Climate Change Water Resource Vulnerability and Adaptation Strategy Assessment – Integrated Management Plan

TOWN OF CARVER, MASSACHUSETTS

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1 Purpose and Need for the Assessment

As part of the Massachusetts Municipal Vulnerability Preparedness (MVP) planning process, the Town of Carver identified top hazards associated with projected climate change and top concerns for impacts related to those hazards. Drought was identified as a top hazard and one that had already demonstrated impacts on the Town and is expected to have ever greater consequences for infrastructure and the environment as climate change progresses. **Section 3** provides information on anticipated climate change impacts to water resources, which are described in **Section 2**. Through the MVP Community Resilience Building workshop, impacts to cranberry bogs and water supplies for fire suppression were identified as areas of concern as summarized in the boxes to the right. To address these concerns and identify opportunities for resilience to the impacts of drought, a top priority action was:

Conduct a detailed vulnerability and risk assessment of surface water supply, with particular focus on water to support fire suppression activities, maintain successful agricultural (cranberry) production, and ensure high surface water quality.

In 2018, The Town of Carver was awarded an MVP Action Grant to conduct a Climate Change Water Resource Vulnerability and Adaptation Strategy Assessment to synthesize readily available background information, limited field data collection, and local input to guide the development of an integrated climate resiliency management plan focused on drought impacts to firefighting and agricultural water supplies. This report and the attached appendices summarize the results of the assessments and include prioritized site-specific and town-wide recommendations to support future implementation projects (**Section 4**) and identification of potential funding sources (**Section 6**) to support the implementation of resiliency measures that include the conceptual designs in **Section 5**. The integrated management plan is intended to help local decision-makers think more strategically about ways to provide more effective approaches to reduce the impacts of drought on water supply, while also benefitting water quality and ecological health.

Cranberry Bogs
The Town's extensive network of cranberry bogs plays a key role in the Town's economy, but also the environment. These bogs are now increasingly threatened by new pests, including cranberry scale insects and footprint disease, as well as by water supply problems. One of the workshop participants indicated that he was having to move his own cranberry operation to a new location because the water supply that services his current bog was no longer sufficient due to new development that was drawing down that supply. Cranberry farmers are also coping with changes in temperature and precipitation that are causing their fields to behave differently than they have in decades past.

Water Supply for Fire Suppression
The Town relies on scattered surface water for firefighting, and while mapping exists of potential water sources, it is unknown whether these ponds will actually contain sufficient water during a time of need. Further complicating the situation, the surface ponds are prone to algal blooms, especially during droughts. This makes the water even harder to access for fire suppression, as pumping equipment can easily become clogged with algae.

2 Summary of Water Infrastructure and Water Resource Conditions

The Town of Carver, Massachusetts is rich in surface water resources that the Town relies on to support water infrastructure for cranberry agriculture and fire-fighting water supply. This section provides a description of surface water resources and water infrastructure as it relates to cranberry-growing and potential fire-fighting across Carver, as well as an assessment of the current conditions of surface water throughout the 40-square mile (25,600 acre) town. This summary focuses on surface water resources and infrastructure and is not an assessment of groundwater supply or condition; however groundwater supply will be touched on in reference to the impact of groundwater on surface water resources.

Water Infrastructure

Water Resources

Figure 1 shows the location of surface water resources throughout the Town of Carver, including ponds, streams, cranberry bogs and wetlands. There are approximately 1,628 acres of ponds and reservoirs in Carver. The two largest open water features in Town are Sampson Pond (300 acres), located north of the intersection of Main Street and Tremont Street, and Atwoods Reservoir (280 acres), located northwest of Main Street and Sampson Pond. Other notable ponds and reservoirs include Muddy Pond and Wenham Pond in the northern section of Town and Federal Furnace Pond located on the Town's eastern border with Plymouth. There are several other small ponds and reservoirs scattered throughout the Town.

There are approximately 54 stream miles within Carver. The Town's major river system is formed by the Weweantic River and its tributaries. The Weweantic River flows south along the Town's western border with Middleboro. Its tributaries include South Meadow Brook, which flows into South Meadow Brook Pond and eventually joins with the Weweantic River, and Rocky Meadow Brook, which enters Carver from Middleboro before also joining with the Weweantic. Indian Brook and Crane Brook flow southwest out of Sampson Pond before joining with the Weweantic. Additional river systems include the Winnetuxet River in the northern section of Town, which flows south into Muddy Brook before eventually entering Muddy Pond, and the Wankinco River which flows along the southeastern border with Plymouth.

There is a large wetland (553 acres) located north of Sampson Pond between Main Street and Tremont Street. This wetland and several others scattered throughout the Town amount to approximately 2,662 acres of wetlands within Carver. The large scale of Carver's cranberry industry is exhibited by the number of cranberry bogs spread throughout the Town, accounting for a total area of approximately 3,740 acres.

Fire Protection

There are approximately 150 fire water supplies distributed throughout the Town of Carver which have been categorized as either open access or restricted access (**Figure 2**). The Fire Chief has also identified 20 critical fire supplies within each zone based on their location and proximity to areas of concern within the Town. The fire supplies are located mainly on the Town's ponds, though there are several fire supplies utilizing rivers, wetlands and cranberry bogs as well.

The Carver Fire Department divides the Town into 3 zones and each zone is further divided into grids. The available water infrastructure for fire-fighting has been identified within each zone and grid. Zone 2 includes the northern section of Town and is bounded by the Town boundary to the north, east, and west. The southern boundary of Zone 2 extends south to Wenham road then roughly follows a line parallel to

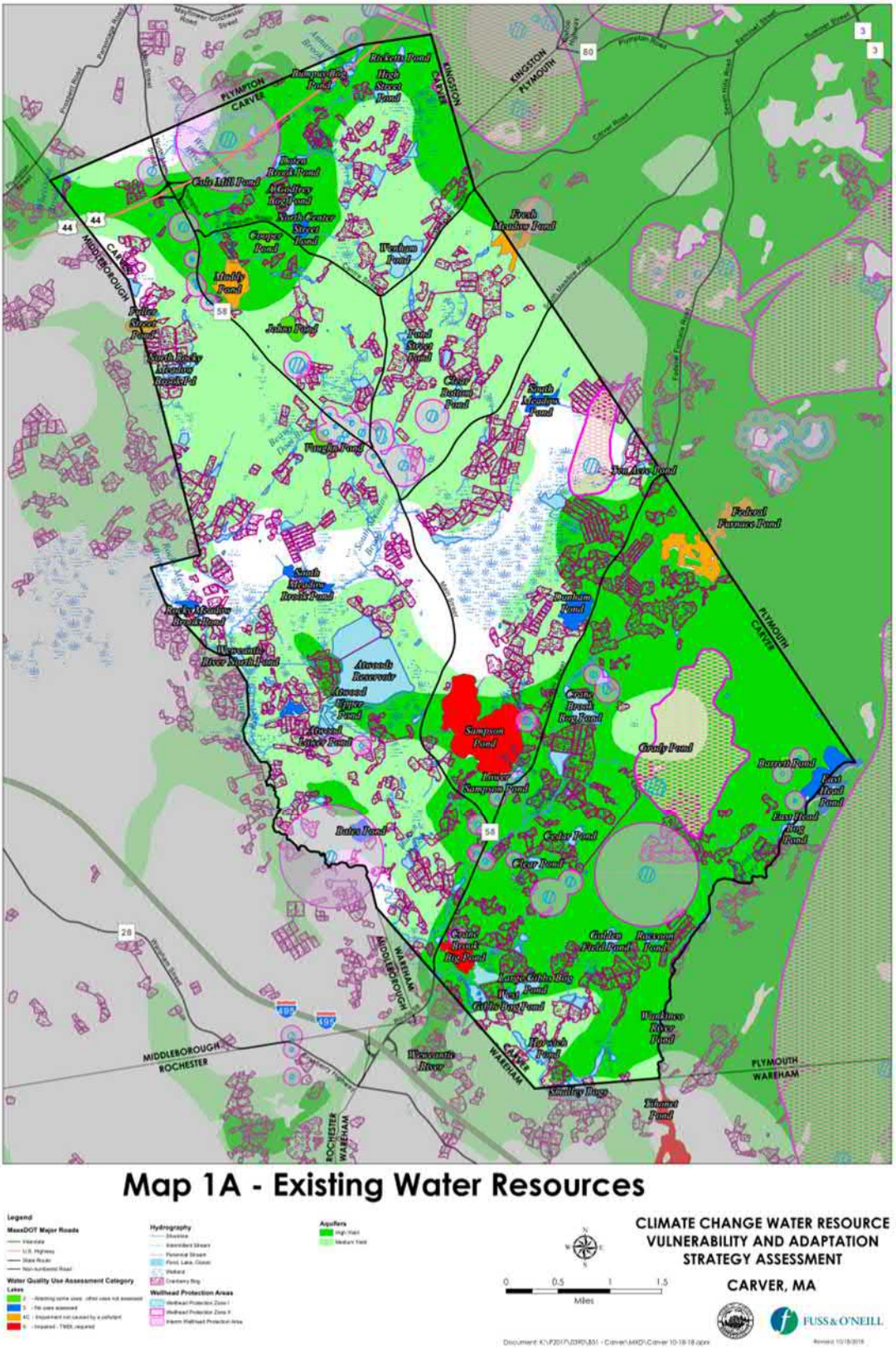


Figure 1. Existing Water Resources in Carver, MA

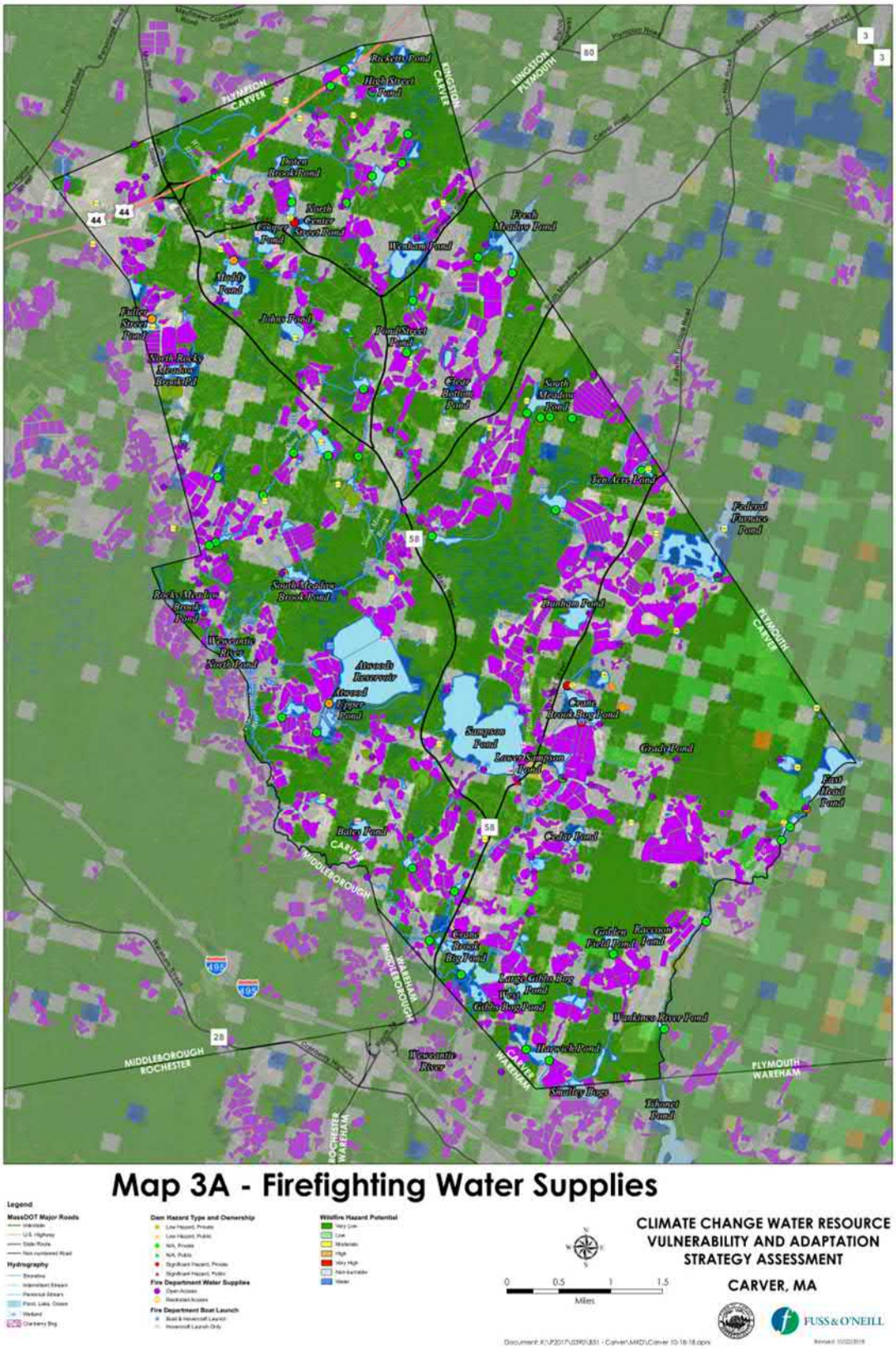


Figure 2. Firefighting Water Supplies in Carver, MA

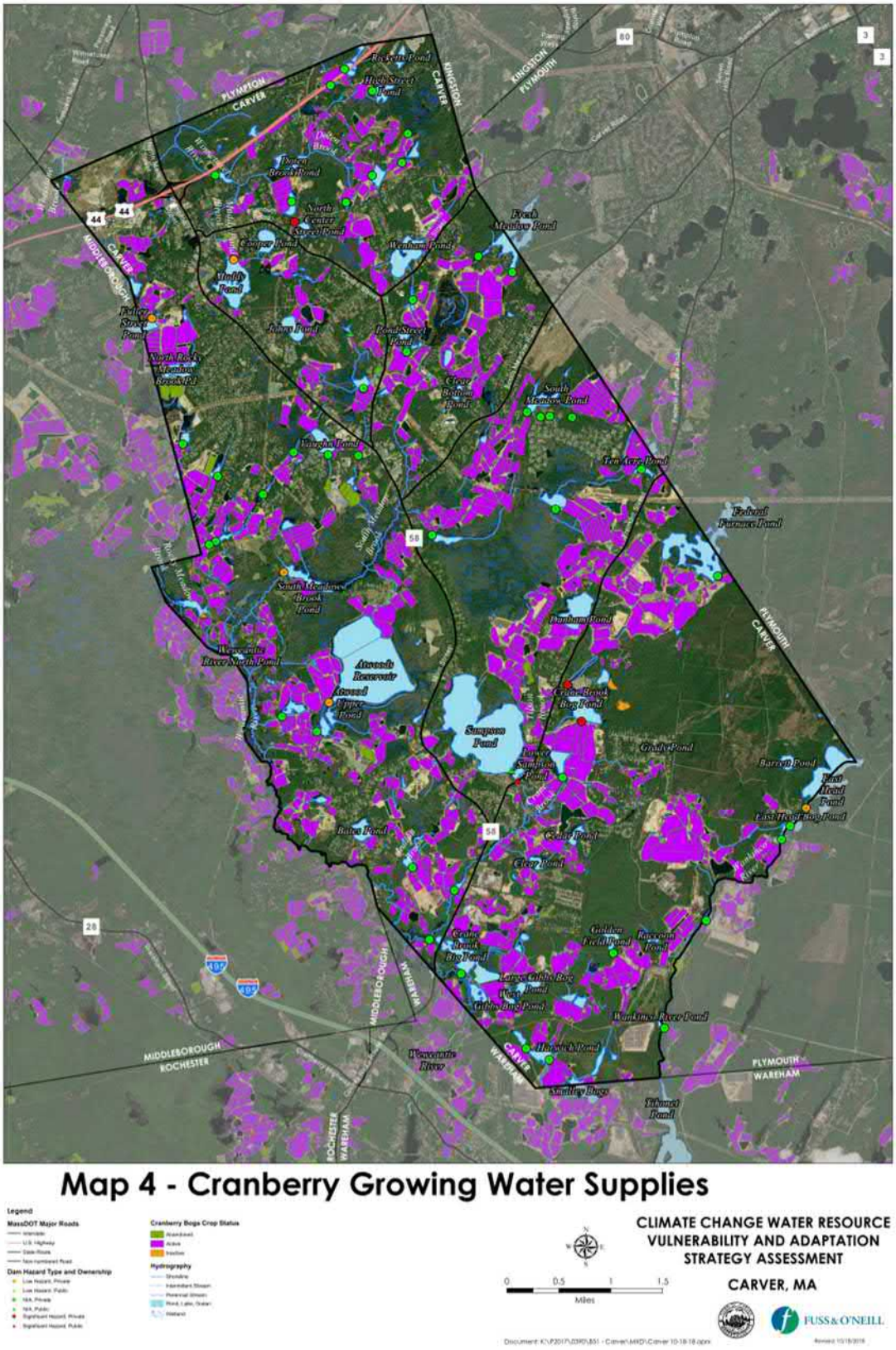


Figure 3. Cranberry Growing Water Supplies in Carver, MA

Silva Street and Purchase Street. The Fire Chief has identified 6 critical fire supplies within this zone. Zone 1 is bounded to the north by Zone 2 and to the east and west by the Town boundary. Zone 1 is roughly bounded to the south by a line running parallel to the southern boundary of Great Cedar Swamp and Atwood Reservoir. Seven critical fire supplies have been identified within Zone 1. Zone 3 is bounded to the north by Zone 1 and to the east, west and south by the Town boundary. The Fire chief has identified 7 critical fire supplies within this zone.

Cranberry Growing

Cranberry bogs in Carver are spread throughout all areas of Town, with the exception of the large wetland north of Sampson Pond, and the densely developed area southwest of Main Street (**Figure 3**). Many of the bogs are located directly adjacent to ponds that are likely used as a water supply. There are large clusters of bogs in the southern section of Town, located near Atwoods Reservoir, Federal Furnace Brook Pond and Crane Brook Pond. There are also clusters of cranberry bogs around the Weweantic River, South Meadow Brook, Beaver Dam Brook and Doten Brook that are likely relying on these rivers for water supply.

Dams

There are 56 dams in Carver, the majority of which are privately owned (**Figure 3**). Ten dams have a Massachusetts DCR Office of Dam Safety hazard classification, with 6 dams identified as Low Hazard and 4 dams identified as Significant Hazard. The Significant Hazard dams are located on Crane Brook Bog Pond (2 dams), Sampson Pond and North Center Street Pond.

Conditions

Streamflow

There are no gaged streams in Carver, so streamflow data from U.S. Geological Survey (USGS) sites 01105876 (Eel River at Rt 3A in Plymouth, MA) and 01108000 (Taunton River in Bridgewater, MA) were used to summarize typical streamflow conditions in the vicinity of Carver. A summary of existing and historic conditions at each site is provided below.

Site 01105876 (Eel River in Plymouth MA):

- The drainage area for the site is 14.7 square miles. Discharge data is available from 2006 to 2019. Incomplete data was excluded from statistics calculations.
- Average annual discharge ranged from 26.7 ft^3/s to 36.4 ft^3/s from 2007 to 2016 (an average of 2.1 cubic feet per second per square mile (csm)).
- Over the period of record, average monthly discharge was typically highest in early spring, began to drop in May or June and reached a low point around late summer before beginning to rise again. Average monthly discharge typically varied by no more than 10-15 ft^3/s throughout the year.
- Over the period of record, 7 day low flow ranged from 16.2 ft^3/s (March 2, 2014) to 28 ft^3/s (Aug 16, 2010) while maximum peak flow ranged from 76 ft^3/s (December 12, 2008) to 148 ft^3/s (July 5, 2014).
- Massachusetts experienced an extreme drought in late 2016. **Figure 4** compares average monthly discharge in 2016 to average monthly discharge over the period of record from 2007 to 2016. Average summer discharge in 2016 was 15% lower than the summer average for the period of record. Average fall discharge in 2016 was 13% lower than the fall average for the period of record.

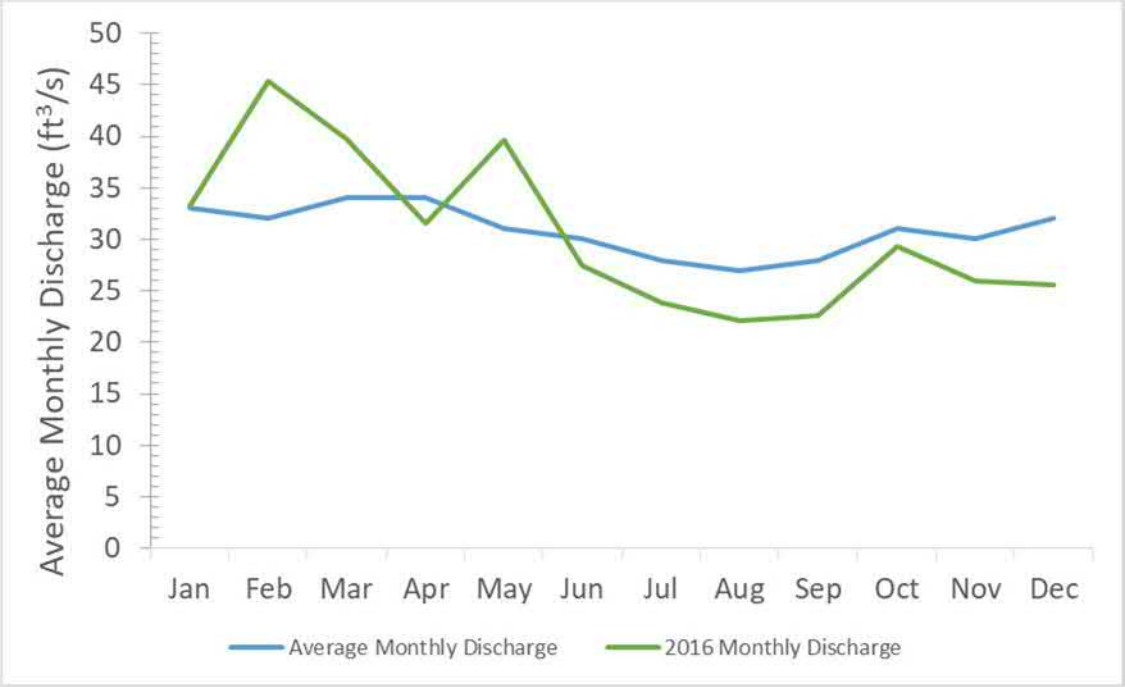


Figure 4. Average monthly discharge in 2016 compared to average for the period of 2007 to 2017 for USGS site 01105876.

