wells. It is possible that the Zone 1(s) for the new wells could overlap onto adjacent MA F&W land. The connection to the system would be about 1,300 long. This site is close to the Mary Dunn wells, which increases vulnerability but does allow the potential for re-connecting Mary Dunn Wells 3 and 4 to a new treatment plant to improve redundancy. Seasonal restrictions on water withdrawal could also be imposed by DEP.

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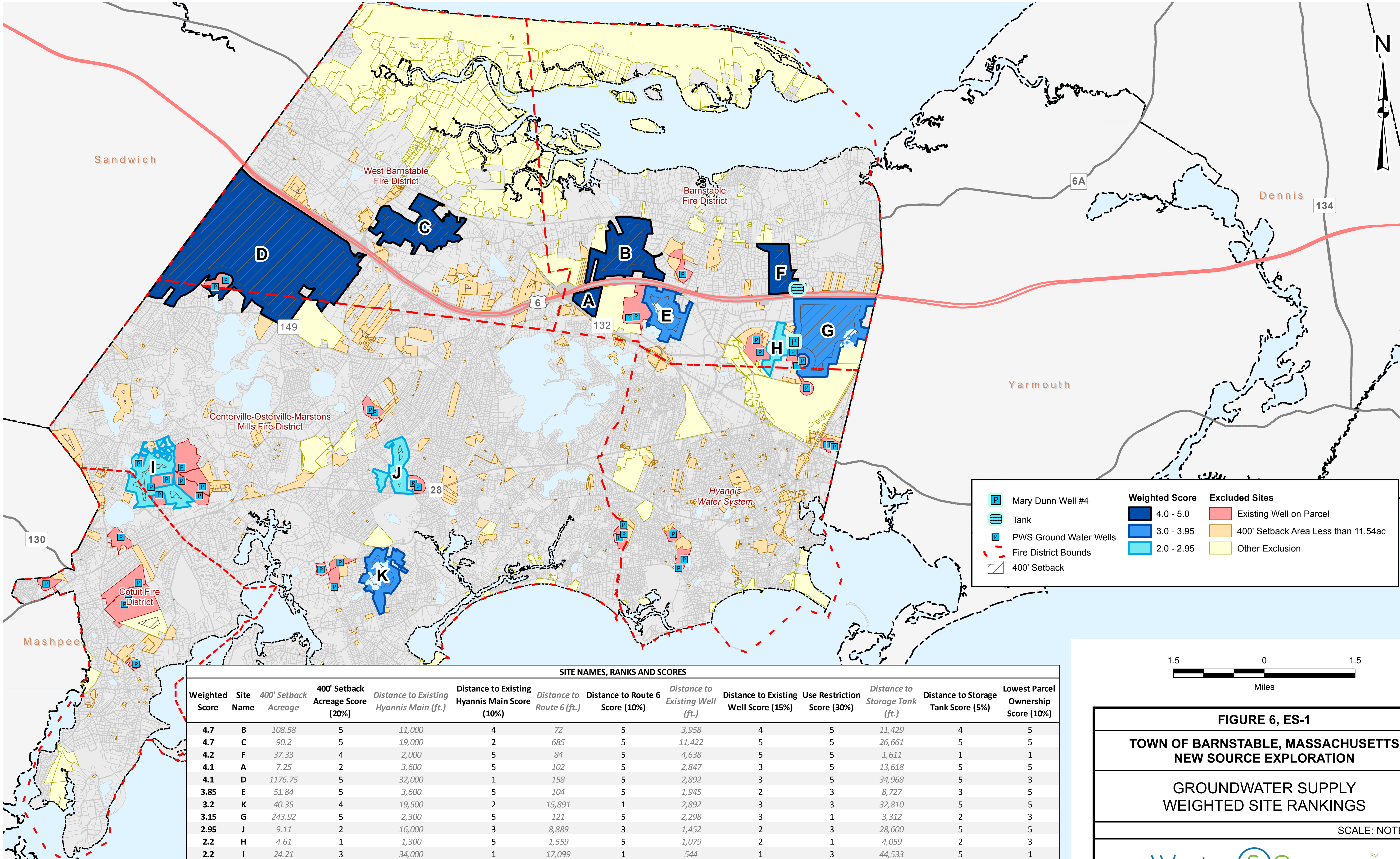