Site 01108000 (Taunton River in Bridgewater, MA):

- The drainage area for the site is 261 square miles. Discharge data is available from 1929 to 2018, with gaps from 1976 to 1985 and 1988 to 1996.
- Average annual discharge ranged from 202.9 ft^3/s to 821.2 ft^3/s from 1930 to 2016 (an average of 1.9 csm).
- Over the period of record, average monthly discharge was typically highest in early spring, began to drop in May or June and reached a low point around late summer before beginning to rise again. Average monthly discharge typically varied by about 1,000 ft^3/s throughout the year.
- Records of 7 day low flows are available for 2005 through 2017 and ranged from 38.6 ft^3/s on August 26, 2016 to 148 ft^3/s on August 18, 2009.
- Maximum peak flow ranged from 1250 ft^3/s on March 25, 1950 to 23,002 ft^3/s on January 28, 1986.
- The drought of record in Massachusetts occurred from 1963 to 1967. **Figure 5** compares average monthly discharge in 1965 to average monthly discharge in 2016 and average monthly discharge over the period of record. The average summer discharge in 1965 was almost 5.7 times lower than the summer average for the period of record and average fall discharge was 4.3 times lower than the fall average for the period of record. Average summer discharge in 2016 was 3.7 times lower than the summer average for the period of record and average fall discharge was 2.6 times lower than the fall average for the period of record

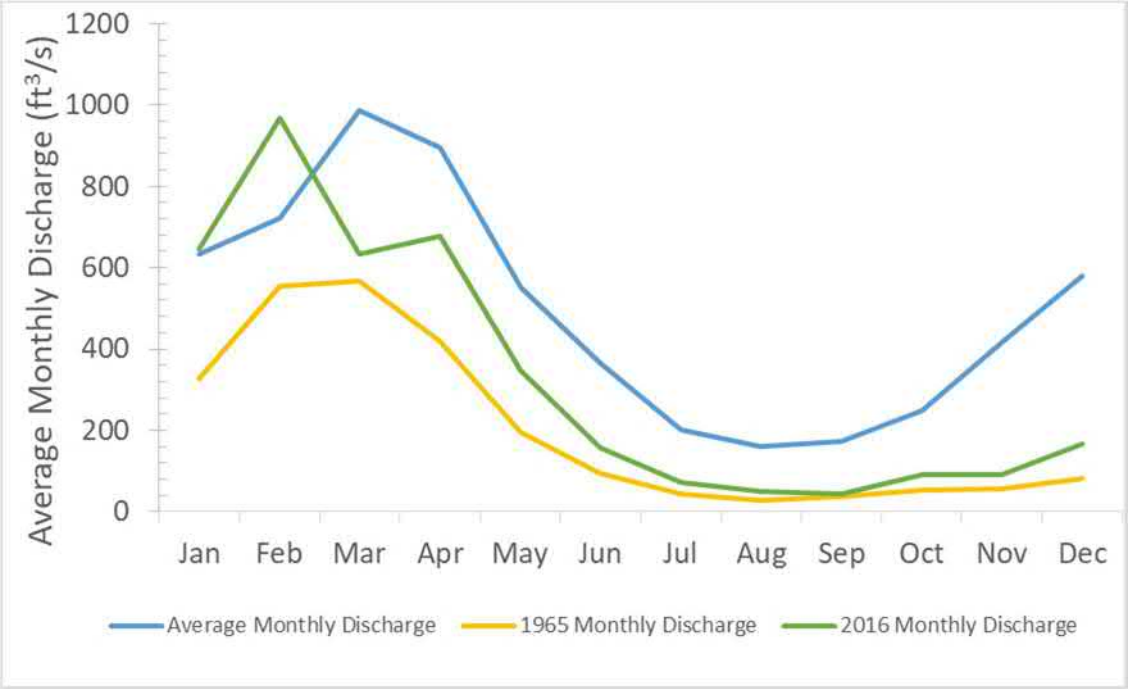


Figure 5. Average monthly discharge in 1965 and 2016 compared to the average for the period of 1930 to 2018 for USGS site 01108000.

Groundwater

Carver's groundwater supply is sourced from the Plymouth-Carver-Kingston-Duxbury (PCKD) aquifer system, an unconfined aquifer composed of glacial sediments. Masterson et al. (2009) conducted a study on the hydrogeology and simulated groundwater levels in the PCKD aquifer. Information from the study that is relevant to groundwater in Carver is presented below.

- Total flow through the aquifer system is approximately 290 Mgal/d, based on calculated recharge rates within the aquifer.
- Carver is located in the western portion of the PCKD aquifer, where the height of the water table is the highest at about 120 feet above NGVD 29 (approximately 123.6 feet above NAVD 88).
- The Weweantic River and the Wankinco River are two of the four largest rivers in the aquifer. These four rivers receive approximately 35% of groundwater discharge from the aquifer.

There are no known long-term groundwater monitoring wells in Carver. The closest monitoring well maintained by USGS is Site 415453070434901 (MA-PWW 22 Plymouth, MA). A summary of existing and historic conditions at the site is provided below.

- The monitoring well is located off of South Meadow Road by the Plymouth Municipal Airport. The period of record is 1956 to 2014. Incomplete data was excluded from statistics calculations. A figure summarizing data from the period of record is provided from USGS as **Figure 6**. The elevation of the land-surface datum of the well is 145 feet above NGVD 29.
- The highest recorded water level was 18.30 feet below land-surface datum on April 26, 2010.
- The lowest recorded water level was 28.99 feet below land-surface datum on January 28, 1966, during the record-holding drought of the mid-1960s.
- From 2015 to 2018, average monthly depth to water level was typically lowest in late fall or early winter and highest in the spring.

- Average annual depth to water level ranged from 28.2 feet below land-surface datum in 1966 to 20.3 in 2008.
- During the 2016 drought, average monthly water levels were 0.6 feet lower during August, September and October than the monthly averages for the period of 2015-2018 (**Figure 7**).

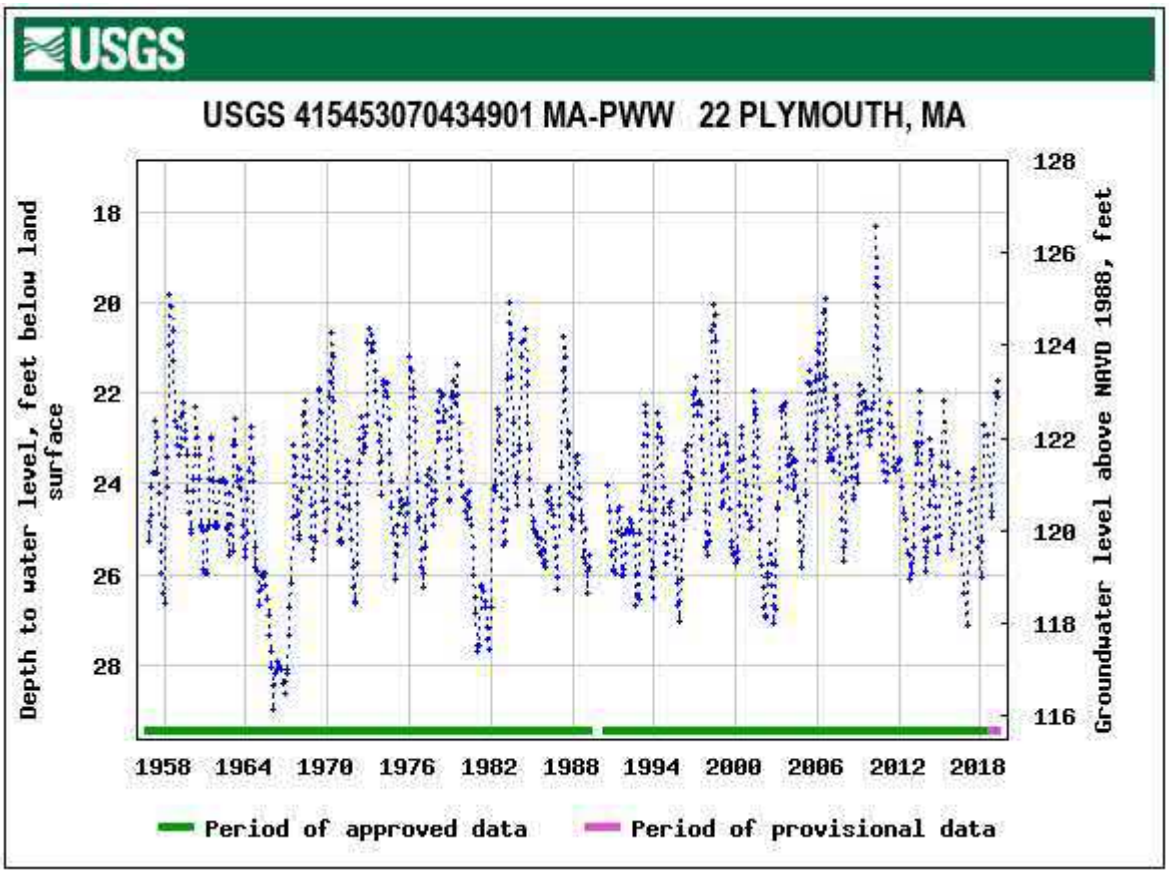


Figure 6. Depth to Water Level (feet below land surface) and Groundwater Level (feet above NAVD 1988) for USGS site 415453070434901 for the period of record from 1956 to 2018.

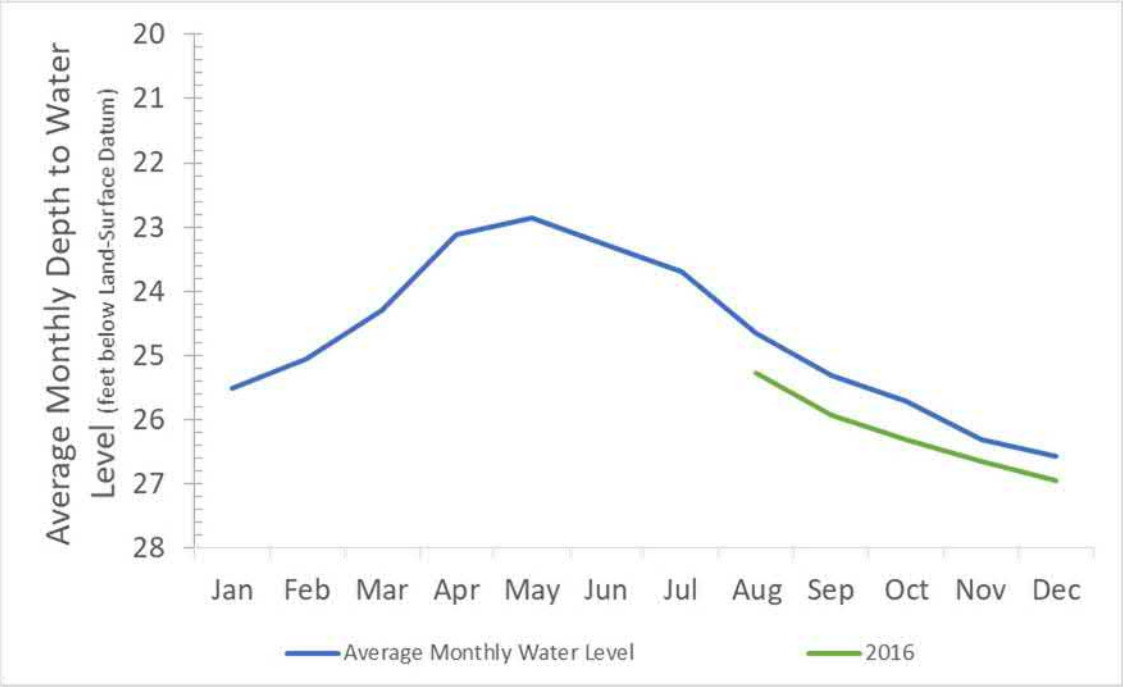


Figure 7. Average Monthly Depth to Water Level in 2016 compared to the average for the period of 2015 to 2018 for USGS site 415453070434901.

A study by Carlson et al. (2017) identified groundwater contributing areas to streams and ponds in the Plymouth-Carver aquifer using groundwater-flow models. The majority of land area within Carver was identified as groundwater contributing area.

The results of the studies mentioned above indicate that surface water levels in Carver depend in-part on groundwater levels. Therefore, a decrease in the height of the water table associated with a drought would be expected to result in decreased surface water levels as well.

Water Quality

While water quality is not the focus of this report, it is important to note that water quality issues can occasionally impact fire water supply. Algal blooms that occur in the summer and early fall can clog fire equipment used to extract water. Drought conditions can exacerbate algal blooms. As reported in the CRB report, this was a particular problem for Sampson Pond during the 2016 drought when water levels dropped 18 inches and algal blooms occurred frequently.

Figure 1 indicates the water quality use assessment of waterbodies in Carver, based on the 2016 Massachusetts Integrated List of Waters. Impaired waterbodies in Carver are listed in **Table 1**. Sampson Pond and several other waterbodies in Carver are impaired for non-native aquatic plants, which often grow prolifically and can cause fire equipment to clog (Weston, Personal communication, 2018). Crane Brook Bog Pond is impaired for Total Phosphorus in addition to Non-native Aquatic Plants and Excess Algal Growth. Excess phosphorus can lead to increased algal bloom occurrence and prolific aquatic plant growth. Dunham Pond is impaired for chlorophyll-a and secchi disk transparency, both of which are associated with increased occurrence of algal blooms.

Table 1. Impaired Waterbodies in the Town of Carver based on the 2016 Massachusetts Integrated List of Waters

Waterbody Name	Waterbody ID	Impairment
Federal Pond	MA95055	Non-native Aquatic Plants
Fresh Meadow Pond	MA95174	Non-native Aquatic Plants
Fuller Street Pond	MA62234	Non-native Aquatic Plants
Muddy Pond	MA62125	Non-native Aquatic Plants
Crane Brook Bog Pond	MA95033	Non-native Aquatic Plants; Excess Algal Growth; Total Phosphorus
Dunham Pond	MA95044	Chlorophyll-a; Secchi Disk Transparency
Sampson Pond	MA95125	Non-native Aquatic Plants; Non-native Fish, Shellfish or Zooplankton; DDT in Fish Tissue; Mercury in Fish Tissue
Weweantic River	MA95-04	Non-native Aquatic Plants; Enterococcus

3 Potential Climate Change Impacts

Across the Commonwealth of Massachusetts, climate change is expected to result in increased temperatures, changes in precipitation and streamflow patterns, and possibly more frequent episodic droughts. Climate change projections for temperature, precipitation, streamflow, drought and sea level rise have been summarized below for the Town of Carver, Massachusetts. Potential impacts to the cranberry industry and fire-fighting capacity in Carver as a result of climate change are subsequently discussed.

Climate Change Projections

Temperature and precipitation

The Northeast Climate Adaptation Science Center (NECASC) at the University of Massachusetts Amherst developed state-wide predictions for changes in temperature and precipitation as a result of climate change over the next 50 to 100 years (NECASC, 2018). Projections for each variable are presented as 30-year mean relative changes at mid-century (2040-2069) and end of century (2080-2099) compared to baseline data from 1971-2000 (NECASC, 2018). The projections are based on the results of 14 climate models run under two different scenarios that reflect possible pathways for global emissions of greenhouse gases.[1] Data is provided at the state, county and drainage basin scale. Following the

[1] The medium (RCP 4.5) and high (RCP 8.5) emission scenarios were chosen for possible pathways of future greenhouse gas emissions. A moderate scenario of future greenhouse gas emissions assumes a peak around mid-century, which then declines rapidly over the second half of the century, while the highest scenario assumes the continuance of the current emissions trajectory. These scenarios represent different pathways that society may or may not follow, to reduce emissions through climate change mitigation measures.

recommendation of NECASC, this study utilizes the projections developed for the Buzzards Bay drainage basin (the drainage basin that contains the majority of the Town's land area).

Temperature Change Projections for the Buzzards Bay drainage basin (NECASC, 2018)

- Average temperatures are expected to increase in the Buzzards Bay drainage basin annually and across all seasons by mid-century and continuing to the end of the century (**Table 2**).
- The number of extremely hot days is also expected to increase, while the number of extremely cold days is expected to decrease (**Table 3**).
- The number of annual Growing Degree-Days (a measure of heat accumulation that correlates to plant growth) are predicted to increase by 486 to 1199 days by mid-century and 655 to 2361 Degree-days by the end of the century.

Table 2. Projected change in average temperature (NECASC, 2018)

	Observed Baseline Average Temperature (°F)	Projected Change in Average Temperature (°F)	
	1971-2000	Mid-Century	End of Century
Annual	50.7	+2.6 to +5.9	+3.3 to +10.3
Winter	31.3	+2.8 to + 6.4	+3.6 to +9.8
Spring	47.3	+2.6 to +5.7	+3.3 to +9.2
Summer	70.1	+2.1 to +6.1	+3.1 to +11.2
Fall	53.6	+3.2 to +6.1	+3.5 to +10.7

Table 3. Projected change in number of extremely hot and extremely cold days (NECASC, 2018)

	Observed Baseline (number of days annually)	Projected Change (number of days annually)	
	1971-2000	Mid-Century	End of Century
Maximum temperature over 90°F	4	+4 to +21	+8 to +55
Maximum temperature over 95°F	1	+1 to +6	+2 to +25
Maximum temperature over 100°F	0	0 to +1	0 to +7
Minimum temperature under 0°F	2	0 to -1	0 to -1
Minimum temperature under 32°F	111	-20 to -44	-24 to -67

Precipitation Change Projections for the Buzzards Bay drainage basin (NECASC, 2018)

- The number of days with precipitation over 1 inch is expected to increase slightly annually, with winter showing the greatest increase of the four seasons (**Table 4**).
- The number of days with precipitation over 2 inches is not expected to increase substantially over the next century. Annually an increase of 0 to 1 day is expected by mid-century, and the same is expected by the end of the century. There is not expected to be an increase in the number of days with precipitation over 2 inches in any season by mid-century or the end of the century.

- The number of days with precipitation over 4 inches is not expected to increase annually or seasonally by mid-century or the end of the century.
- Total annual precipitation is expected to increase annually and in winter. Spring, summer and fall predictions are more variable**,** with the possibility of a decrease or an increase predicted (**Table 5**).
- The number of consecutive dry days is expected to increase slightly annually and in the fall. Winter, spring, and summer predictions are more variable (**Table 6**).

Table 4. Projected change in number of days with precipitation >1 inch (NECASC, 2018)

	Observed Baseline (number of days with precipitation >1")	Projected Change (number of days with precipitation >1")	
	1971-2000	Mid-Century	End of Century
Annual	8	+1 to +3	+1 to +4
Winter	2	0 to +1	0 to +2
Spring	2	0 to +1	0 to +1
Summer	2	0 to +1	0 to +1
Fall	2	0 to +1	0 to +1

Table 5. Projected change in total precipitation (NECASC, 2018)

	Observed Baseline Total Precipitation (inches)	Projected Change in Total Precipitation (inches)	
	1971-2000	Mid-Century	End of Century
Annual	47.8	+0.3 to +5.4	+0.3 to +6.8
Winter	12.6	0 to +1.9	+0.1 to +3.9
Spring	12.2	-0.1 to +2.2	+0.1 to +2.7
Summer	11.0	-0.9 to +1.5	-2.3 to +1.8
Fall	12.1	-1.0 to +1.5	-1.7 to +1.2

Table 6. Projected change in number of consecutive dry days (NECASC, 2018)

	Observed Baseline (number of consecutive dry days)	Projected Change (number of consecutive dry days)	
	1971-2000	Mid-Century	End of Century
Annual	17	0 to +2	0 to +4
Winter	10	-1 to +1	-1 to +2
Spring	11	-1 to +1	-1 to +1
Summer	14	-1 to +2	0 to +3
Fall	13	0 to +3	0 to +3

Streamflow

Streamflow patterns are closely linked to climatic factors such as precipitation, temperature and evapotranspiration and therefore may be impacted by climate change over the next century.

Alder and Hostetler (2013) developed climate change projections for Plymouth County for the period of 2050 to 2074 compared to the period of 1981 to 2010 under both medium and high emission scenarios. The results of the models indicate that there is expected to be a seasonal shift, with average monthly

runoff increasing slightly in winter and decreasing slightly in spring, but with no predicted change to overall annual runoff volumes.

A study by Demaria, Palmer and Roundy (2015) used climate models to predict changes to peak flow (3-day peak flow), low flow (7-day low flow) and mean baseflow in the Northeast and Midwest for the period of 2028-2082, compared to 1951-2005. While the results of the study show mixed results for the magnitude of 3-day peak flows in Southern New England, 7-day low flows in the area were generally predicted to decrease in magnitude. In addition, the frequency of days of peak flows and low flows is anticipated to increase, and that the length of the low-flow season (traditionally May 1st to October 31st) will extend under high emissions scenarios.

Streamflow patterns are complex and can be influenced by multiple factors including geology, topography, urbanization, groundwater as well as climate, making it difficult to predict exactly how streamflow patterns will change in Carver over the next 50 to 100 years. The results of the studies mentioned above indicate that streamflow patterns will become more variable as climate change progresses over the next century. The Town of Carver should be prepared for impacts associated with both increases and decreases in streamflow.

Drought

Increases in temperatures and variable predictions for summer precipitation totals in Buzzards Bay basin may lead to more frequent episodic droughts in Carver in the future (NECASC, 2018). Alder and Hostetler (2013) predict that the mean evaporative deficit (the difference between potential evapotranspiration and actual evapotranspiration) is expected to increase by 0 to 0.2 in/mo by mid-century (2050 to 2074), indicating that drought conditions may be more likely.

A study on the Plymouth-Carver-Kingston-Duxbury (PCKD) aquifer by Masterson et al. (2009) looked at the effect that a drought similar to the record-holding drought that occurred from 1963-1967 would have on water levels and streamflows under current (2005) and future (2030) pumping conditions.

Results of the study showed that under simulated drought conditions with current pumping conditions, water-levels within the PCKD aquifer are predicted to decrease by 0 to 1 feet throughout most of the Town of Carver, with isolated sections in the northern section of the Town experiencing a decrease of 1 to 4 feet, and a small portion of the central eastern section of Town experiencing a decrease of 4 to 6 feet.. The Weweantic River in Carver experienced a decrease in streamflow of about 50%, but water levels in areas within the vicinity of the river only decreased by less than 1 foot. The authors note that the presence of stream networks seemed to mitigate the reduction in water level in the areas within the vicinity of the stream. Compared to other areas of the aquifer, the Weweantic River watershed had the lowest predicted changes in water levels.

Figure 8 reflects the simulated groundwater drop in Carver as depicted in the Masterson study.

The study also found that pumping from large-capacity wells can result in decreases in down-gradient pond and streamflow levels. As the population continues to increase, groundwater withdrawals can also be expected to increase in the future. When coupled with the climate change impacts to temperature and precipitation, increased groundwater withdrawals may result in decreased surface water levels over the next 50 to 100 years.

Sea Level Rise

Coastal towns in Massachusetts are expected to see increases in relative mean sea level ranging from 4 to 10 feet by the end of the century (NECASC, 2018). Sea level rise has the potential to affect coastal aquifers by increasing the height of the water table, decreasing the depth to groundwater, increasing stream baseflow and causing saltwater intrusion. A study on the Cape Cod aquifer predicted that 6 feet of sea level rise may result in more than a 2-foot rise in water table altitude (Walter et al., 2016). Carver is approximately 8 miles from the coast and impacts of sea level rise on the PCKD aquifer have not been predicted, but the potential for the effects listed above exists.

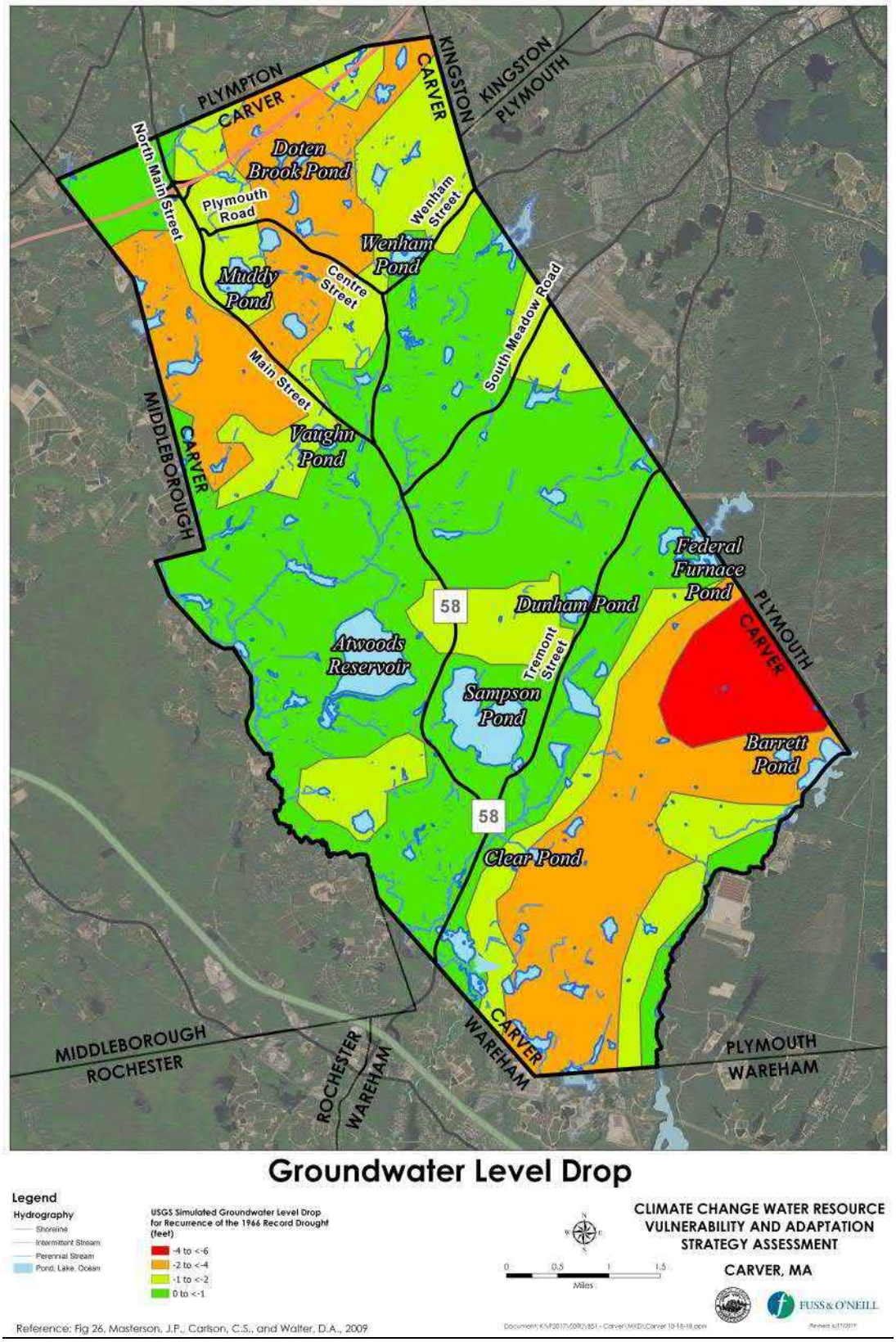


Figure 8. USGS simulated changes in groundwater level from average conditions for simulated drought conditions in October of 1966 with 2005 pumping rates.

Climate Change Impacts

Cranberries and Climate

The cranberry industry in Carver and through New England is vulnerable to the impacts of climate change. Cranberries require between 1000 and 2500 chill hours (accumulated hours between 32°F and 45°F) (Gareau et al., 2018) for successful bud development. The average winter temperature in the Buzzards Bay drainage basin from 1971 to 2000 was 31.3 °F (NECASC, 2018). Average winter temperatures are predicted to increase by as much as 9.8 °F by the end of the century. An increase in winter temperatures of this magnitude would dramatically decrease the number of available chill hours.

Seasonal freshwater flooding of the bogs in the fall, winter and spring to varying degrees is necessary for harvest and protection from frost and pests. The cranberry growers in the Town of Carver primarily use surface water from nearby ponds, swamps, or streams for this purpose. Increased annual and summer temperatures may result in an increased number of droughts. As reported above, a drought comparable to the record-holding drought of the 1960s could result in decreased water levels throughout the PCKD aquifer. Resulting competition for and depletion of surface and groundwater supplies may result in limited access to water for flushing the bogs. Increased temperatures may also result in a lengthened growing season. A lengthened growing season may result in increased flooding requirements for harvest and pest protection, thereby increasing the cost for the cranberry growers.

The Massachusetts Climate Adaptation Partnership has noted that the frost-free season is predicted to increase by 1 to 2 months in New England by the end of the century (University of Massachusetts Amherst, 2017). The average date of last frost in Massachusetts has gotten earlier, while average date of first frost in the fall has gotten later (University of Massachusetts Amherst, 2017). A longer frost-free season will result in extension of the growing season earlier in the spring and/or later in the fall. As the seasons shift, it can be expected that temperatures may fluctuate above and below freezing during the shoulder seasons. These fluctuations may result in frost damage to early spring buds.

Cranberry scald is a physical problem that affects the fruit of the plant. Scald is associated with high temperatures, low soil moisture, and high water demand (Croft, 1995). Climate change is predicted to cause an increase in the number of extremely hot days and the number of consecutive dry days in the Buzzards Bay Basin, which may result in increased incidences of scald. Increased temperatures may be also be favorable for pests that are detrimental to cranberries, including false armyworms, cranberry weevils and winter moths (Armstrong, 2016).

Wildfires and Climate

The Town of Carver may experience an increase in drought conditions over the next 100 years due to a combination of an increase in spring and summer temperatures, an increase in the number of extremely hot days and modest changes to current spring and summer precipitation patterns. Drought conditions reduce forest growth and increase susceptibility to pests and diseases, often leading to tree mortality. These conditions are favorable for wildfires and may result in more frequent wildfires in the future (USDA, 2017).

According to the Massachusetts State Hazard Mitigation and Climate Adaptation Plan, Massachusetts is currently likely to experience at least one wildfire a year (Massachusetts State Hazard Mitigation and Climate Adaptation Plan, 2018). Plymouth County is listed in the plan as one of two counties that are most vulnerable to wildfires due to vegetation, sandy soils and wind conditions (Massachusetts State Hazard Mitigation and Climate Adaptation Plan, 2018). The Town of Carver is adjacent to and also includes a

portion of Myles Standish State Forest[2], increasing the Town's vulnerability to wildfire risk from dead wood.

The Town of Carver uses surface water for firefighting. Wildfires are likely to occur during drought conditions, when surface water supply is likely to already be stressed. Large surface water withdrawals that would be required to fight a wildfire during drought conditions could negatively impact the cranberry industry, aquatic ecosystems, and recreational water access.

4 Prioritized Recommendations

A representative number of the approximately 150 firefighting water sources and the 216 active cranberry bogs in Carver were identified and evaluated in detail to better understand the nature of these sources, how they are used, what their shortcomings are, how the most recent significant drought in 2016 affected water availability and what measures could be implemented to improve their resiliency to anticipated climate change induced droughts in the future. The information gathered from this representative subset can be used to make town-wide recommendations for increased resiliency to drought.

Water sources were identified that represented the range of water supply types and sizes and cranberry farming activities in town in order to get as representative a sampling as possible. Craig Weston, Carver's Fire Chief, and Brian Wick, Executive Director of the Cape Cod Cranberry Growers Association were consulted to assist in the identification of the specific sources to be field visited and evaluated. Fifteen (15) Priority Fire Fighting Water Sources were identified out of an initial list of twenty (20) sources and five (5) Cranberry Farm Water Sources were identified for field evaluation.

The findings of the field evaluations, and further research into their vulnerability to drought, and ultimately the identification of improvement measures that can increase their resiliency to climate change drought, and drought in general, can be used to inform evaluation and management of the balance of the water sources in town. Information gathered in this study can also be used as a catalyst for other resiliency measures, for example, information gathered on anticipated declines in ground water levels could be utilized to identify residential wells that are most vulnerable in drought conditions.

Fire Fighting Water Sources

For Fire Fighting Water Sources (FF sources), specific improvements have been recommended for each of the 15 FF sources evaluated. Without having the detailed information for the balance of the FF sources in town, a simplified approach was developed to determine the magnitude of measures that would be required on a townwide basis to improve the resiliency of all of these sources. Since the 15 sources that were evaluated were to represent a sampling of all of the FF sources in town, the approach was to prorate the recommended measures for these 15 sources to the full number of FF sources in town. Cost estimates were developed for the range of resiliency measures that could be undertaken. There is uncertainty in the exact quantities of sediments to be removed, as well as the ultimate quality of this sediment and whether it can be reused on site or elsewhere with no restriction, or whether it has to be disposed of at a licensed disposal facility. Added to this uncertainty is that the town DPW crews are highly resourceful professionals who may be able to undertake some of these measures on their own without

[2] The State of Massachusetts is currently in the process of reviewing a fire management plan for the Myles Standish State Forest. When the plan is released to the public, it should be reviewed for additional climate change impacts to the Town of Carver related to wildfires.

the involvement of private construction contractors. That could result in a reduction in the estimated cost of implementing these improvements. None the less assumptions were made and a budget range for the implementation of resiliency measures at the 15 sites has been developed to account for some of the uncertainty. Similarly a rough estimate of the potential range of costs for making all 150 FF sources resilient was developed.

Cranberry Farm Water Sources

For the Cranberry Farm Water Sources (CF sources), a method for identifying potential recommended resiliency improvements has been developed as previously discussed. The potential recommended improvements for each farm would then be evaluated by the individual grower to determine, based upon many considerations known to the grower, which if any of the potential resiliency measures would be implemented. For purposes of estimating the cost of implementing these measures for a cranberry farm, it was originally proposed that several hypothetical farms scenarios would be developed and potential resiliency improvements would be assumed. Cost estimates would be developed for these improvements, and then would be applied on a prorated basis to the full number of cranberry farms in town. A range of costs would have to be developed for the hypothetical cases, since each farm differs in size, water demand and water management agreements with adjacent, upstream or downstream growers. It was recognized that this prorating a varying suite of hypothetical resiliency measures to all of the farms in town would provide a questionable range of potential costs to undertake these resiliency improvements. It was concluded that it was premature to attempt to develop cost estimates for resiliency measure implementation since too many unknowns exist that would reduce the accuracy and value of the estimates. Another approach has been recommended and will be discussed in more detail. Growers are highly resourceful professionals who can undertake substantial measures on their own without the involvement of private construction contractors. Similar to the FF sources, it is not clear now what level of resiliency measure implementation could be undertaken by, in this case, the growers. It is likely that their capability could result in a reduction in the cost of implementing these improvements.

Site Specific Recommendations

Fire Fighting Water Sources

The range of resiliency measures that could potentially be applied to the 15 Priority Fire Fighting Water Sources (FF Sources) were identified in Task 2 and consist of the following:

- **Fire Supplies (15 Water Supplies)**
    - Dredge ponds deeper to intercept groundwater levels as they drop in drought
    - Dredge larger area of pond deeper to provide the volume of storage needed for fire fighting
    - Remove aquatic plants and algae that obstruct water pumping activities
    - Provide adequate are for a minimum of two trucks to pump simultaneously to capitalize on the water sources that have the most water and to get the trucks as close as possible to the receding water's edge
    - While undertaking resiliency measures, seek opportunities for ecological enhancement including:
        - Removal of invasive species
        - Planting of emergency aquatic vegetation where it will not interfere with storage or pumping
        - Planting of bank and riparian area vegetation

The following table identifies the specific resiliency measures that are recommended for each of the 15 FF Sources.

Table 7. Priority Firefighting Water Supply Recommendations

Firefighting Water Source Recommendation Selection Tool
Municipal Vulnerability Preparedness Planning (MVP) Process
Town of Carver, MA

	Recommendations for Drought Resilience						Recommendations for Continuing Maintenance & Ecological Enhancement Opportunities			
Potential Resiliency Measure -->	**Dredge Firefighting Water Supply Sediment Bottom Minimum Area**	**Dredge Firefighting Water Supply Sediment Bottom Minimum Depth**	**Maintain Normal Water Levels At Higher Levels Where Control Structures Exist**	**Engage Private Property Owners or Residential Communities Where Water Supply Improvements are Planned**	**Continue to Engage the Farming Community**	**Identify Implementation Sustainable Funding Sources**	**Clear Banks of Vegetation**	**Remove Aquatic Vegetation**	**Planting Emergent Aquatic Vegetation**	**Remove Invasive Plant Species**
Fire Department Water Source	**Priority Level**									
DH 3-38	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority	Not Priority	Not Priority	Not Priority
W 1-1	Not Priority	Priority	Not Priority	Not Priority	Not Priority	Priority	Priority	Not Priority	Not Priority	Not Priority
W 1-25	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority
W 1-33	Priority	Priority	Not Priority	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority
W 1-5	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority	Not Priority	Not Priority	Not Priority
W 2-10	Not Priority	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority	Not Priority	Not Priority
W 2-12	Priority	Priority	Not Priority	Priority	Not Priority	Priority	Priority	Priority	Not Priority	Not Priority
W 2-19	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority	Not Priority	Not Priority	Not Priority
W 2-26	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority
W 2-28	Priority	Priority	Not Priority	Priority	Not Priority	Priority	Priority	Not Priority	Priority	Not Priority
W 3-19	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority
W 3-28	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority	Priority	Not Priority
W 3-35	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority	Priority	Priority	Priority
W 3-36	Not Applicable	Not Applicable	Not Applicable	Priority	Not Applicable	Priority	Not Applicable	Not Applicable	Not Applicable	Not Applicable
W 3-6	Priority	Priority	Priority	Priority	Priority	Priority	Priority	Not Priority	Priority	Not Priority

Note: All resiliency recommendations are based on water source infrastructure and surrounding agriculture infrastructure information available at the time.

Cranberry Farm Water Sources

The range of resiliency measures that could potentially be applied to the Cranberry Farm Water Sources (CF Sources) were identified in the Task 3 report (**Appendix H**) and are provided below. The potential resiliency measures are recommended for consideration for each CF Source based upon asking and answering the following questions followed by the recommended resiliency measure. An example was provided in Task 3 of a Hypothetical bog and how the potential resiliency measures are identified:

The potential resiliency measures are recommended for consideration for each CF Source based upon asking and answering the questions in **Table 8**.

Ecological Resiliency Opportunities

According to MassDEP, there are 17 inactive or abandoned cranberry bogs in Carver. It is not known what the long term plans are for these bogs, but in conversation with Brian Wick of the Cape Cod Cranberry Growers Association there are farmers who are seeking to expand their cranberry growing operations so some of these inactive bogs may be put back into production in the future. If it becomes apparent at some time in the future that these bogs will likely not come back into production for whatever reason, there may be opportunities to repurpose the bogs and partially or fully restore them to a natural wetlands/watercourse ecosystem. That is happening on a very limited basis in this region through the cooperation of former cranberry growers and the Massachusetts Department of Fish & Game, Division of Ecological Restoration (DER). DER can bring funding to implement these ecological restorations. It is not clear if there are opportunities to provide some CF Source resiliency measures in these ecological restoration projects that could benefit adjacent or downgradient farms during periods of extreme drought, but if the opportunity exists, it could be pursued with DER.

Table 8. Carver Agricultural Water Sources Resiliency Recommendations – Potential Measures Summary

Dredge to Remove Sediment or Increase Capacity	
Applicable Question	***Potential Resiliency Measure***
Has pond lost substantial storage volume due to sediment accumulation?	*Dredge accumulated sediments from storage ponds*
Has capacity of diversion channels diminished over time due to debris and or sediment accumulation?	*Remove debris from and dredge diversion channels to restore diversion capacity*
Is there room for existing pond to be expanded in surface area?	*Expand area of pond*
Is normal pond depth only 3 feet or did pond go nearly dry in 2016?	*Dredge accumulated sediment*
Is there room to excavate a new storage pond into groundwater?	*Over excavate to a 12 foot overall depth to intercept anticipated drought condition*
Has pond lost substantial storage volume due to sediment accumulation?	*Excavate new storage pond*
Augment With Groundwater	
Applicable Question	**Potential Resiliency Measure**
Are there locations for the drilling of a gravel packed well given proper setbacks from existing on site sanitary waste disposal systems or other wells or surface water sources that could be influenced by well drawdown?)	Drill wells
Increase Water Control Options	
Applicable Question	**Potential Resiliency Measure**
Are earthen berms or dams in poor condition (such as leakage, erosion, covered in trees, etc.) or in need of maintenance?	Repair earthen berm to reduce leakage and enhance stability and durability
Are flume board structures in poor condition (such as leakage, erosion, corrosion, covered in trees, etc.) or in need of maintenance?	Repair flume board structure to reduce leakage and enhance useful life
Are flume board structures sized properly?	Evaluate hydraulic adequacy of flume board structures
Can water level be raised without causing upstream flooding of infrastructure or bogs?	Raise water level with additional flume boards
Are water sources with surplus storage located downstream?	Install pumps and piping systems
Has capacity of existing well(s) diminished over time?	Restore original well capacity by redeveloping existing well(s) by appropriate methodology
Increase Water Conservation/Reuse	
Applicable Question	***Potential Resiliency Measure***
Are pipes or pumps leaking?	*Repair leaking pumps and pipes*
Are wet harvesting methods currently employed?	*Convert to dry harvesting*
Is water not currently recycled for reuse?	*Recycle water for reuse*
Is the Bog currently an Old type bog?	*Convert to New Type Bog*
Does site currently irrigate manually?	*Install autostart Irrigation Technology with temperature probes, and ultimately soil probes*
Water Sharing/Diversion	
Applicable Question	***Potential Resiliency Measure***
Are there water sources with known surplus as evidenced by 2016 drought in reasonably close proximity?	*Seek shared water sources*
Are water sources with surplus storage located upstream?	*Install diversions*

Town-wide Recommendations

Firefighting Water Sources

The cost of making the firefighting water sources (FF Sources) resilient to drought is substantial. Making a FF Source resilient such that it can still be an adequate source of water during the occurrence of a 1966 magnitude drought could be on the order of $96,000 to $146,000 in 2019 dollars depending upon the disposal requirements for the accumulated sediments. Making a FF Source resilient for a drought of the 50 year or 2016 magnitude drought could be on the order of $80,000 to $100,000, again depending upon sediment disposal requirements. If one assumes an average cost of $90,000 to make a FF Source resilient to drought, then making all 150 FF Sources in Town resilient would cost on the order of $13.5 million 2019 dollars. This is not a cost that could reasonably be accommodated by the Town of Carver. A more strategic approach to improving FF Source resiliency to drought is recommended as described below.

The Carver Fire Department has identified 15 critical FF Sources that it relies upon regularly. These 15 sources were evaluated as part of this study. In the very cold winter months when most of the 150 FF Sources develop ice cover, the Carver Department of Public Works keeps the thick ice broken at those 15 critical FF Sources. In the cold winter months the Fire Department plans it responses to fire calls knowing that they may only have those 15 sites readily available for rapid response if dense ice covers the balance of the FF Sources. Understanding that the Fire Department has a methodology in place to work around those potential limitations of source availability, a plan to improve drought resiliency has been developed that similarly focuses on those 15 critical FF Sources.

This study has developed several tools for use by the Town in developing a drought resilience strategy. They include:

- Mapping of FF Sources (**Figure 11**)
- Prioritization for FF Sources Resiliency Measures Tool
    - Vulnerability Index (**Table 9**)
    - Prioritization Tool (**Table10)**
- 1966 Simulated Drought (Drought of Record) Ground Water Level Drop Mapping Showing FF Sources (**Figure 12**)
- 1966 Simulated Drought (Drought of Record) Ground Water Level Drop for Each FF Source (**Table 11**)

The following Townwide Fire Fighting Water Sources Resiliency Plan (**Figure 10**) is recommended.