SITE NAMES, RANKS AND SCORES

Weighted Score	Site Name	*400' Setback Acreage*	400' Setback Acreage Score (20%)	*Distance to Existing Hyannis Main (ft.)*	Distance to Existing Hyannis Main Score (10%)	*Distance to Route 6 (ft.)*	Distance to Route 6 Score (10%)	*Distance to Existing Well (ft.)*	Distance to Existing Well Score (15%)	Use Restriction Score (30%)	*Distance to Storage Tank (ft.)*	Distance to Storage Tank Score (5%)	Lowest Parcel Ownership Score (10%)
4.7	B	*108.58*	5	*11,000*	4	*72*	5	*3,958*	4	5	*11,429*	4	5
4.7	C	*90.2*	5	*19,000*	2	*685*	5	*11,422*	5	5	*26,661*	5	5
4.2	F	*37.33*	4	*2,000*	5	*84*	5	*4,638*	5	5	*1,611*	1	1
4.1	A	*7.25*	2	*3,600*	5	*102*	5	*2,847*	3	5	*13,618*	5	5
4.1	D	*1176.75*	5	*32,000*	1	*158*	5	*2,892*	3	5	*34,968*	5	3
3.85	E	*51.84*	5	*3,600*	5	*104*	5	*1,945*	2	3	*8,727*	3	5
3.2	K	*40.35*	4	*19,500*	2	*15,891*	1	*2,892*	3	3	*32,810*	5	5
3.15	G	*243.92*	5	*2,300*	5	*121*	5	*2,298*	3	1	*3,312*	2	3
2.95	J	*9.11*	2	*16,000*	3	*8,889*	3	*1,452*	2	3	*28,600*	5	5
2.2	H	*4.61*	1	*1,300*	5	*1,559*	5	*1,079*	2	1	*4,059*	2	3
2.2	I	*24.21*	3	*34,000*	1	*17,099*	1	*544*	1	3	*44,533*	5	1

FIGURE 6, ES-1

TOWN OF BARNSTABLE, MASSACHUSETTS
NEW SOURCE EXPLORATION

GROUNDWATER SUPPLY
WEIGHTED SITE RANKINGS

SCALE: NOTED

Weston & Sampson SM

New Supply Development Costs: To develop new water supplies, we recommend the initiation of hydrogeologic and water quality investigations in all six areas, A through F. The Town of Barnstable should proceed to investigate each of these potential sites for development of new groundwater sources. Estimated costs for development of new supplies with a total capacity of 2.5 MGD range from approximately $5 to $15 million depending upon the site location and the level of treatment necessary.

Source Improvement Schedule: The suggested schedule to implement the recommended improvements to existing sources of supply and the development of new supplies is shown on the table below. A second round of new supply development beginning in 2028 is recommended to provide additional capacity to keep pace with growth and/or to replace existing lost capacity of existing sources.

Table 21: Preliminary Schedule of Water Source Improvements

Preliminary Schedule of Water Source Improvements

	Start Date	End Date	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Existing Supplies																							
Reactivate SW#1	2018	2019																					
Relocate MD#4	2018	2020																					
Upgrade Maher Water Treatment	2019	2020																					
Continue Purchase of Yarmouth Water	2018	2020																					
Evaluate & Upgrade Mary Dunn Water	2020	2024																					
Evaluate & upgrade Straightway Water	2020	2024																					
New Supply Development Phase 1																							
GW Exploration, Testing & Permitting	2019	2021																					
Preliminary Well & Treatment Design	2020	2022																					
New Source Approval, Design & Permitting	2021	2024																					
Construct New Wells with Treatment	2025	2029																					
New Supply Development Phase 2																							
GW Exploration, Testing & Permitting	2028	2030																					
Preliminary Well & Treatment Design	2029	2031																					
New Source Approval, Design & Permitting	2030	2033																					
Construct New Wells with Treatment	2034	2038																					

Best Management Practice Recommendations: The Town of Barnstable, through its Water Supply Division, should consider implementation of resource stewardship and management practices to ensure the future reliability of the groundwater resources available to the Town.

- Develop and implement an intensive program of water conservation to achieve reduction of summer peak demand by five (5%) percent.
- Partner with local, state and regional agencies responsible for wastewater disposal, treatment and permitting to better coordinate decision making relative

to chemical constituents in treated effluents discharged to the groundwater regime within the Sagamore Lens.

- Partner with local, state and regional agencies to coordinate the management and discharge of stormwater including seasonal runoff associated with snow and ice control of impervious surfaces that contribute runoff to groundwater recharge zones.
- Initiate study of water pricing strategies directed at achieving seasonal peak flow demand reductions, either in addition to or as part of the water conservation program expansion described above.
- Initiate the creation of a planning group to include Town, Water Division, state and regional agencies to analyze the management of water in an integrated resource management framework recognizing the interaction and interdependency on the Sagamore Lens as a sole source aquifer for multiple purposes.

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