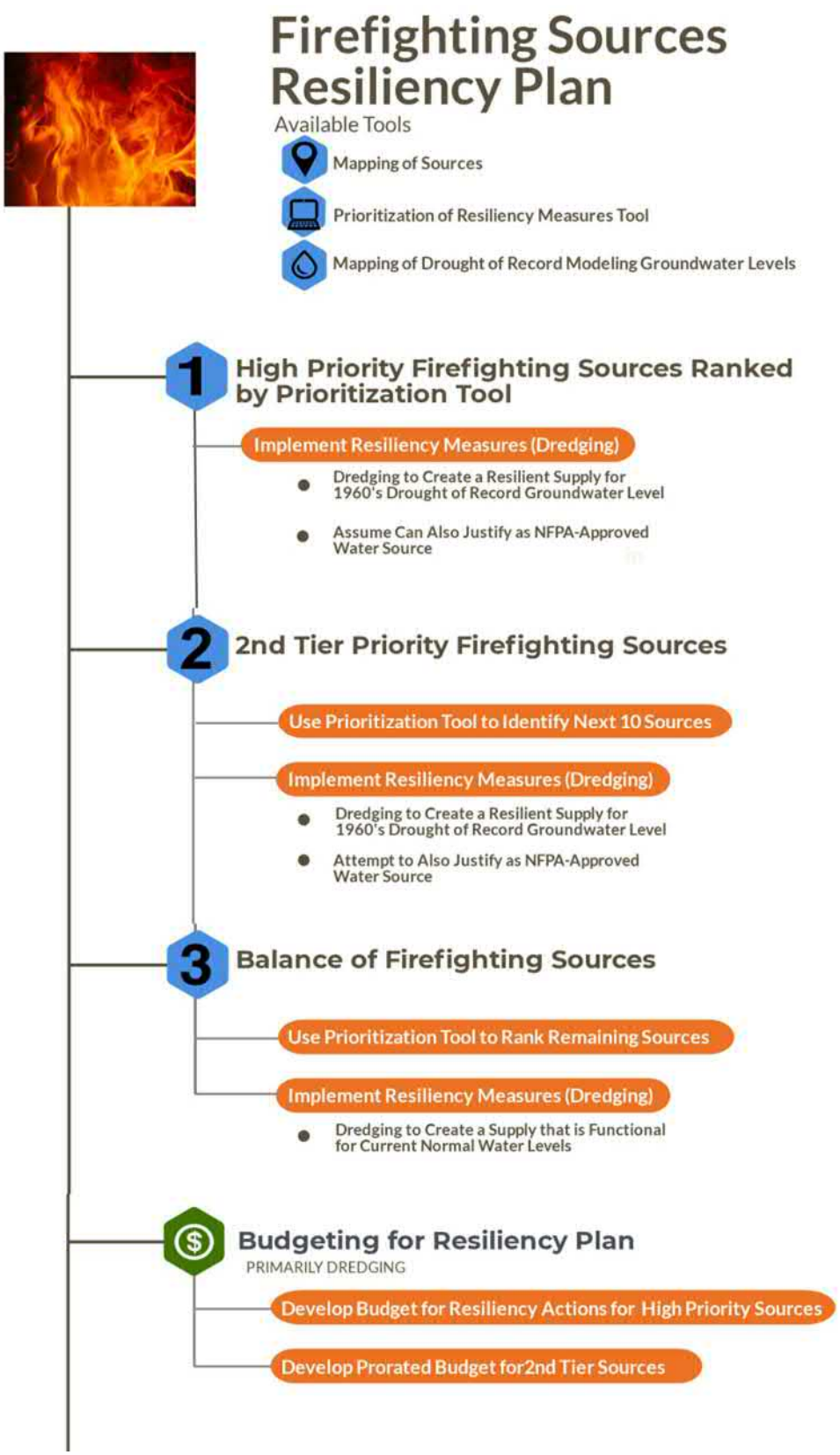


Figure 10. Firefighting Sources Resiliency Plan

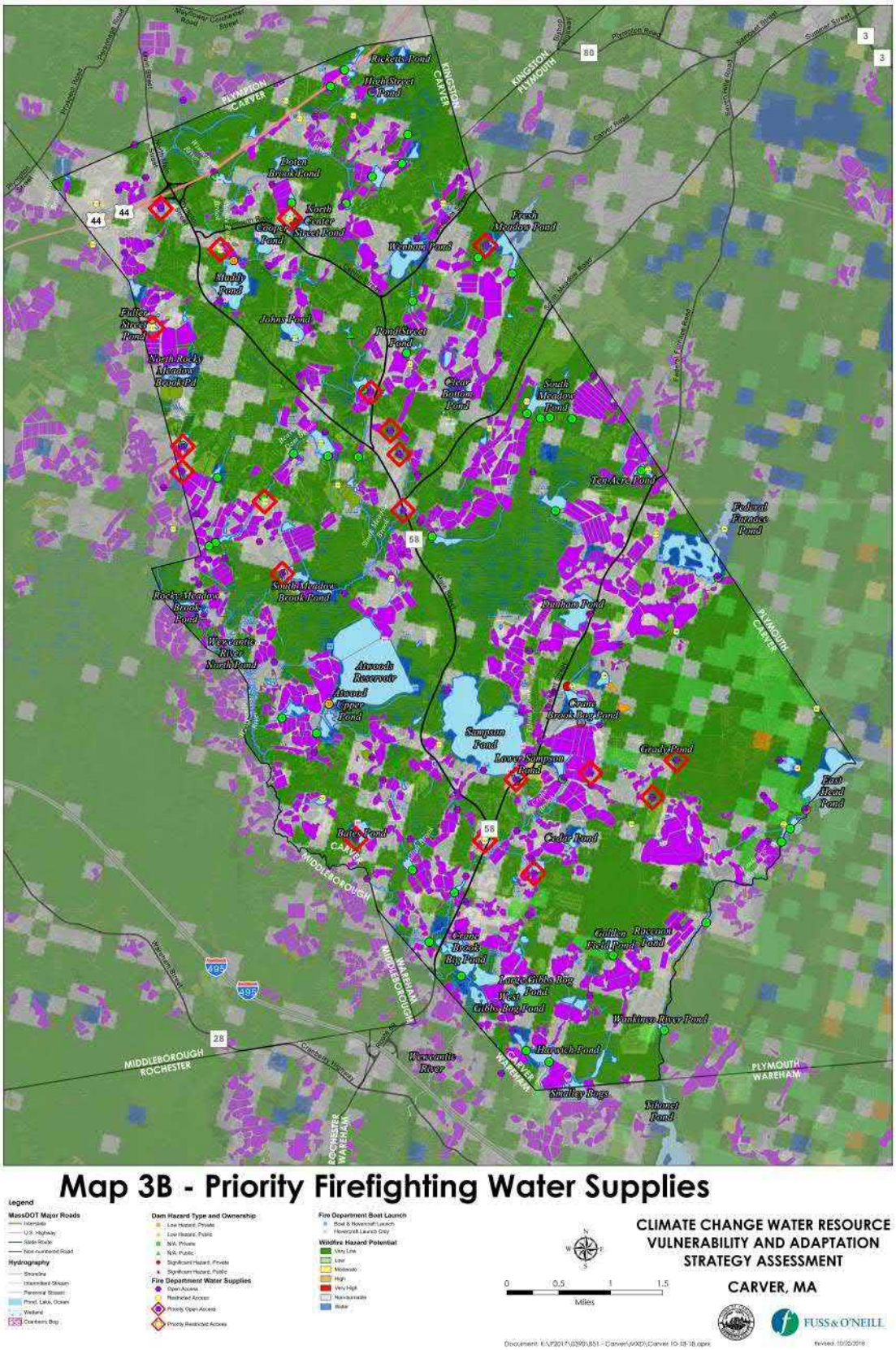


Figure 11. Priority Firefighting Water Supplies

Table 9. Calculated SpDVIF for Priority Fire Department Water Supplies

Fire Department Water Supplies	Descriptive Location (Street or Water Source)	SpDVIF
W 2-10	Muddy Pond Brook	10.00
W 2-12	Shaw's Grocery Store	10.00
W 2-26	Fuller Street Pond	10.00
W 3-6	Bates Pond	10.00
W 3-28	Clear Pond	8.33
W 1-25	Beaver Dam Brook	6.67
W 1-5	Old Center Street	6.67
W 3-19	Lower Sampson Pond	6.67
W 1-1	Route 58 Bridge	5.00
W 2-19	Leland Way	5.00
W 3-35	Sampson Pond	5.00
W 1-33	South Meadow Brook Pond	5.00
DH 3-38	Grady Pond	3.33
W 2-28	North Center Street Pond	3.33
W 3-36	Cranberry Road	0.00

Table 10. Firefighting Water Supply Prioritization Results

Water Supply Site Identifier	Descriptive Location (Street or Water Source)	Domain #1: DVI Score (0-10)	Domain #2: Implementation Score (0-10)	PRIORITIZATION SCORE (MAX = 20)	PRIORITIZATION SCORE (0-10)	PRIORITY RATING High (Dark Green) Medium (Light Green) Low (Gray)
W 3-6	Bates Pond	10.00	9.64	19.64	10.0	10.00
W 2-12	Shaw's Grocery Store	10.00	6.43	16.43	7.4	7.43
W 2-26	Fuller Street Pond	10.00	3.57	13.57	5.1	5.14
W 1-1	Route 58 Bridge	5.00	8.21	13.21	4.9	4.86
W 3-28	Clear Pond	8.33	4.64	12.98	4.7	4.67
W 2-19	Leland Way	5.00	6.07	11.07	3.1	3.14
W 1-33	South Meadow Brook Pond	5.00	6.07	11.07	3.1	3.14
W 2-10	Muddy Pond Brook	10.00	0.00	10.00	2.3	2.29
W 3-36	Cranberry Road	0.00	10.00	10.00	2.3	2.29
W 1-25	Beaver Dam Brook	6.67	3.21	9.88	2.2	2.19
W 3-19	Lower Sampson Pond	6.67	2.86	9.52	1.9	1.90
W 1-5	Old Center Street	6.67	2.50	9.17	1.6	1.62
W 2-28	North Center Street Pond	3.33	5.00	8.33	1.0	0.95
DH 3-38	Grady Pond	3.33	4.64	7.98	0.7	0.67
W 3-35	Sampson Pond	5.00	2.14	7.14	0.0	0.00

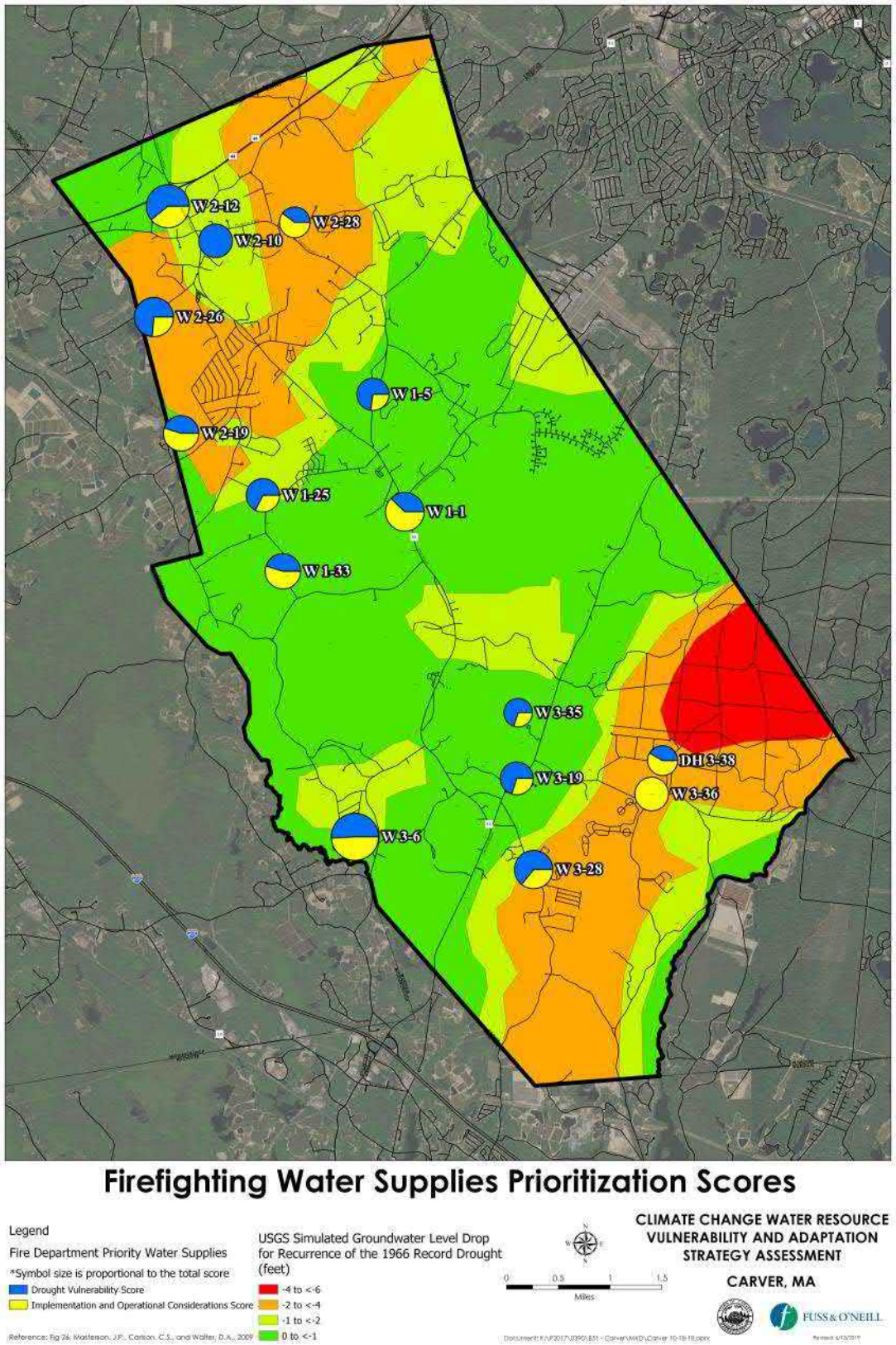


Figure 12. Priority Firefighting Water Supplies Prioritization Scores and USGS Simulated Groundwater Level Drop

Table 11. USGS Simulated Groundwater Drop for each Priority Firefighting Water Supply

Water Supply Site Identifier	Descriptive Location (Street or Water Source)	USGS Simulated Groundwater Level Drop for Recurrence of the 1966 Record Drought (ft)	Maximum USGS Simulated Groundwater Level Drop for Recurrence of the 1966 Record Drought (ft)
DH 3-38	Grady Pond	-2 to <-4	-4
W 1-1	Route 58 Bridge	0 to <-1	-1
W 1-25	Beaver Dam Brook	0 to <-1	-1
W 1-33	South Meadow Brook Pond	0 to <-1	-1
W 1-5	Old Center Street	0 to <-1	-1
W 2-10	Muddy Pond Brook	-1 to <-2	-2
W 2-12	Shaw's Grocery Store	0 to <-1	-1
W 2-19	Leland Way	0 to <-1	-1
W 2-26	Fuller Street Pond	-2 to <-4	-4
W 2-28	North Center Street Pond	-2 to <-4	-4
W 3-19	Lower Sampson Pond	0 to <-1	-1
W 3-28	Clear Pond	-2 to <-4	-4
W 3-35	Sampson Pond	0 to <-1	-1
W 3-36	Cranberry Road	-2 to <-4	-4
W 3-6	Bates Pond	-1 to <-2	-2

Source: Fig 26, Masterson, J.P., Carlson, C.S., and Walter, D.A., 2009

First Tier Priority FF Sources

- The 15 High Priority FF Sources identified by the Town and field investigated as part of this study should undergo the recommended resiliency measures in the priority order as determined by the Prioritization Tool (**Table 10**). Recommended implementation measures to be undertaken are identified in **Table 7**. In almost all cases the resiliency measures include dredging to increase the area and depth of the FF Source. The FF Source should be dredged such that it will be an effective water source with sufficient volume available during an occurrence of the 1966 drought. The depth of dredging anticipated to be sufficient to accommodate the 1966 groundwater level drop as indicated on **Table 11.** The assumption based upon research with the National Fire Protection Association (NFPA) is that this level of resiliency will assure adequate volume and flow to be available during the occurrence of the 50 year drought as defined by NFPA and that the FF Source can be considered an NFPA Approved Water Source. An NFPA Approved Water Source designation attests to the insurance industry that this water source has a high level of reliability for a particular level of fire fighting flow. It results in lowered fire insurance premiums if this level of fire source water reliability can be attained, since it means that sufficient water exists to minimize the potential for catastrophic fire losses.

Second Tier Priority FF Sources

- The Prioritization Tool will be utilized to identify the next 10 highest priority FF Sources in Town. The Town had initially identified 20 First Tier Priority FF Sources that were shortlisted to 15. Those remaining 5 may well be amongst the 10 Second Tier Sources identified utilizing the Prioritization Tool. These 10 FF Sources should be evaluated for and undergo recommended resiliency measures in the order as determined by the Prioritization Tool. The implementation measures should be identified in the same manner as with the 15 First Tier Priority FF Sources. Each FF source should be dredged such that it will be an effective water source with sufficient volume available during an occurrence of the more severe of the 2016 drought or the 50 year drought as defined by the NFPA. If it is determined that the 1966 drought is a sufficient surrogate for the NFPA 50 year drought, then the depth of dredging will be sufficient to accommodate the 1966 groundwater level drop as indicated on **Table 11**.

Balance of FF Sources

- The Prioritization Tool will be utilized to rank the priority of the remaining FF Sources in Town. Maintenance measures are recommended at all of these sites in the order in which they have been prioritized. The Maintenance measures will consist of removal of accumulated sediments down to the original pond bottom elevations, removal of brush, aquatic vegetation and algae that has grown in the pond since it was originally constructed and that blocks the minimum area required for pumping. Clearing of brush that has become overgrown should be undertaken to provide sufficient access area for fire trucks. The intent of this maintenance is to restore the FF Source such that it is a functional FF Source for current normal water level ranges throughout the season. Where invasive species have been identified, part of the maintenance restoration could include eradication and control of invasive species colonization.

- Budgeting For The Townwide FF Sources Resiliency Plan
    - Resiliency Measures
        - Budgets were developed for all 15 First Tier Priority FF Sources to be made resilient as recommended. The excavation associated with enlarging and/or deepening the FF Sources will require permits since this activity is more than maintenance dredging. Field bathymetric survey, locating wetland boundaries,

development of a base map and development of a design plan with details will be required for permits from the Conservation Commission and any additional agencies with regulatory authority. It is assumed that this level of new design, permitting and construction would have to be undertaken by consultants and construction contractors retained by the Town.

- Based upon the recommended measures, cost estimates have been developed and are found in **Appendix B**. The total estimated cost for making the 15 High Priority Sources resilient to drought ranges from $900,000 to $2,560,000 in 2019 dollars. The range represents unrestricted versus restricted sediment removal. It is anticipated, that based upon the screening level sediment sampling that was undertake, that at least some of the sediments would be restricted for disposal or reuse. Based upon this, it is recommended that the budget be on the order of $1,700,000.

- A budget range was developed for an assumed number of 10 Second Tier Priority FF Sources to be made resilient. The resiliency measures are assumed to be the same type recommended for the First Tier Priority FF Sources. The excavation associated with enlarging and/or deepening the FF Sources will require permits since it could not be considered strictly maintenance dredging. Field bathymetric survey, locating wetland boundaries, development of a base map and development of a design plan with details will be required for permits from the Conservation Commission and any additional agencies with regulatory authority. It is assumed that this level of new design, permitting and construction would have to be undertaken by consultants and construction contractors retained by the Town.
  - Cost estimates were developed simply as a range by prorating against the range of cost provided for the 15 First Priority FF Sources. This may be conservative, since it may be found that the NFPA 50 year drought requirements are closer to the 2016 drought groundwater level drop and therefore less sediment excavation would be required in that case for some of the 10 Second Tier FF Sources. The range was prorated to be $600,000 to $1,700,000 (See cost estimation spreadsheets in **Appendix B**). Understanding that this may be conservative, the recommended prorated budget to carry should be less on a prorated basis than that recommended for the 15 First Tier Priority sources. The total estimated cost for making the 10 Second Tier Priority FF Sources resilient to drought is approximately $1,115,000 in 2019 dollars.

- A budget for the maintenance of the balance of the FF Sources (125 Sources) was not developed since it was understood that this is part of the Town's ongoing maintenance of their FF Sources. This maintenance work is assumed to be within the capability and purview of the Fire Department and the Department of Public Works. This work will be undertaken on an as needed basis as the staffing and equipment is available to undertake the work and the construction effort can be undertaken within the current operational budget for the Town of Carver. Additional costs associated with disposal sediments is not currently covered under a Carver budget item, and would need to be budgeted for on an

annual basis to allow the maintenance restoration of the FF Sources over several years. Once the First Tier and Second Tier FF Sources are improved to meet climate change drought resiliency as recommended, the cost of managing sediments as well as the production capability of the two departments to take on this work will be much better understood. Much more accurate budgets can be developed at that time.

Cranberry Farming Water Sources

The Cranberry industry in Carver is critical to the economic success of the Town. The Cranberry industry represents the major employer in Carver and therefore contributes substantially to the health of the local economy. It is important that the Carver's cranberry growers are given the tools to make their farms resilient to the anticipated increase in drought frequency and severity associated with climate change. **Figure 13** outlines the general approach to implementing resiliency measures.

This study has developed several tools for use by the growers in developing a drought resilience strategy for their Cranberry Farm Water Sources (CF Sources). They include:

- Mapping of CF Sources (**Figure 14**)
- Potential Resiliency Measure Identification Tool (**Table 12**)
- 1966 Simulated Drought (Drought of Record) Ground Water Level Drop Mapping Showing CF Sources (**Figure 15**)

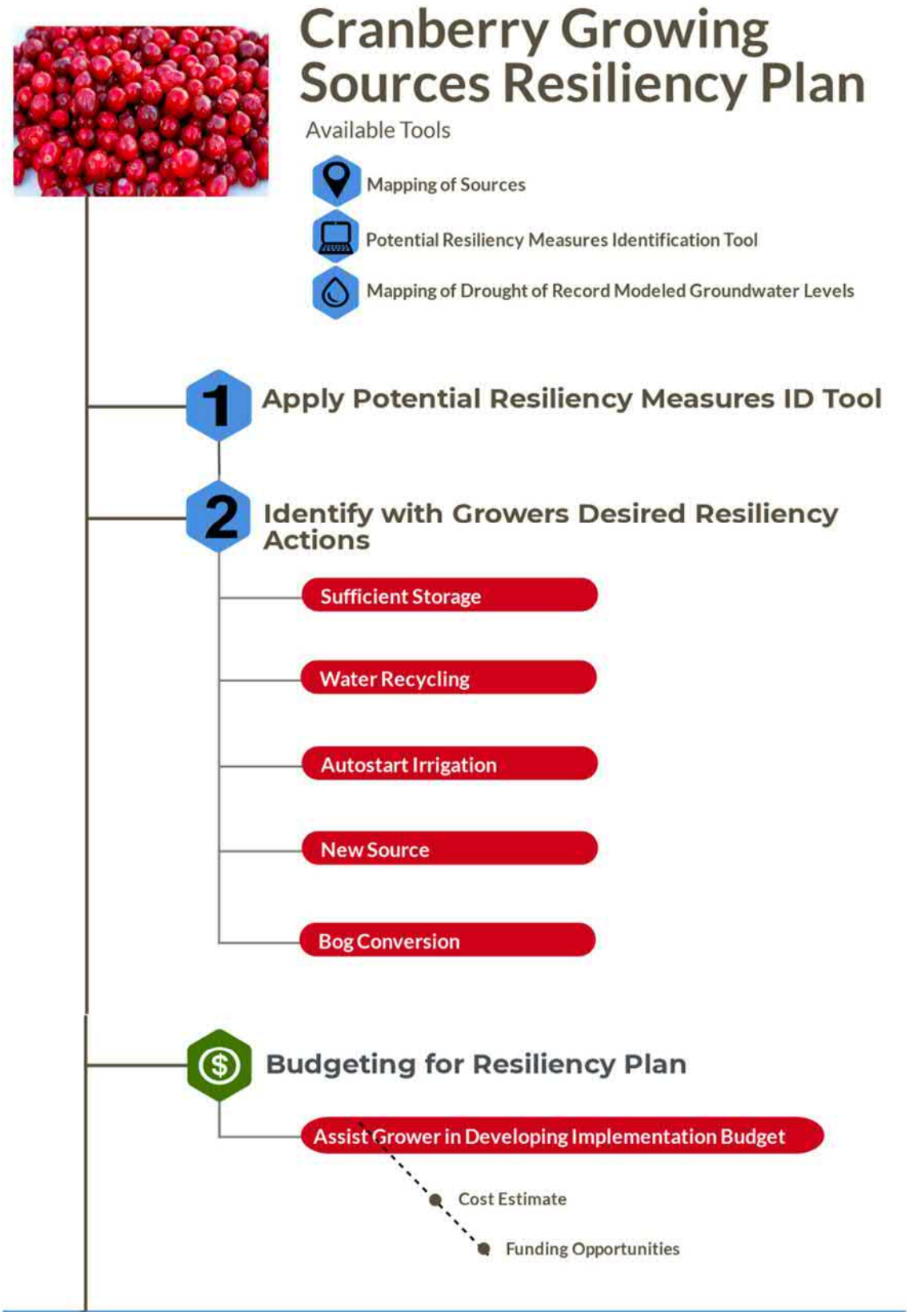


Figure 13. Cranberry growing sources resiliency plan

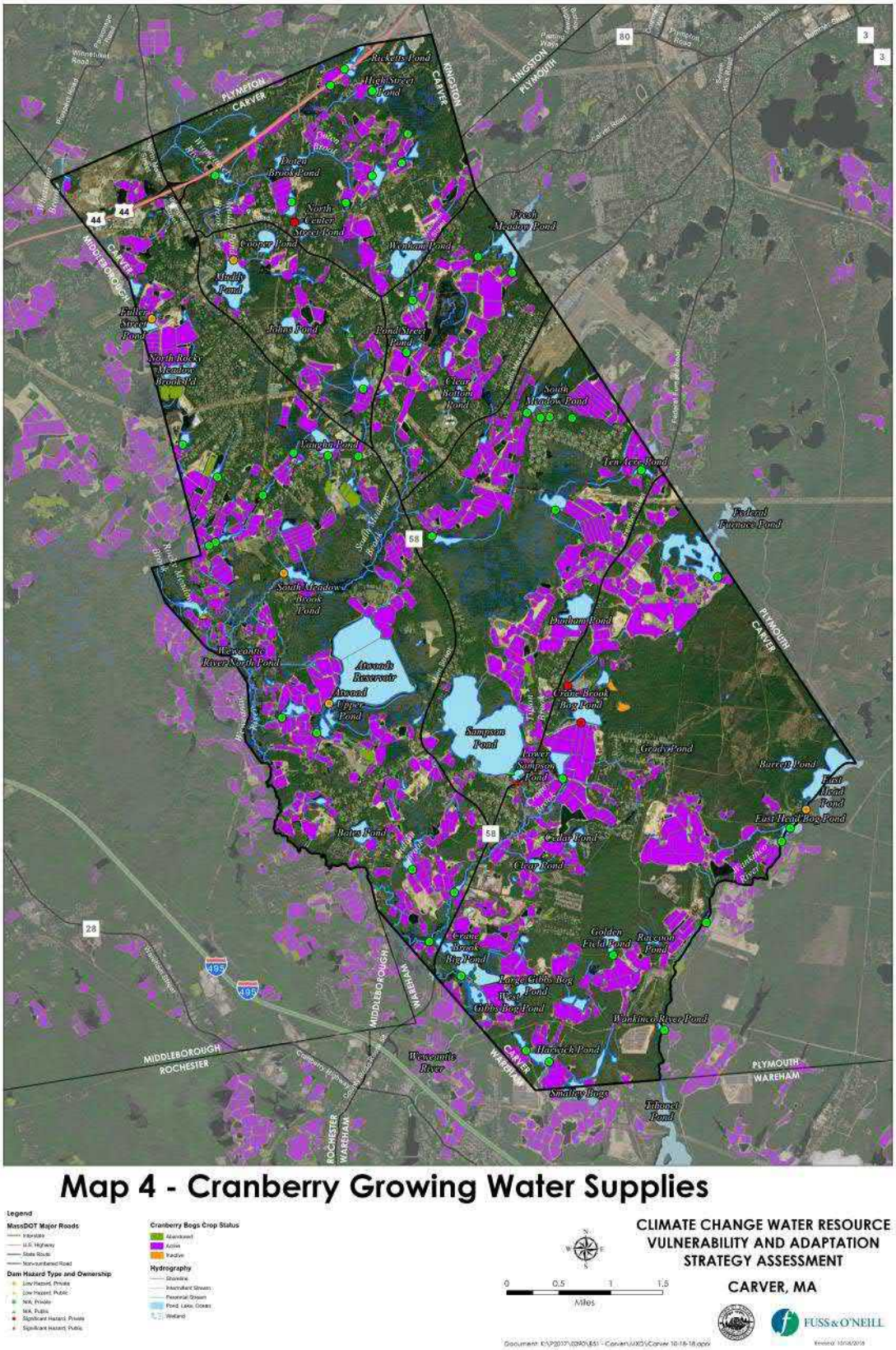


Figure 14. Cranberry Growing Water Supplies

Table 12. Cranberry Bog Water Source Resiliency Recommendations

Cranberry Bog Name: Hypothetical Bog		Potential Resiliency Measure															
Potential Resiliency Measure -->		Dredge accumulated sediments from storage ponds	Remove debris from and dredge diversion channels to restore diversion capacity	Expand area of existing pond	Over excavate pond to a 12 foot overall depth to intercept anticipated drought condition groundwater levels	Excavate new storage pond	Drill new well	Repair earthen berm to reduce leakage and enhance stability and durability	Repair flume board structure to reduce leakage and enhance useful life	Raise water level with additional flume boards	Install pumps and piping systems	Restore original well capacity by redeveloping existing well(s) by surging, hydrofracturing, or defouling.	Repair leaking pumps and pipes	Develop back up provisions for dry harvesting	Recycle water for reuse	Seek shared water sources	Install diversions
Applicability	**Response**	**Priority Level**															
Has pond lost substantial storage volume due to sediment accumulation?	(•) Yes ( ) No	Priority															
Has capacity of diversion channels diminished over time due to debris and or sediment accumulation?	(•) Yes ( ) No		Priority														
Is there room for existing pond to be expanded in surface area?	( ) Yes (•) No			Not Priority													
Is normal pond depth only 3 feet or did pond go nearly dry in 2016?	(•) Yes ( ) No				Priority												
Is there room to excavate a new storage pond into groundwater?	( ) Yes (•) No					Not Priority											
Are there locations for the drilling of a gravel packed well given proper setbacks from existing on site sanitary waste disposal systems or other wells or surface water sources that could be influenced by well drawdown?	( ) Yes (•) No						Not Priority										
Are earthen berms or dams in poor condition (such as leakage, erosion, covered in trees, etc.) or in need of maintenance?	(•) Yes ( ) No							Priority									
Are flume board structures in poor condition (such as leakage, erosion, corrosion, covered in trees, etc.) or in need of maintenance?	( ) Yes (•) No								Not Priority								
Can water level be raised without causing upstream flooding of infrastructure or bogs?	( ) Yes (•) No									Not Priority							
Are water sources with surplus storage located downstream?	( ) Yes (•) No										Not Priority						
Has capacity of existing well(s) diminished over time?	( ) Yes (•) No											Not Priority					
Are pipes or pumps leaking?	( ) Yes (•) No												Not Priority				
Are wet harvesting methods currently employed?	(•) Yes ( ) No													Priority			
Is water not currently recycled for reuse?	(•) Yes ( ) No														Priority		
Are there water sources with known surplus as evidenced by 2016 drought in reasonably close proximity?	( ) Yes (•) No															Not Priority	
Are water sources with surplus storage located upstream?	( ) Yes (•) No																Not Priority

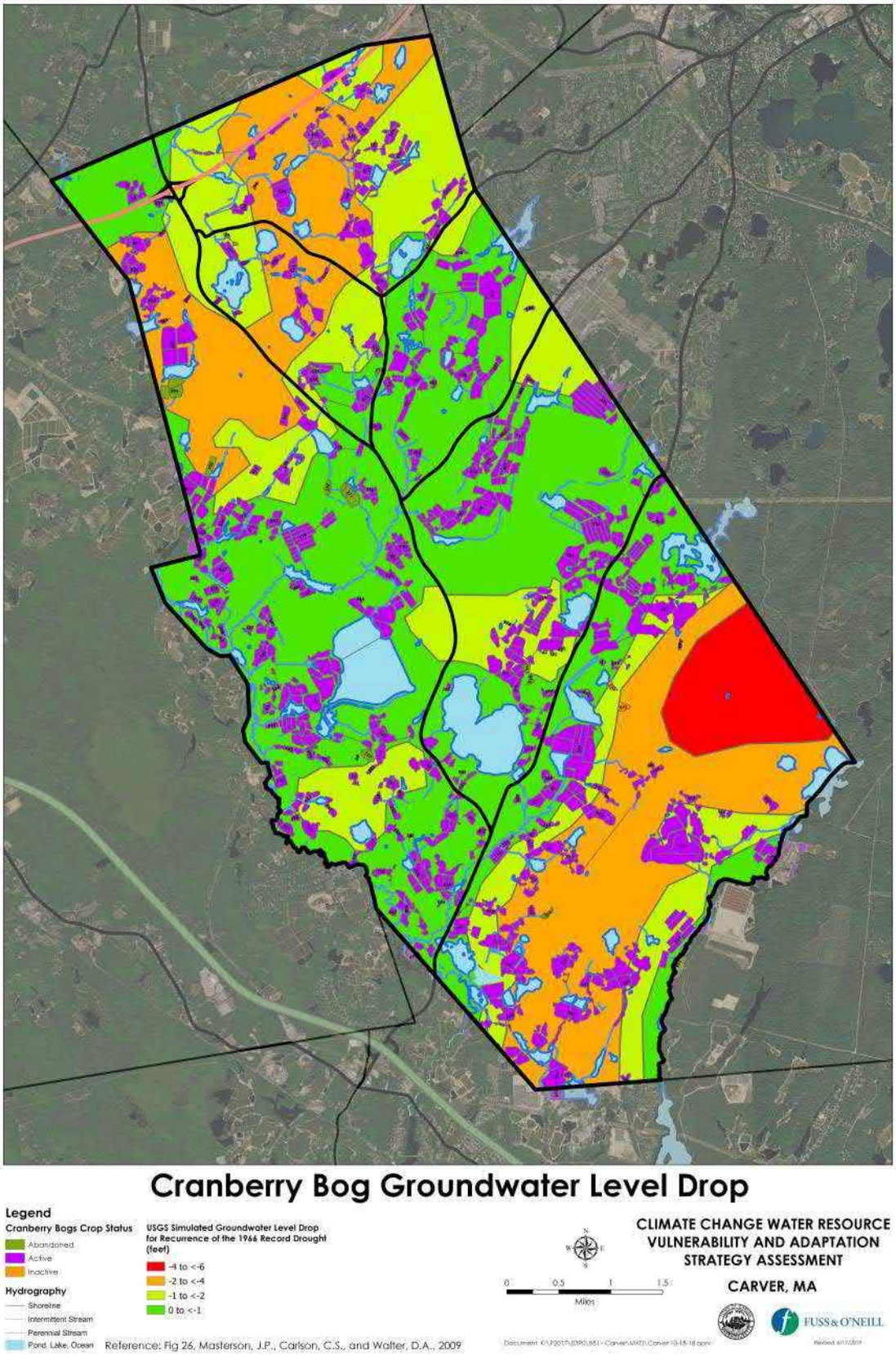


Figure 15. Cranberry Bog Water Supply USGS Simulated Groundwater Level Drop

The Potential Resiliency Measure Identification Tool will assist a grower in determining what resiliency measures might apply to their farm. The grower would then need to determine which if any resiliency measures they wish to implement given information that is not readily available at this time, but that is known to them. Once they determine which measures they believe are applicable, it will then be possible to determine a cost associated with the implementation of those measures for each farm.

For the Town to develop a plan that might provide funding assistance to the growers in the implementation of those resiliency measures, it would be helpful for a prioritization methodology to be developed. For all of the farms whose growers wish to implement resiliency measures and seek financial assistance from the Town who in turn can seek grants through the MVP Action Grant program, the Town could look to prioritize those farms that would appear to be the most vulnerable to drought as they currently exist.

The priority of resiliency measure implementation could be related to the current resiliency of the CF Source for each farm. This could relate to the current depth and volume of the CF Source as compared to the 1966 Ground Water Level Drop mapping that has been developed. This represents a relative vulnerability of the CF Sources to drought based upon the degree of impact anticipated from a recurrence of this record drought in the Northeastern United States, and certainly in the Carver area. Dual use of the CF Source as a FF Source could also be considered in the prioritization.

Sufficient Storage

A CF Source would need to show that it has an adequate volume for wet harvest and for frost protection flooding to be undertaken during the occurrence of a drought of the magnitude of the 1966 drought. If it was determined for instance that a CF Source does not have adequate storage volume for critical farm operations, then options for increasing the storage volume by over excavating the depth of the source should be evaluated. If the source cannot be made resilient by over excavating for an event of this magnitude, then other resiliency measures would need to be implemented. The storage should be provided below the level of the 1966 ground water drop level to be considered sufficiently resilient. The 50 year drought level or the 2016 level drought as previously discussed with the FF sources, should be seen as an absolute floor for resiliency measures.

Water Recycling

Water recycling resiliency measures should be evaluated. The capture of water from the most downgradient bog and the pumping back to the head pond for storage and ultimately reuse would reduce the demand for water overall. If it is found not to be feasible or would not provide a sufficient reduction in water demand to make the farm water resilient, then other resiliency measures should be evaluated.

Autostart Irrigation

Autostart irrigation technology can help to reduce the demand for water and should be evaluated next as a potential resiliency measure. The autostart technology currently relies on temperature monitors, but there is great promise for the use of soil moisture monitors to help substantially reduce the demand for irrigation water. Any farm having autostart technology installed should have the equipment flexibility to add soil moisture monitors at some point in the future as that technology becomes more reliable. If autostart technology is already being utilized and it is believed that the farm may still not have the level of resiliency to withstand the ground water level drop associated with the 1966 drought, then more substantial remedial measures should be considered.

New Source

The expansion of an existing or installation of a new CF Source, whether surface water or well, would be evaluated to determine if it would to attain the necessary depth and/or flow to be considered resilient by storing the requisite volume of water or having access to the flow required for the critical farm operations. This could involve the expansion of an existing natural swamp area, the excavation of a new pond, or the installation of a new well. All of these sources would be designed to assure the adequate volume of water be available for critical farm operations during the occurrence of a drought of the magnitude of the 1966 drought. The installation of a new diversion would need to be made from a source that can be clearly shown to have the resiliency to the groundwater level drop of a significant drought. Surface water will be at very short supply during a major drought and again the bulk of the available water will be from stored water that has depths substantially below the ground water level drop of that significant or very severe drought. Consideration of potential impacts to adjacent property water supplies (well or surface water) would also need to be evaluated.

Bog Conversion

The long term goal for many cranberry farmers is to eventually convert their cranberry farms from old style bogs to new style bogs. This is a very disruptive and very expensive process that will take the bogs being converted out of production for many years. It does however provide the ability to grow and harvest the cranberry crop with a substantially reduced demand for water, and with a much higher level of control of the use of fertilizers and other agricultural chemicals such as pesticides and herbicides. Again the cost is so substantial that has dissuaded or prevented many growers undertaking that conversion. For some farms that may have CF Sources that are very vulnerable to drought, and where the typical resiliency measures are quite expensive to implement, or where many are not possible to implement, the cost of converting to a new type bog in comparison may not seem that substantial, or the conversion may be the only effective alternative in providing sufficient water resiliency. In those circumstance, it could be found that for a relatively small additional cost, the farm can be converted to the new type bog. An evaluation should be made on each farm as to how vulnerable it is to drought, what the potential resiliency measures are, what resiliency measures are feasible, what they would cost, and how resilient they would make the farm. At that time a comparison could be made to the cost of making the farm resilient to drought with the implementation of resiliency measures found feasible, versus the cost of converting the farm from old to new type bogs.

5 Conceptual Design Recommendations

Fire Fighting Water Sources Conceptual Design Recommendations

Conceptual resiliency measures have been developed for the Fire Fighting Water Sources (FF Sources) to reflect the major measures that have been recommended for improving the resiliency of these sources to anticipated drought associated with climate change.

The resiliency measures for the FF Sources consist of a number of measures that make the source more resilient to the lowered ground water levels anticipated with drought, and make the site more accessible to critical equipment needed for firefighting. These measures include dredging accumulated sediments to deepen pond bottoms, dredging sediments to create a volume of storage large enough for immediate firefighting needs, space for fire trucks to get access to the water, particularly more important as the water level recedes the trucks need to be as close as possible to the water's edge. The opportunities for ecological habitat enhancement may exist and should be implemented along with the resiliency measures. These are of minimal cost, but will help increase the habitat value of the water source through selective

removal and/or elimination of invasive species. The resiliency measure for FF Sources will consist of these three major components:

- Pond Dredging and installation of dry hydrant to provide sufficient water
- Fire Truck accommodation by clearing vegetation and providing a travel surface
- Ecological Enhancement (Emergent vegetation and/or Riparian Area planting)

The following figures reflect the several levels of drought resiliency that have been considered related to the ground water level drop that is predicted to occur for severe drought. In addition, measures that have the potential to improve on the ecological health and value of these water sources are provided on the plans as well.

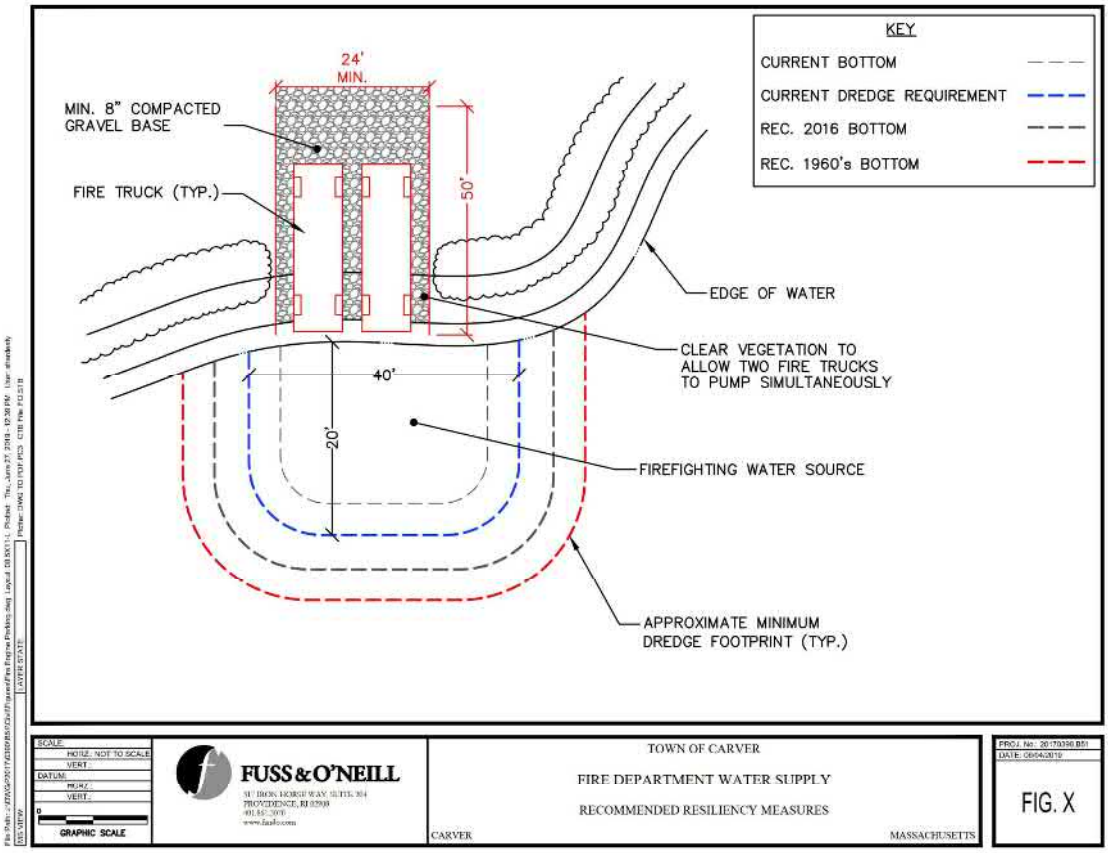


Figure 16. Fire fighting water supply recommended resiliency measures (plan view)

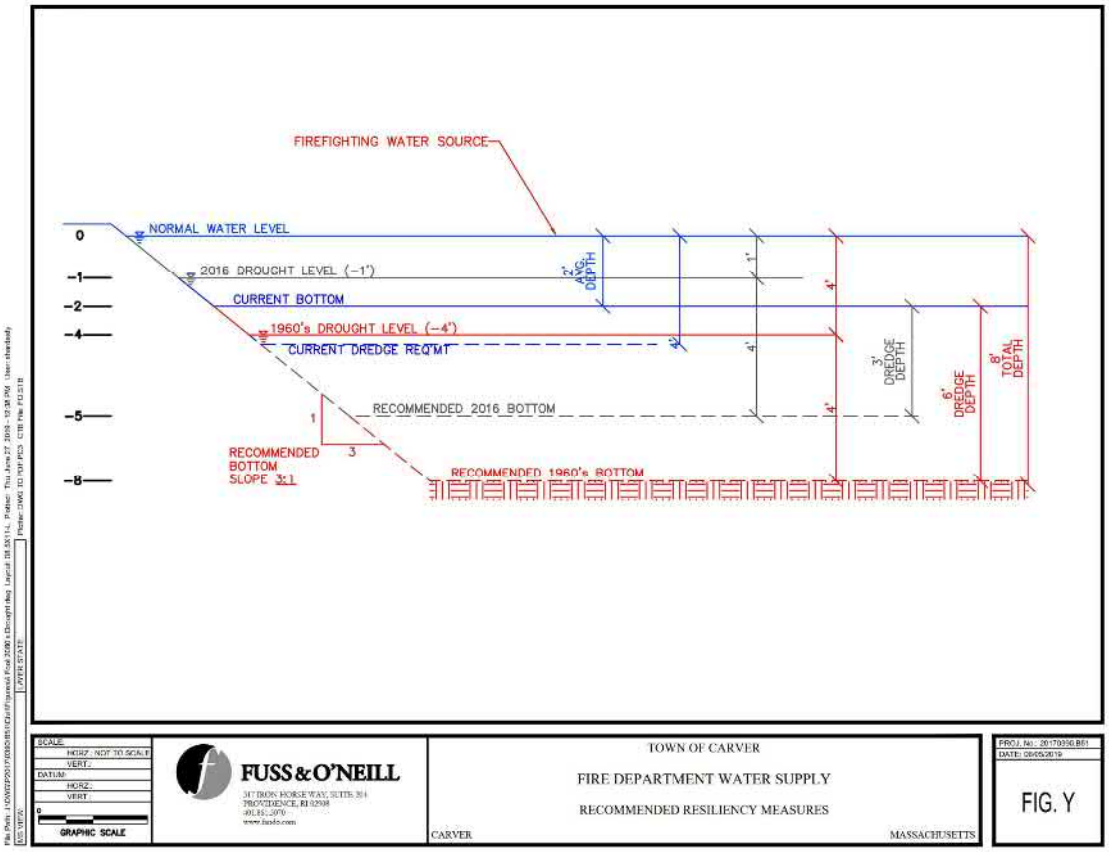


Figure 17. Fire fighting water supply recommended resiliency measures (profile view)

The major objective of the conceptual design measures is to make the FF Source more resilient by deepening the source to better be able to intercept the depressed groundwater levels that occur during drought conditions. Based upon available USGS groundwater level simulations for severe drought conditions, a recurrence of the 1966 record drought, mapping has been developed that reflects the potential degree of groundwater level drop across Carver. The conceptual design recommendations were tailored to reflect the anticipated level of groundwater drop affecting each individual FF Source. The deeper the anticipated groundwater level drop, the deeper the recommended depth to bottom of the FF Source, which generally translates to the greater the depth of sediment excavation.

Cranberry Farm Water Sources Conceptual Design Recommendations

Conceptual resiliency measures have been developed for the CF Sources to reflect the major measures that have been recommended for improving the resiliency of these sources to anticipated drought associated with climate change. A range of resiliency measures have been identified and described in the Task 3 report (**Appendix H**), and they are graphically exhibited in **Figure 18**.

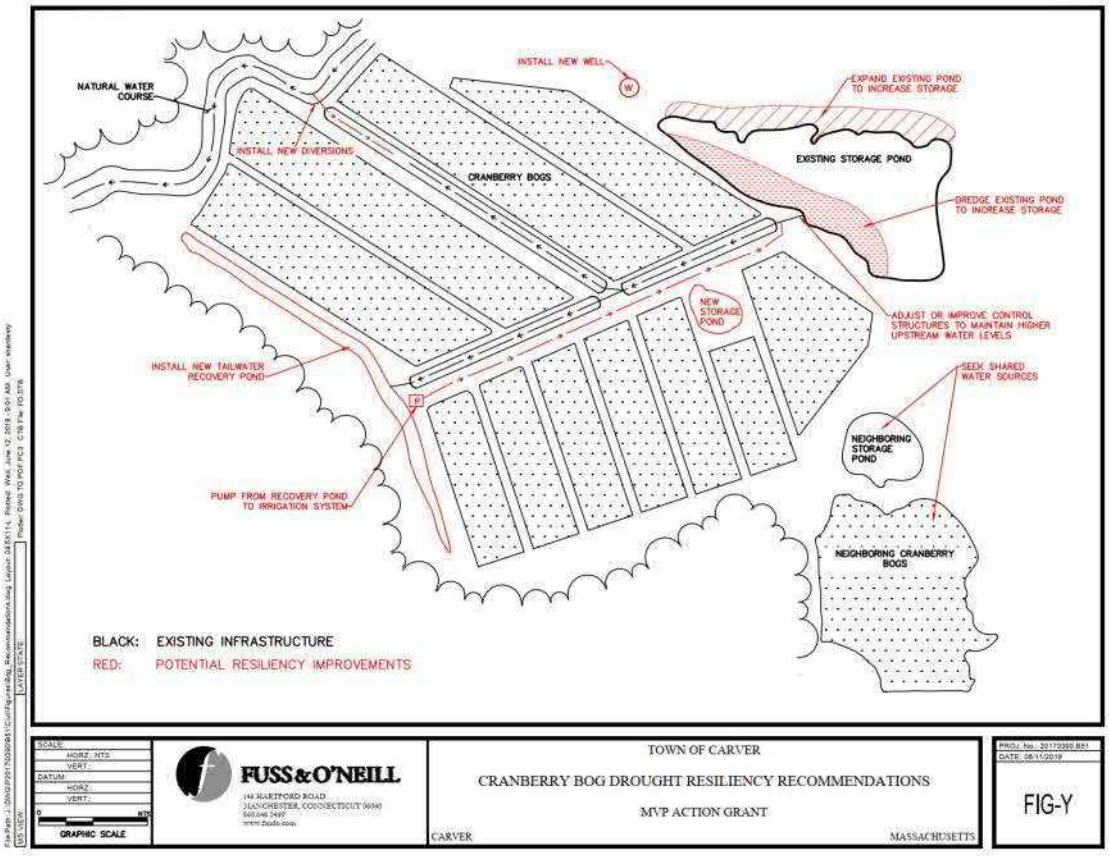


Figure 18. Cranberry bog recommended resiliency measures (plan view)

6 Potential Funding Strategies and Sources

Funding Strategy for Fire Fighting Water Sources

With an estimated cost of approximately $2,870,000 to undertake the recommended resiliency measures on the 15 First Tier Priority FF Sources, and the 10 Second Tier Priority Sources, it is recommended that the Town of Carver seek funding for implementation of resiliency measures on eight (8) of these 15 FF Sources for the upcoming MVP Action Grant at a total cost of $920,000. This would require the Town to provide a monetary or in-kind services match of 25% or $230,000. This 1st phase of work would allow the Town to develop the site specific permitting drawings, and to implement the resiliency measures on the eight highest priority FF Sources of the total 15. This initial effort will allow the town to fine tune the permitting and construction process. It will allow the Town to determine what, if any, efforts the Town can undertake with Town staff to reduce the cost of making the balance of the 15 total sites resilient.

Upon completion of the resiliency measures for all 15 sites, presumably after year two of the FF Source Drought Resiliency program, the Town can begin to focus on the ten Second Tier Priority FF Sources. By the time these sources are ready for permitting and construction a very efficient process of undertaking these resiliency measures would have been developed and it is envisioned that the Town will have a good understanding of the measures that Town staff can implement, which will result in less funding being

sought to implement these measures.

Upon completion of the resiliency measure implementation for all First and Second Tier FF Sources, the Town can begin to undertake a more concerted effort on the maintenance activities for the remaining FF Sources. It is envisioned that the measures to be implemented will be relatively minimal and since the Town will have developed a highly efficient system of undertaking these measures the cost should be relatively minimal, costs should be able to be accommodated within the Town's ongoing budget appropriations.

The MVP Action Grant Program appears to be the most appropriate funding program for these measures to address the vulnerability of the FF Sources that was identified as part of the MVP resiliency planning undertaken by the Town. Other sources of funding that are referenced below may have some application for a small group of the FF Sources on a case by case basis, but are not seen as a substantial source of funding for these resiliency measures.

Funding Strategy for Cranberry Farm Water Sources

Funding for the implementation of Cranberry Farm Water Sources (CF Sources) resiliency measures can come from a variety of sources. The cranberry farms are agricultural enterprises and have some capacity to reinvest in their businesses to improve efficiency, reduce cost and assure the viability of the business. The growers are extremely resourceful and have some capacity to undertake some of the resiliency measures with their own equipment and labor. However, there are more substantial resiliency measures that have been recommended that some, if not all, of the growers will be unable to implement without the services of outside equipment suppliers and/or construction contractors. In addition it is assumed that outside help could be required for some of the more complex permits that might be required for installing new CF Sources or substantially expanding existing sources, or installation of new recycling systems consisting of pumps and hoses, and certainly the installation of new equipment such as autostart irrigation systems. Funding assistance could be sought to assist the growers in implementing these more substantial resiliency measures.

The MVP Action Grant program could be a good source of funding to assist the Town in addressing the climate change vulnerabilities that were identified in the MVP planning process, specifically the climate change induced drought that will affect the cranberry industry. It is recommended that an MVP Action Grant be sought that can assist the growers in determining what potential resiliency measures are applicable to their individual cranberry operations, and to assist them in developing a comprehensive program of improving resiliency on a stepwise basis. Using the Carver Agricultural Commission or a similar Town representative to champion the effort and lead coordination with growers, the first step would be to identify the specific measures from the shortlist of potential resiliency measures that the growers wish to pursue. This would involve defining the magnitude of the measures, what aspects of the measures the grower can implement with their own forces, and what aspects they will need outside assistance with. A prioritization of the specific measures would be undertaken and budgets for implementation of the specific measures can be developed. The Town could make the grant request for the MVP Action Grant(s) and the growers could provide that portion of the 25% match required by the grant. It would be proposed for consideration in the MVP Action Grant Application that in-kind services would include the efforts of the growers in their implementation of aspects of the resiliency measures that they are capable of undertaking with their labor and equipment.

As part of the development of the cranberry farm drought resiliency implementation plan, other sources

of funding should be evaluated to determine if they can provide a portion of the funding required. The grant programs that are listed below have a number of programs that are agriculturally based and could potentially be a source of some funding for the drought resiliency program proposed for specific cranberry farms.

Potential Funding Programs

The following list provides some of the available grant programs that may be able to support, but not entirely fund implementation of priority projects identified through this MVP Action Grant.

1. **Agricultural Climate Resiliency & Efficiencies (ACRE) Grant Program**

   https://www.mass.gov/service-details/agricultural-climate-resiliency-efficiencies-acre-program

   The Agricultural Climate Resiliency & Efficiencies (ACRE) program is a competitive, reimbursement grant program that funds materials and labor for the implementation of practices that address the agricultural sector's vulnerability to climate change, improves economic resiliency and advances the general goals identified in the Massachusetts Local Action Food Plan. This includes projects that improve soil management, improve water use efficiency and availability, and/or promote efforts to reduce or limit greenhouse gas emissions or to enhance greenhouse gas sequestration including produce post-harvest practice upgrades. Part I: Adaptation & Mitigation Projects and Part II: Agricultural Energy Projects. Maximum funding per applicant for each Part is 80% of total project costs up to $25,000 (so maximum total project cost = $31,250). Produce operations applying for post-harvest practice upgrades must have an average annual value of produce sold during the previous three-year period of $25,000 or more. Sales must be for produce covered under the Produce Safety Rule (PSR).

   The program deadline for applications was May 2019, so confirmation that this grant program will be repeated in the coming years is required.

2. **Farm Viability Enhancement Program (FVEP)**

   https://www.mass.gov/service-details/farm-viability-enhancement-program-fvep

   The Farm Viability Enhancement Program (FVEP) provides business planning and technical assistance to help established farms identify strategies to increase farm viability such as, new or expanded enterprises, increased productivity, marketing, and/or environmental sustainability. Participants selected to participate in the program may be offered grant funds of $25,000 to $125,000 to implement strategies identified during the planning process in return for signing an agricultural covenant on the farm property to keep it in agricultural use for a 5 or 10-year term.

   Eligible uses of funds are capital projects on the farm such as building or repairing barns, farmstands or other agricultural buildings, modernizing equipment, or improving food processing capacity.

   Cranberry operators must own, or be a co-applicant with the owner of, a minimum of twenty (20)

acres total, with at least three (3) acres of cranberry bogs currently in production and at least ten (10) acres of non-wetland (upland). Responders must have an NRCS Farm Conservation Plan dated no earlier than 2014, or be actively involved in a planning process with the County Conservation District and, prior to responding to this RFR, have signed a Co-operator's Agreement with the District showing intent to complete an up-to-date Conservation Plan. The acreage as defined in the Farm Conservation Plan, if any, will govern farm eligibility.

The program deadline for applications was May 2019, so confirmation that this grant program will be repeated in the coming years is required.

3. **Agricultural Environmental Enhancement Program (AEEP)**

https://www.mass.gov/service-details/agricultural-environmental-enhancement-program-aeep

AEEP is a competitive, reimbursement grant program that funds materials and labor for conservation practices that mitigate or prevent negative impacts to the state's natural resources that may result from agricultural practices. Practices funded include those that prevent direct impacts on water quality, ensure efficient use of water, and address agricultural impacts on air quality. Reimbursement grants up to $25,000 will be awarded on a competitive basis.

4. **Local Acquisitions for Natural Diversity (LAND) Grant Program**

https://www.mass.gov/service-details/local-acquisitions-for-natural-diversity-land-grant-program

The LAND Grant Program helps cities and towns acquire land for conservation and passive recreation purposes. The grants reimburse cities and towns for the acquisition of land in fee or for a conservation restriction. If the conservation land acquired under this program could be used for backup water sources for FF or CF, then this program may be of assistance.

5. **Drinking Water Supply Protection Grant Program**

https://www.mass.gov/service-details/drinking-water-supply-protection-grant-program-1

Drinking Water Supply Protection Grant Program provides financial assistance for the purchase of land in existing Department of Environmental Protection (DEP)-approved drinking water supply protection areas, or land in estimated protection areas of identified and planned future water supply wells or intakes. If a water supply well were to be developed for both potable water and fire suppression water flow, this program could potentially assist the development of additional FS sources.

6. **Landscape Partnership Grant Program**

https://www.mass.gov/service-details/landscape-partnership-grant-program

This program seeks to protect large blocks of conservation land. Local, state, and federal government agencies and non-profit groups can use this grant to work together to protect at least 500 acres of land. Eligible projects include purchase of land in fee simple for conservation, forestry, agriculture, or water supply purposes, purchase of a Conservation Restriction, Agricultural Preservation Restriction, or Watershed Preservation Restriction, or construction of a

park or playground. This could have the potential to assist in the protection of current or development of future potential CF sources.

7. **Division of Ecological Restoration**

   https://www.mass.gov/how-to/become-a-der-priority-project

   The Division of Ecological Restoration selects wetland, river and flow restoration projects through a state-wide, competitive process. We choose high-priority projects that bring significant ecological and community benefits to the Commonwealth.
   - Dam Removal: https://www.mass.gov/river-restoration-dam-removal
   - Streamflow: https://www.mass.gov/river-restoration-streamflow
   - Culvert Replacements: https://www.mass.gov/river-restoration-culvert-replacements
   - Urban River Revitalization https://www.mass.gov/river-restoration-urban-river-revitalization
   - Wetlands Restoration: https://www.mass.gov/wetlands-restoration

8. **Massachusetts Land and Water Conservation Fund Grant Program**

   https://www.mass.gov/service-details/massachusetts-land-and-water-conservation-fund-grant-program

   The Federal Land & Water Conservation Fund provides up to 50% of the total project cost for the acquisition, development, and renovation of parks, recreation, and conservation areas. Eligible projects include acquisition of parkland or conservation land, creation of new parks, renovations to existing parks, and development of trails. If conservation areas preserved under this program has water sources, or water sources could be developed to support CF and FF sources, then this program could be of assistance.

9. **State Revolving Fund (SRF) Loan Program**

   https://www.mass.gov/state-revolving-fund-srf-loan-program

   The Clean Water SRF Program helps municipalities comply with federal and state water quality requirements by focusing on watershed management priorities, storm water management, and green infrastructure. The Drinking Water Program provides loans to communities to improve water supply infrastructure and drinking water safety. If these funds could be used for the enhancement of FF sources, then this program could be of value.

10. **Conservation Partnership Grant Program**

    https://www.mass.gov/how-to/apply-for-a-conservation-partnership-grant

    The Conservation Partnership Grant funds the acquisition of conservation land by non-profit entities. This program provides funding to assist non-public, not-for-profit corporations and conservation districts in acquiring and holding interests in lands suitable for conservation or recreation purposes. Municipalities interested in conserving a land through a Conservation Partnership Grant can coordinate with a non-profit entity to achieve the desired conservation goal. If conserved land under this program can also be used as a backup source for CF or FF, then this program could be of assistance.

11. Dam and Seawall Repair or Removal Program Grants and Funds

https://www.mass.gov/service-details/dam-and-seawall-repair-or-removal-program-grants-and-funds

The Dam and Seawall Repair or Removal Grants and Funds can be used to support the repair or removal of dams, seawalls and other coastal infrastructure, and levees. The cranberry bog dams are small and generally pose a Low Hazard. They are additionally privately owned. Based on the current requirements of this grant program and how it has been implemented to date, these structures, if they needed improvements, would rate very low on the priority for funding.

12. Coastal Resilience Grant Program

http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/grants/

The Massachusetts Office of Coastal Zone Management (CZM) administers the Coastal Resilience Grant Program to provide financial and technical support for local efforts to increase awareness and understanding of climate impacts, identify and map vulnerabilities, conduct adaptation planning, redesign vulnerable public facilities and infrastructure, and implement non-structural (or green infrastructure) approaches that enhance natural resources and provide storm damage protection. Managed through CZM's StormSmart Coasts program, grants are available for a range of coastal resilience approaches—from planning, public outreach, feasibility assessment, and analysis of shoreline vulnerability to design, permitting, construction, and monitoring. None of Carver is currently within the regulated Coastal Zone so at this time this grant program would not apply.

13. MassBays Healthy Estuaries Grants

https://www.mass.gov/massbays-healthy-estuaries-grants

MassBays provides small grants to nonprofit organizations, academic institutions, and municipalities for projects that advance progress toward the goals of our Comprehensive Conservation and Management Plan. MassBays seeks proposals that will fill in gaps in knowledge about assessment areas, demonstrate new approaches to monitoring or protecting near-shore habitats, or lay the groundwork for future restoration. None of Carver is currently within the regulated Coastal Zone or has estuary systems so at this time this grant program would not apply.

14. MET Drive for a Better Environment (DFBE) Grants Program

https://www.mass.gov/service-details/met-drive-for-a-better-environment-dfbe-grants-program

The DFBE Grants Program provides funding to innovative and well-designed projects that support the advancement of marine animal conservation efforts and restoration and enhancement of aquatic ecosystems within Massachusetts. None of Carver is currently within the regulated Coastal Zone or has estuary systems so at this time this grant program would not apply.

Appendix A

References

Alder, J. R. and S. W. Hostetler. 2013. USGS National Climate Change Viewer. US Geological Survey. Accessed April 2019. https://www2.usgs.gov/climate_landuse/clu_rd/nccv/viewer.asp

Armstrong, C. 2016. Cranberries and a changing climate. The University of Maine Cooperative Extension. Accessed April 2019. https://extension.umaine.edu/cranberries/wp-content/uploads/sites/40/2017/03/Cranberries-and-a-Changing-Climate.pdf

Carlson, C.S., Masterson, J.P., Walter, D.A., and Barbaro, J.R. 2017. Development of simulated groundwater-contributing areas to selected streams, ponds, coastal water bodies, and production wells in the Plymouth-Carver region and Cape Cod, Massachusetts: U.S. Geological Survey Data Series 1074, 17 p., https://doi.org/10.3133/ds1074.

Croft, P.J. 1995. Field conditions associated with cranberry scald. Hortscience. 30(3):627.

Demaria, E.M.C., Palmer R.N., and Roundy J.K. 2016. Regional climate change projections of streamflow characteristics in the Northeast and Midwest U.S. Journal of Hydrology: Regional Studies. 5, 309-323.

Gareau, B.J., Huang X and Gareau T.P. 2018. Social and ecological conditions of cranberry production and climate change attitudes in New England. PLoS ONE 13(12): e0207237. https://doi. org/10.1371/journal.pone.0207237

Massachusetts Division of Watershed Management Watershed Planning Program. 2017. Massachusetts Year 2016 Integrated List of Waters. Accessed April 2019. https://www.mass.gov/files/documents/2017/08/zu/16ilwplist.pdf

Massachusetts Executive Office of Energy & Environmental Affairs, 2017, "MCP Numerical Standards." Massachusetts Department of Environmental Protection

Massachusetts State Hazard Mitigation and Climate Adaptation Plan. 2018. Accessed April 2019. http://nescaum-dataservices-assets.s3.amazonaws.com/resources/production/SHMCAP-September2018-Full-Plan-web.pdf

Masterson, J.P., Carlson, C.S., and Walter, D.A., 2009, Hydrogeology and simulation of groundwater flow in the Plymouth-Carver-Kingston-Duxbury aquifer system, southeastern Massachusetts: U.S. Geological Survey Scientific Investigations Report 2009–5063, 110 p.

Neri, Carolina, and Víctor Magaña., 2016, "Estimation of Vulnerability and Risk to Meteorological Drought in Mexico." Weather, Climate, and Society, vol. 8, no. 2, pp. 95–110., doi:10.1175/wcas-d-15-0005.1.

Northeast Climate Adaptation Science Center (NECASC). 2018. Massachusetts Climate Change Projections. Resilient MA Climate Change Clearinghouse for the Commonwealth (resilient MA). Accessed April 2019. http://www.resilientma.org/resources/resource::2152

Rajsekhar, Deepthi, et al., 2015, "Integrated Drought Causality, Hazard, and Vulnerability Assessment for Future Socioeconomic Scenarios: An Information Theory Perspective." Journal of Geophysical Research: Atmospheres, vol. 120, no. 13, pp. 6346–6378., doi:10.1002/2014jd022670.

United States Department of Agriculture. 2018. New England and Northern New York Forest Ecosystem Vulnerability Assessment and Synthesis.

University of Massachusetts Amherst. 2017. Change in timing of seasons. Massachusetts Wildlife Climate Action Tool. Accessed April 2019. https://climateactiontool.org/content/change-timing-seasons

Walter, D.A., McCobb, T.D., Masterson, J.P., and Fienen, M.N. 2016. Potential effects of sea-level rise on the depth to saturated sediments of the Sagamore and Monomoy flow lenses on Cape Cod, Massachusetts (ver. 1.1, October 18, 2016): U.S. Geological Survey Scientific Investigations Report 2016–5058, 55 p., http://dx.doi.org/10.3133/sir20165058.

Wilhite, D.A.; and M.H. Glantz., 1985, "Understanding the Drought Phenomenon: The Role of Definitions." Water International, vol. 10, no. 3, pp. 111–120.

Appendix B

Cost Estimates for Resiliency Measures

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	1966 Drought Simulation 4' GW Level Drop	
LOCATION :	Carver, Massachusetts - FF Source W3-36		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifiations and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	356	25.00	$8,900.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	356	150.00	$53,400.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Bank Grading & Seeding/Plantings	S.F.	50	5.00	$250.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					$0.00
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$119,900.00
	CONTINGENCY (15%)				$35,970.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$156,000.00

Contaminated Sediment	$145,765.00
Clean Sediment	$94,590.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adap	1966 Drought Simulation 4' GW Level Drop	
LOCATION :	Carver, Massachusetts - FF Source DH 3-38		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	356	25.00	$8,900.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	356	150.00	$53,400.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Bank Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$118,650.00
	CONTINGENCY (15%)				$35,595.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$154,000.00

Contaminated Sediment	$143,765.00
Clean Sediment	$92,590.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adap	2016 Drought Simulation 1' GW Level Drop	
LOCATION :	Carver, Massachusetts FF Source W1-1		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	25	25.00	$625.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	25	150.00	$3,750.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Bank Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$60,725.00
	CONTINGENCY (15%)				$18,217.50
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$79,000.00

Contaminated Sediment	$78,281.25
Clean Sediment	$74,687.50

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	2016 Drought Simulation 1' GW Level Drop	
LOCATION :	Carver, Massachusetts FF Source W1-25		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	132	25.00	$3,300.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	132	150.00	$19,800.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
	Bank Grading & Seeding/Plantings	S.F.	50	5.00	$250.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$81,700.00
	CONTINGENCY (15%)				$24,510.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$106,000.00

Contaminated Sediment	$102,205.00
Clean Sediment	$83,230.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	2016 Drought Simulation 1' GW Level Drop	
LOCATION :	Carver, Massachusetts FF Source W1-5		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	132	25.00	$3,300.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	132	150.00	$19,800.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Bank Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$79,450.00
	CONTINGENCY (15%)				$23,835.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$103,000.00

Contaminated Sediment	$99,205.00
Clean Sediment	$80,230.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	2016 Drought Simulation 1' GW Level Drop	
LOCATION :	Carver, Massachusetts FF Source W1-33		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	132	25.00	$3,300.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	132	150.00	$19,800.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
	Bank Grading & Seeding/Plantings	S.F.	50	5.00	$250.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$81,700.00
	CONTINGENCY (15%)				$24,510.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$106,000.00

Contaminated Sediment	$102,205.00
Clean Sediment	$83,230.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	1966 Drought Simulation 2' GW Level Drop	
LOCATION :	Carver, Massachusetts FF W2-10		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	40	25.00	$1,000.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	40	150.00	$6,000.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Bank Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$63,350.00
	CONTINGENCY (15%)				$19,005.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$82,000.00

Contaminated Sediment	$80,850.00
Clean Sediment	$75,100.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	2016 Drought Simulation 1' GW Level Drop	
LOCATION :	Carver, Massachusetts FF Source W2-12		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	132	25.00	$3,300.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	132	150.00	$19,800.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
	Bank Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$80,450.00
	CONTINGENCY (15%)				$24,135.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$105,000.00

Contaminated Sediment	$101,205.00
Clean Sediment	$82,230.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	2016 Drought Simulation 1' GW Level Drop	
LOCATION :	Carver, Massachusetts FF Source W2-19		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	132	25.00	$3,300.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	132	150.00	$19,800.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Bank Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$79,450.00
	CONTINGENCY (15%)				$23,835.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$103,000.00

Contaminated Sediment	$99,205.00
Clean Sediment	$80,230.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	1966 Drought Simulation 4' GW Level Drop	
LOCATION :	Carver, Massachusetts - FF Source W2-26		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	356	25.00	$8,900.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	356	150.00	$53,400.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
	Bank Grading & Seeding/Plantings	S.F.	50	5.00	$250.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$120,900.00
	CONTINGENCY (15%)				$36,270.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$157,000.00

Contaminated Sediment	$146,765.00
Clean Sediment	$95,590.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	1966 Drought Simulation 4' GW Level Drop	
LOCATION :	Carver, Massachusetts - FF Source W2-28		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	356	25.00	$8,900.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	356	150.00	$53,400.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Bank Grading & Seeding/Plantings	S.F.	50	5.00	$250.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$119,900.00
	CONTINGENCY (15%)				$35,970.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$156,000.00

Contaminated Sediment	$145,765.00
Clean Sediment	$94,590.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	1966 Drought Simulation 2' GW Level Drop	
LOCATION :	Carver, Massachusetts FF W3-6		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	195	25.00	$4,875.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	195	150.00	$29,250.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Bank Grading & Seeding/Plantings	S.F.	50	5.00	$250.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$91,725.00
	CONTINGENCY (15%)				$27,517.50
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$119,000.00

Contaminated Sediment	$113,393.75
Clean Sediment	$85,362.50

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	2016 Drought Simulation 1' GW Level Drop	
LOCATION :	Carver, Massachusetts FF Source W3-19		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	132	25.00	$3,300.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	132	150.00	$19,800.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
	Bank Grading & Seeding/Plantings	S.F.	50	5.00	$250.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$81,700.00
	CONTINGENCY (15%)				$24,510.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$106,000.00

Contaminated Sediment	$102,205.00
Clean Sediment	$83,230.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	1966 Drought Simulation 4' GW Level Drop	
LOCATION :	Carver, Massachusetts - FF Source W3-28		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	356	25.00	$8,900.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	356	150.00	$53,400.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	0	5.00	$0.00
	Bank Grading & Seeding/Plantings	S.F.	50	5.00	$250.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$119,900.00
	CONTINGENCY (15%)				$35,970.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$156,000.00

Contaminated Sediment	$145,765.00
Clean Sediment	$94,590.00

FUSS & O'NEILL, INC.

146 HARTFORD ROAD
MANCHESTER, CONNECTICUT

OPINION OF CONSTRUCTION COST		DATE PREPARED :	11-Jun-19
Type:	**Order of Magnitude**		
PROJECT :	Carver Climate Change Water Resources Vulnerability and Adapta	2016 Drought Simulation 1' GW Level Drop	
LOCATION :	Carver, Massachusetts FF Source W3-35		
DESCRIPTION:	Fire Fighting Water Sources Resiliency Measures		
DRAWING NO. :		ESTIMATOR : PWM	CHECKED BY : SAH

OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor(s)' methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifiations and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner shall employ an independent cost estimator.

ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
SOIL AND EROSION CONTROL					
	Sedimentation and Erosion Control	L.S.	1	1,000.00	$1,000.00
	Anti-Tracking Apron	L.S.	1	500.00	$500.00
FIRE TRUCK PARKING AREA					
	Clearing and Grubbing	S.F	1200	1.25	$1,500.00
	8" Processed Aggregate Base	C.Y.	140	35.00	$4,900.00
WATER CONTROL					
	Cofferdams	L.S.	1	500.00	$500.00
	Dewatering Dredge Area	L.S.	1	500.00	$500.00
DREDGING					
	Dredging & Sediment Reuse On Site (Clean)	C.Y.	132	25.00	$3,300.00
	Dredging & Sediment Disposal Off Site (Contaminated)	C.Y.	132	150.00	$19,800.00
DRY HYDRANT INSTALLATION					
	Dry Hydrant Installation	EA.	1	15,000.00	$15,000.00
SITE STABILIZATION WORK					
	Pond Bottom Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
	Bank Grading & Seeding/Plantings	S.F.	50	5.00	$250.00
	Riparian Zone Grading & Seeding/Plantings	S.F.	200	5.00	$1,000.00
GENERAL CONDITIONS					
	Mobilization & Demobilization	L.S.	1	1,000.00	$1,000.00
	Survey, Construction Stakeout	L.S.	1	1,000.00	$1,000.00
	Temporary Utilities	N/A			$0.00
	Toilets/Drinking Water	Month	0.25	1,000.00	$250.00
	Site Trailer	Month	0		$0.00
	Testing Laboratory Sample	EA	4	300.00	$1,200.00
	Traffic Control	L.S.	1	2,000.00	$2,000.00
ENGINEERING					
	Design	L.S.	1	15,000.00	$15,000.00
	Permitting	L.S.	1	9,000.00	$9,000.00
	Construction Administration	L.S.	1	3,000.00	$3,000.00
	SUBTOTAL				$81,700.00
	CONTINGENCY (15%)				$24,510.00
	TOTAL COST (ROUNDED TO NEAREST $1,000)				$106,000.00

Contaminated Sediment	$102,205.00
Clean Sediment	$83,230.00

Appendix C

NFPA Description

FUSS & O'NEILL

Further Considerations for Water Supply Resiliency

- National Fire Protection Association (NFPA) Codes for Water Supplies
  The NFPA has established minimum requirements for firefighting water supplies. NFPA Code 1142 Standard on Water Supplies for Suburban and Rural Fire Fighting, 2017, Chapter 7 Water Supply 1142-10, 7.1 Approved Water Supply.

  7.1.7 "To be acceptable, water supply sources shall maintain the minimum capacity and delivery requirements on a year round basis, based on the 50 year drought for the water source."

  The calculation of the 2% annual probability, or more commonly called the 50 year return frequency drought, is not described in the code. The traditional method for determining annual probability of hydrologic events is to statistically analyze a hydrologic record for the specific watershed or locale, or a surrogate watershed or locale that is similar and where the historical record exists. The historical record would be flow gauge records from a surface water course, and/or water level records from a monitoring well. The length of record should be long enough to at least encompass the drought of the 1960s that occurred in the Northeast since that is the greatest drought on record and is the baseline that potable water supplies are measured against. It has a dramatic impact on the statistical analyses of water availability.

  Recommendations have been made in this study to increase the resiliency of these firefighting water supplies by dredging and deepening storage water bodies to better be able to intercept depressed groundwater levels associated with droughts. We have been able to identify the potential drop in groundwater levels that could be expected should a drought of the severity of the 1960s drought reoccur based upon a USGS study that indicated a groundwater level drop of 0 to 6 feet could be expected. Mapping that has been produced as part of the study indicates the areas in town and the estimated level of groundwater drop that would be expected. Not surprisingly the areas of town with substantial surface water (ponds, wetlands, streams, cranberry bogs) have the least expected drop in groundwater level. This is due to the fact that surface water recharges groundwater during a drought which further points to the anticipated loss of surface water during a severe drought, and the importance of groundwater as the major source of water.

  As a comparison to this USGS simulation in Carver, a USGS monitoring well in Plymouth, MA, the adjacent town to Carver, experienced ab approximately 10 feet of drop during the most severe period of the 1960s drought, in 1966. It would be helpful to know how the 50 year drought compares to the anticipated groundwater level drop associated with a reoccurrence of the 1960s drought in Carver.

  According to Climatologist W.C. Palmer W.C. Palmer, who commented in 1965, before the maximum severity of the 1960s drought was attained:

  "From the standpoint of severity and duration, the current drought in the northeastern United States is such a rare event that we should ordinarily expect it to occur in this region only about once in a couple of centuries."

From: "Drought" Weekly Weather and Crop Bulletin, National Summary, U.S. Weather Bureau, vol. 52, No. 30, July 26, 1965, p.8.

(http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.395.2938&rep=rep1&type=pdf)

If this meteorological estimation from 1965, that the 1960s drought was a 200 year drought is reasonably correct, then it would indicate that the 50 year drought would be somewhat less than the 0 to 6 feet of groundwater level drop that has been recently estimated by the USGS for Carver. The 50 year drought would likely result in a groundwater level drop somewhere between that which was experienced in 2016 (up to one foot) and the 1960s drought (up to 6 feet as predicted). Given the observed groundwater level drop of 10 feet in Plymouth in 1966, it may be reasonable to continue to recommend that the ponds be designed to provide the necessary water storage assuming a drop in groundwater level as simulated by the USGS for the 1966 drought of record, even if it may be more severe than the 50 year drought. This seems like a reasonable assumption given the available information and the substantial effort that would be required with calculating the 50 year drought for the several hundred water sources in Carver as discussed below.

- Conference Calls with NFPA on 6/12/19 and then on 6/18/19 to discuss determination of 50 year drought effects to firefighting water supplies within Carver. Participants in the calls

June 12, 2019	June 18th, 2019
William Watters – NFPA	William Watters – NFPA
Mike Morash – NFPA	Mike Morash – NFPA
Sal Izzo – NFPA	Sal Izzo - NFPA
Craig Weston – Town of Carver	Craig Weston – Town of Carver
Sage Hardesty – Fuss & O'Neill	Sage Hardesty – Fuss & O'Neill
Phil Moreschi – Fuss & O'Neill	Phil Moreschi – Fuss & O'Neill
	Kevin Koontz – NFPA
	Sheri Who (sp?)

NFPA indicated that the proper way to determine the 50 year drought is to use the USDA NRCS TR-19 Computer Model for the specific watershed related to the subject water supply. That model will indicate that flow and volume that can be relied upon for an occurrence of the 50 year drought. It is a very data intensive program, and would be an extremely substantial effort to undertake the necessary analyses for water sources in Carver. Drainage area determination in Carver is challenging due to the very flat relief and the lack of mapping of proper resolution to determine exact drainage boundaries. Complicating that is the extensive network of diversions and water control structures associated with the Cranberry farming operations that make drainage area boundaries change as water is being moved around.

A large portion of the Firefighting water supplies in carver are simply dug ponds that intercept groundwater with little surface water contribution. Thus Fuss & O'Neill operating with the assumption that the water level in the water supply is a direct representation of the underlying ground water levels, expect for supplies as part of a larger watercourse.

There is lacking data on how to determine 50 year drought statistics. Fuss & O'Neill provided NFPA with a USGS study (Masterson, 2006) investigating how groundwater level in the Plymouth/Carver region would respond to the record drought (occurring in 1966) given current day pumping rates. It is difficult to put a recurrence interval on this record drought, however some experts at the time believed it was a 1-in-200 year occurrence. This study predicted groundwater levels dropping between 1-6 feet within Carver. The variation in groundwater drop is dependent on the abundance of surrounding surface waters that act as a buffer, recharging groundwater levels. So generally in areas rich with surface water such as ponds and watercourses, the groundwater level is anticipated to drop less than in other areas of town where there is less surface water.

NFPA is willing to accept the much more conservative 1-in-200 year event in place of the typical 50 year drought benchmark if the town is able to demonstrate that there would still be adequate accessible water held in the water supply to meet their standards under these drought conditions. This includes accounting for the water that will be inaccessible during the winter months in the form of ice on the surface as well the water on the bottom of the water column that is inaccessible because of the use of the pump's strainer, approximately 2 feet. In the case where a water source falls just short of the NFPA standards, NFPA believe it is reasonable to round the capacity up to meet the standard given the much more conservative benchmark being used and would be open to that discussion. NFPA would expect that stage storage information be collected in the way of bathymetric data that would clearly indicate the volume of water available from the source at various water level elevations to be able to calculate an accurate available volume for different groundwater levels. In addition the Masterson study would have to be reviewed to determine what time of year the Groundwater Level drops were simulated and then the "normal" water level based on available records for that time of year would have to be determined for each source as a starting point to measure predicted groundwater level drop from.

NFPA also states that the town will have to provide proof that the water in the supplies is still accessible from the shore during these drought conditions. Chief Officer Craig Weston mentions that the fire department sites were specifically chosen with that necessity in mind, and that the fire department has never been unable to access water within a source via their pumps. Fuss & O'Neill brings up the possibility of dredging a channel to convey water from the center of the source towards the shore so that water is always accessible. These types of channels would need to be maintained to be clear of silt and sedimentation. NFPA referred to these channels as an "open pit pipeline". A dry hydrant pipe could also be installed that accesses that low water some distance from shore to allow that low water to be accessed when distant from shore.

Fuss & O'Neill concluded their understanding that there are two ways to assess compliance of a source with the NFPA 1142 standard. The original guidance provided by NFPA in last week's call was calculation of available storage and flow utilizing the USDA NRCS TR-19 software program. Today's discussion indicated that use of the USGS Masterson Simulation of anticipated groundwater level drops in Carver due to a recurrence of the 1966 drought would be an acceptable way to assess compliance.

Appendix D

Cranberry Bog Lookup Table

Cranberry Bog #	BOG_NAME	WMA_NO	OWNER	ADDRESS	TOWN	Basin
0	Maki Bog	42418205	Kenneth & Bettygene Harju	Wenham Rd.	Carver	Buzzards Bay
1	Barrows Bog	42405290	Wenham Pond Cran. Co. LLC	off Route 44	Carver	Buzzards Bay
3	North Carver Bog Ssect	42405290	Wenham Pond Cran. Co. LLC	off Route 44	Carver	Buzzards Bay
28	Heinz Bog	42405226	Gilmore Cranberry Co Inc	Cranberry Rd.	Carver	Buzzards Bay
32	Snappit	42505214	A.D. Makepeace Co.	Snappit Rd.	Carver	Taunton
35	Chase Bog	42518218	Harju Brothers Cranberries Inc	High St.	Carver	Taunton
36	Mahutchett Brook	42505204	LSC Investment Trust	Montello St.	Carver	Taunton
38	0	certified	Jennifer May Cranberry Co.	Snappit Rd.	Carver	Taunton
43	Bayberry Bog	42505224	Robert C. Melville	Montello St.	Carver	Taunton
44	Sherman Meadow	V42505230	David W. Parker	Gate St.	Carver	Taunton
45	Sherman Meadow bog	abandoned	Allen M. Maynard	Plymouth St.	Carver	Taunton
61	Ward No. 2	42405245	SRD Real Estate LLC	Main St.	Carver	Taunton
62	Ward No. 3	42405245	SRD Real Estate LLC	Wenham St.	Carver	Buzzards Bay
63	Harju Bog	42405246	Fiilus Harju Cran. Co.	Meadow St.	Carver	Buzzards Bay
67		42405221	Pratt Cranberry Bogs	Wenham Rd.	Carver	Buzzards Bay
68	2nd Alarm Bog	42405276	W.D. Bogs, Inc.	Holmes St.	Carver	Buzzards Bay
69	Home Bog	42405230	J.W. Johnson Cranberries	South Main St.	Carver	Buzzards Bay
76	Diamond Bog	42405268	Gary Weston	Main St.	Carver	Buzzards Bay
77	Centre St. Bog	42405268	Gary Weston	Center St.	Carver	Buzzards Bay
78	Edaville Bog	42405269	Heikkila Cran. Bogs	Eda Ave.	Carver	Buzzards Bay
79	Pine St. Bog	42405269	Heikkila Cran. Bogs	Pine St.	Carver	Buzzards Bay
80	Clear Pond Bogs	42405286	Bailey Bogs, Inc.	Wareham St.	Carver	Buzzards Bay
81	Sturtevant Bog	42405286	Bailey Bogs, Inc.	Wareham St.	Carver	Buzzards Bay
114		9P442431004	Decas Cranberry Co. Inc.	Tremont St.	Carver	Buzzards Bay
151	N. Carver Bog (N sect)	42405290	Wenham Pond Cran. Co. LLC	Plymouth Rd.	Carver	Buzzards Bay
152	N. Carver Bog (N sect)	9P442405208	Wenham Pond Cran. Co. LLC	Plymouth Rd.	Carver	Buzzards Bay
157	Johnson Bogs	42405212	David F. Penney	Meadow St.	Carver	Buzzards Bay
161	abandoned acreage	abandoned	Decas Cranberry Co. Inc.	Mayflower Rd.	Carver	Buzzards Bay
162	abandoned acreage	abandoned	Decas Cranberry Co. Inc.	Mayflower Rd.	Carver	Buzzards Bay
163	abandoned acreage	abandoned	Decas Cranberry Co. Inc.	Mayflower Rd.	Carver	Buzzards Bay
164		42431016	Decas Cranberry Co. Inc.	Mayflower Rd.	Carver	Buzzards Bay
204		42405258	Kim W. Cardon	Wenham Rd.	Carver	Buzzards Bay
205	Weil Bog	42405258	Kim W. Cardon	Wenham Rd.	Carver	Buzzards Bay
209	Forest Street	42405217	Johnson Brothers Cran LLC	Forest St.	Carver	Buzzards Bay
217	Reg xfer to Redler's	abandoned	Perry's Berries Inc.	Center St.	Carver	Buzzards Bay
218	Rochester Rd.	V42405205	Perry's Berries Inc.	Rochester Rd.	Carver	Buzzards Bay
220	Slug	42505207	Franklin Marsh, LLC	Plymouth Rd.	Carver	Taunton
227	Simeone Bog	42405281	Simeone Bog/Craig Weston	Meadow St.	Carver	Buzzards Bay
228	Braddock Bog	V42505231	Julian Arnold	Center St.	Carver	Taunton
233	0	abandoned	Leonard A. Pierce	Wareham St.	Carver	Buzzards Bay
236	Fosdick St. Bog	42418212	Harju Brothers Cranberries Inc		Carver	Buzzards Bay
244	Washburn Bog	9P242405203	Oiva Hannula & Sons, Inc.	Rochester Rd.	Carver	Buzzards Bay
245	Washburn Bog	9P242405203	Oiva Hannula & Sons, Inc.	Eda Ave.	Carver	Buzzards Bay
247	0	none	unknown	0	Carver	Buzzards Bay
248	0	none	unknown	0	Carver	Buzzards Bay
249	0	none	David Piper, Jr.	Cranberry Rd.	Carver	Buzzards Bay
250	0	none	Eric Johnson	Wareham St.	Carver	Buzzards Bay
251		none	Robert D Williams Trustee	Wareham Street	Carver	Buzzards Bay
252		certified	Waino & Sons Cranberries Ltd.	Rochester Rd.	Carver	Buzzards Bay
253	0	none	unknown	0	Carver	Buzzards Bay
254	Ryan's Country Bogs	42405264	Shoestring Bogs	Tremont St.	Carver	Buzzards Bay
255	0	none	Paul D. Shimkus	Center St.	Carver	Buzzards Bay
256	0	none	Pimental Realty Trust	Popes Point Rd.	Carver	Buzzards Bay
257	0	none	Oiva Rinne	Popes Point Rd.	Carver	Buzzards Bay
258	France St. Bog	42405214	Frederick W. & Virginia Weston	France St.	Carver	Buzzards Bay
259		42405219	Edwin K. & Elaine J. Harju	Popes Point Rd.	Carver	Buzzards Bay
267	Pierce Bog	42418225	Lawrence W. Pink	Meadow St.	Carver	Buzzards Bay
268		none	Delores Haarala	France St.	Carver	Buzzards Bay
270	0	none	Joseph Ferreira, Jr.	59-B Wenham Rd	Carver	Buzzards Bay
271	0	abandoned	Kevin Ferreira	West St.	Carver	Buzzards Bay
272	0	abandoned	Kevin Ferreira	West St.	Carver	Buzzards Bay
285	Black Brook Bog	42418205	Kenneth & Bettygene Harju	Popes Point Rd.	Carver	Buzzards Bay
286	Cranebrook Bog	42405294	Cranebrook Cranberry LLC	Tremont St.	Carver	Buzzards Bay
287	John's Pond Bog	42505234	Nantasket Cranberry Ltd Ptshp	Purchase St.	Carver	Taunton

310		none	unknown	Ryan Rd.	Carver	Buzzards Bay
311		none	Suominen Inc.	Ryan Rd.	Carver	Buzzards Bay
325	Maki Bog	certified	Edwin Maki	Wareham St.	Carver	Buzzards Bay
362	0	none	0	0	Carver	Buzzards Bay
367	Bates Pond	42405233	Alex Johnson & Sons	Meadow St.	Carver	Buzzards Bay
368	Company Bogs	42405233	Alex Johnson & Sons	Meadow St.	Carver	Buzzards Bay
369	Maki Bog	42405233	Alex Johnson & Sons	Wareham St.	Carver	Buzzards Bay
370	Alves Bog	42405252	Cranberry Country Bogs	Cross St.	Carver	Buzzards Bay
383	Fosdick Rd. Bogs	42405252	Cranberry Country Bogs	Fosdick Rd.	Carver	Buzzards Bay
384	Crane Brook Bog	42405286	Bailey Bogs, Inc.	Cranberry Rd.	Carver	Buzzards Bay
393		42405255	Mark F. Weston	France St.	Carver	Buzzards Bay
394		42423903	Eric Haarala	France St.	Carver	Buzzards Bay
401	Line Bog	42431032	Bayside Agricultural Inc.	Tremont St.	Carver	Buzzards Bay
408	Lunar Berries	42426401	Lunar Fruits LLC	Jabez Bridge Rd.	Carver	Buzzards Bay
451		42423906	Cedar Meadow Cranberry Inc	South Meadow Rd.	Carver	Buzzards Bay
453		42405280	Eugene D. Cobb	Canterbury Dr.	Carver	Buzzards Bay
465	Harwich	42431033	A.D. Makepeace Co.	Wareham St.	Carver	Buzzards Bay
473	Sampson Pond Bog	42405295	Pride of Carver Cran Ltd Ptnrs	Tremont St.	Carver	Buzzards Bay
474	Gibbs Bog	42405224	Slocum-Gibbs Cran.Co.Inc.	Wareham St.	Carver	Buzzards Bay
482		none	Clement Pappas	Pond St.	Carver	Buzzards Bay
485	Carver Bog	42405207	Mary Korpinen	Tremont St.	Carver	Buzzards Bay
486	Kallio/Old Dam Bogs	42405211	Kallio Bogs	Tremont St.	Carver	Buzzards Bay
487	Plymouth Airport	42405225	Meadow Pond Farm	Ward St.	Carver	Buzzards Bay
488	Meadow Pond Farm	42405225	Meadow Pond Farm	Ward St.	Carver	Buzzards Bay
489	Ira Thomas Bog	42405276	W.D. Bogs, Inc.	Holmes St.	Carver	Buzzards Bay
492	Mutton Island Bog	42405296	Mutton Island Realty Trust	Tremont St.	Carver	Buzzards Bay
495	Atwood B	42424001	Edgewood Bogs LLC	Tremont St.	Carver	Buzzards Bay
496	Queen Bog	42424001	Edgewood Bogs LLC	South Meadow Rd.	Carver	Buzzards Bay
522	Front Ave.	42505217	Domingo Fernandes	Front Ave.	Carver	Taunton
523	North Main St.	42505217	Domingo Fernandes	North Main St.	Carver	Taunton
550	Harwich	42431033	A.D. Makepeace Co.	Wareham St.	Carver	Buzzards Bay
551	Harwich	42431033	A.D. Makepeace Co.	Wareham St.	Carver	Buzzards Bay
559		42405269	Heikkila Cran. Bogs	Meadow St.	Carver	Buzzards Bay
564		none			Carver	Buzzards Bay
568	Decas Bog 18 abandoned	abandoned	Decas Cranberry Co. Inc.	Mayflower Rd.	Carver	Buzzards Bay
573	Battles Bog	42418205	Kenneth & Bettygene Harju	Plymouth St.	Carver	Buzzards Bay
574	Lucas Bog	42405268	Gary Weston	Main St.	Carver	Buzzards Bay
594		42431016	Decas Cranberry Co. Inc.	Mayflower Rd.	Carver	Buzzards Bay
595		42431016	Decas Cranberry Co. Inc.	Mayflower Rd.	Carver	Buzzards Bay
597	Steva 2	9P342418201	Kenneth & Bettygene Harju	Center St.	Carver	Buzzards Bay
610	Clear Pond Bog	42431027	Beaton's, Inc.	Wareham St.	Carver	Buzzards Bay
624	Godfrey Bog	42514606	Bayside Agricultural Inc.	Gate St.	Carver	Taunton
625	High Street Bog	42505204	LSC Investment Trust	High St.	Carver	Taunton
626	Bumpus Bog	42518225	Mill Bogs - Peter Paquin	High St.	Carver	Taunton
627		42405251	Walker Cranberries, LLC	Bow St.	Carver	Buzzards Bay
628	Flax Pond Bog	42405249	Flax Pond Cranberry Co.	Robbins Path	Carver	Buzzards Bay
636	Snappit Bogs	42505205	Tim Tom Cranberry	Snappit Rd.	Carver	Taunton
637		42505233	Marian C. Roche	Snappit Rd.	Carver	Taunton
641	Fisk Bog	V42431066	ADM Cranberry Co LLC	Hammond St.	Carver	Buzzards Bay
643	Thomas Bog	42405214	Frederick W. & Virginia Weston	Holmes St.	Carver	Buzzards Bay
651	0	none	Richard D Banks	Beaver Dam Rd	Carver	Buzzards Bay
664	Heikkila Bog #2	42405269	Heikkila Cran. Bogs	Meadow St.	Carver	Buzzards Bay
665	Westgate Bogs	42405282	Brandon G. Westgate	Meadow St.	Carver	Buzzards Bay
666	Part of Site 1	42405285	Weston Bros. Cranberries LLC	Lakeview St.	Carver	Buzzards Bay
670		42405244	Cedarbrook Cranberry Harvest	West St.	Carver	Buzzards Bay
681	T.Randall Bog	42416902	Bartholomew Family Bogs LLC	Hammond St.	Carver	Buzzards Bay
682	Smith Hammond	42431033	A.D. Makepeace Co.	Federal Rd.	Carver	Buzzards Bay
689	0	none	Manual T. Neves Jr.	North Main St.	Carver	Taunton
699	Shurtleff Bog	42431021	Daniel E & Janis R Johnson	Tremont St.	Carver	Buzzards Bay
700	Harwich Upper	42431033	A.D. Makepeace Co.	Wareham St.	Carver	Buzzards Bay
709	0	none	D.A.D. Line Construction Inc.	Cranberry Road	Carver	Buzzards Bay
710		42405223	Stanley & Anne-Marie Lowell	Cranberry Rd.	Carver	Buzzards Bay
711		42405262	Williams & Alger Inc.	Wareham St.	Carver	Buzzards Bay
712	Murdock Bog	42405224	Slocum-Gibbs Cran.Co.Inc.	Wareham St.	Carver	Buzzards Bay
714	East Head Bog	42405260	Bowers & Russell	East Head Rd.	Carver	Buzzards Bay

715	Shoe String Bog	42405294	Cranebrook Cranberry LLC	Tremont St.	Carver	Buzzards Bay
719	Swanson Bog	42405224	Slocum-Gibbs Cran.Co.Inc.	Wareham St.	Carver	Buzzards Bay
720		42405237	SK Wainio Bogs Inc.	Tremont St.	Carver	Buzzards Bay
738		42419601	Rivers Edge Realty LLC	Rochester Rd.	Carver	Buzzards Bay
739	Home Bog	42405270	Oiva Hannula & Sons, Inc.	Indian St.	Carver	Buzzards Bay
740	E13	42405285	Weston Bros. Cranberries LLC	Indian St.	Carver	Buzzards Bay
741	Part of Site 1	42405285	Weston Bros. Cranberries LLC	Lakeview St.	Carver	Buzzards Bay
742	Jungle Bog	42405287	Roger W. Shores	Rochester Rd.	Carver	Buzzards Bay
743	Bailey Bog	42405270	Oiva Hannula & Sons, Inc.	Main St.	Carver	Buzzards Bay
744	Shaw Bog	9P242405203	Oiva Hannula & Sons, Inc.	Main St.	Carver	Buzzards Bay
745	Shaw Bog	42405270	Oiva Hannula & Sons, Inc.	Main St.	Carver	Buzzards Bay
754	Lakenham Bk	42505209	Paul M. Rodrigues	Gate St.	Carver	Taunton
755	0	42405263	Dave M. Cowan	South Meadow Rd.	Carver	Buzzards Bay
756	Ward No. 1	42405245	SRD Real Estate LLC	West St.	Carver	Buzzards Bay
757	Meadow St. Bog	42405210	Curtis T. Young	Meadow St.	Carver	Buzzards Bay
759	Atwood Bogs	42405294	Cranebrook Cranberry LLC	Meadow St.	Carver	Buzzards Bay
760	Atwood Bogs	abandoned	Cranebrook Cranberry LLC	Meadow St.	Carver	Buzzards Bay
761		42405294	Cranebrook Cranberry LLC	Eda Ave.	Carver	Buzzards Bay
762		42405227	William Shurtleff	Rochester Rd.	Carver	Buzzards Bay
775		none	Michael Paduch	West St.	Carver	Buzzards Bay
776	Pass Bog	42418205	Kenneth & Bettygene Harju	Main St.	Carver	Buzzards Bay
777	Sampson Pond	42405261	Davison Partners	Mayflower Rd.	Carver	Buzzards Bay
778	Remeskyla	42405235	William Remes	Mayflower Rd.	Carver	Buzzards Bay
797		none	Kirsti Kaski	Meadow St.	Carver	Buzzards Bay
798	0	none	Richard Johnson	0	Carver	Buzzards Bay
799		42405228	Tilson Brook Cranberry LLC	Tremont St.	Carver	Buzzards Bay
800	Big Bog	42405283	Benson Pond Inc.	East Head Rd.	Carver	Buzzards Bay
820		42505203	Eric & Elaine Weston	Plymouth St.	Carver	Taunton
821	North Carver Bog	42505203	Eric & Elaine Weston	Plymouth St.	Carver	Taunton
822		certified	Fred Carlson	Snapit Rd.	Carver	Taunton
825		42505232	Greenn 1A LLC	Center St.	Carver	Taunton
826	Walker Rd.	42505217	Domingo Fernandes	Walker Rd.	Carver	Taunton
834	Sites 4 & 5	42405285	Weston Bros. Cranberries LLC	Tremont	Carver	Buzzards Bay
835	Sites 2 & 3	42405285	Weston Bros. Cranberries LLC	Tremont St.	Carver	Buzzards Bay
836	Bartholomew Bogs	42405285	Weston Bros. Cranberries LLC	Tremont St.	Carver	Buzzards Bay
837	Cross Street	42405217	Johnson Brothers Cran LLC	Cross St.	Carver	Buzzards Bay
838		42405256	Derek Medico & Ward Hannula	Popes Point Rd.	Carver	Buzzards Bay
839		42405256	Derek Medico & Ward Hannula	Popes Point Rd.	Carver	Buzzards Bay
856	0	none	George A. Peck	High St.	Carver	Taunton
857	Finney 5-15 Bogs	42505214	A.D. Makepeace Co.	Snappit Rd.	Carver	Taunton
858		V42505228	Rose Cranberry Realty Trust	Snappit Rd.	Carver	Taunton
859	Vochell Bog	42405229	Stephen Peltola	Main St.	Carver	Buzzards Bay
860	Home Bog	42405268	Gary Weston	Main St.	Carver	Buzzards Bay
861	Cedar Swamp Bog	42405210	Curtis T. Young	Main St.	Carver	Buzzards Bay
862	Goose Pond Bog	42423910	William B. Stearns III & IV	Tremont St.	Carver	Buzzards Bay
883	South Carver Bog	42405226	Gilmore Cranberry Co Inc	Cranberry Rd.	Carver	Buzzards Bay
884	Lawson Bog	42405243	David A. Lawson, Jr.	Old South Meadow Rd.	Carver	Buzzards Bay
891	Carver Bog	none	Richard A. Johnson	Tremont Street	Carver	Buzzards Bay
892		none	DCR	Shoestring Road	Carver	Buzzards Bay
893	T.B. Smart Bog	none	Benson Pond Inc.	Shoestring Road	Carver	Buzzards Bay
894	Shoestring Bogs	42405264	Shoestring Bogs	Tremont St.	Carver	Buzzards Bay
898	Charlie Bings & Log Sw	abandoned	Charles R. Johnson	Purchase St.	Carver	Buzzards Bay
899	Log Swamp	42405218	Johnson Cranberries Ltd Ptn	Fuller St.	Carver	Buzzards Bay
900		abandoned	Charles R. Johnson	Fosdick Rd.	Carver	Buzzards Bay
901	Fosdick Bog	42405218	Johnson Cranberries Ltd Ptn	Fosdick Rd.	Carver	Buzzards Bay
904	BOC Bogs	42405297	Michael & Sherrie Bassignani	Meadow St.	Carver	Buzzards Bay
905	Atwood C16 & C17	42405294	Cranebrook Cranberry LLC	Meadow St.	Carver	Buzzards Bay
908	Bent Bog	42418212	Harju Brothers Cranberries Inc	Popes Point Rd.	Carver	Buzzards Bay
917		42505221	Gary S. Randall	Green St.	Carver	Taunton
918	Swan Holt	42431033	A.D. Makepeace Co.	Bunny's Rd.	Carver	Buzzards Bay
919	was DiPlacido & Hiller	42405294	Cranebrook Cranberry LLC	Pond St.	Carver	Buzzards Bay
920		42405238	Edward Silva Jr.	Old Center St.	Carver	Buzzards Bay
921	Steva 1	42418205	Kenneth & Bettygene Harju	Center St.	Carver	Buzzards Bay
926	Atwood A	42424001	Edgewood Bogs LLC	Tremont St.	Carver	Buzzards Bay
927	Federal Bog	42405209	Federal Furnace Cranberry Co.	Tremont St.	Carver	Buzzards Bay

929	Finney 1-4A Bogs	42505214	A.D. Makepeace Co.	Snappit Rd.	Carver	Taunton
930	Main St. Bog	42405255	Mark F. Weston	Main St.	Carver	Buzzards Bay
933	Burgess Bog	42505234	Nantasket Cranberry Ltd Ptshp	Fuller St.	Carver	Taunton
939	Center St.	42405291	Franklin Marsh, LLC	Center St.	Carver	Buzzards Bay
940	Site 1 Bogs E3 & E4	42405285	Weston Bros. Cranberries LLC	Lakeview St.	Carver	Buzzards Bay
942	Paduch Bog	42405274	Ward R. Hannula	Meadow St.	Carver	Buzzards Bay
945	0 & 1 Bog	V42405289	David Piper, Jr.	Cranberry Rd.	Carver	Buzzards Bay
946		V42405288	G.Gregory White	Cranberry Rd.	Carver	Buzzards Bay
947	White Spring Bog	42405254	Hamlin Realty LLC	Cranberry Rd.	Carver	Buzzards Bay
953	Carverside	abandoned	A.D. Makepeace Co.	Federal Rd.	Carver	Buzzards Bay
954	Carverside	42431033	A.D. Makepeace Co.	Federal Rd.	Carver	Buzzards Bay
967	South Meadow Bog	42424001	Edgewood Bogs LLC	South Meadow Road	Carver	Buzzards Bay
968	South Meadow Bk	42431041	David & Eleanor Eldredge	Meadow St.	Carver	Buzzards Bay
970	Thomas Bog	42405226	Gilmore Cranberry Co Inc	Cranberry Rd.	Carver	Buzzards Bay
975	Beaver Dam Bog	42405295	Pride of Carver Cran Ltd Ptnrs	Beaver Dam Rd.	Carver	Buzzards Bay
976	Holmes Bog	42405229	Stephen Peltola	Holmes St.	Carver	Buzzards Bay
980		none	Curtis T. Young	Tremont St.	Carver	Buzzards Bay
981	0	none	John Gomes	0	Carver	Taunton
982		NONE	Williams Brothers	Fuller St.	Carver	Buzzards Bay
984	Wade St	42431033	A.D. Makepeace Co.	Wade St.	Carver	Buzzards Bay
989	Wankinco	42431033	A.D. Makepeace Co.	Cranberry Rd.	Carver	Buzzards Bay
990		42419603	John G. Shurtleff	Meadow St.	Carver	Buzzards Bay

Appendix E

Priority Firefighting Water Source Site Summaries

Fire Department Water Supply Site #1 – W 1-1

The CFD (Carver Fire Department) draft from the surface of this small unnamed tributary off of South Meadow Brook alongside Main Street. This site is readily accessible year round with adequate room for a firetruck. There is the potential for permitting complexity at this site because of its location within a wetland in a nonagricultural area.

- Waterbody Name: Unnamed Tributary
- Estimated Surface Area: N/A
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 13.21

Drought Vulnerability Index Score: **5.00**
Implementation and Operation Score: **8.21**

Recommendations:

Dredge water supply sediment bottom to required depths and clear bank vegetation to allow access year round.

Fire Department Water Supply Site #2 – W 1-25

The CFD draft from the surface of Beaver Dam Brook in close proximity to Beaver Dam Road. Vegetation along the banks may seasonally prevent access to the site and aquatic vegetation within the site may clog pumping apparatuses. Additionally, the site has a history of algal blooms and the potential for future sedimentation due to upstream agricultural land use upstream.

- Waterbody Name: Beaver Dam Brook
- Estimated Surface Area: 96,500 sf
- Depth Near Shore: Less than 2 feet

Prioritization Score: 9.88

Drought Vulnerability Index Score: **6.67**
Implementation and Operation Score: **3.21**

Recommendations:

Dredge sediment bottom to required depths and area, use control structures to maintain high water levels, clear bank and aquatic vegetation, and plant new emergent aquatic vegetation.

Fire Department Water Supply Site #3 – W 1-33

The CFD draft near the banks of South Meadow Brook Pond from Holmes Street. The site is accessible year round with room for multiple firetrucks, however aquatic vegetation within the site may clog pumping apparatuses. Additionally, the site has a history of algal blooms and the potential for future sedimentation due to upstream agricultural land use. The Town of Carver's Master Plan categorizes land neighboring the site as a potential future growth area.

- Waterbody Name: South Meadow Brook Pond
- Estimated Surface Area: 1,080,000 sf
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 11.07

Drought Vulnerability Index Score: **5.00**
Implementation and Operation Score: **6.07**

Recommendations:

Dredge sediment bottom to required depths and area, clear bank and aquatic vegetation, and plant new emergent aquatic vegetation.

Fire Department Water Supply Site #4 – W 1-5

The CFD draft from the surface of a small detention pond on Old Center St that is part of a large cranberry farm irrigation system fed by a large reservoir. The site is easily accessible by multiple firetrucks. This pond has a history of algal blooms and the potential for future sedimentation due to the surrounding agricultural land use.

- Waterbody Name: Unnamed Reservoir
- Estimated Surface Area: N/A
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 9.17

Drought Vulnerability Index Score: **6.67**
Implementation and Operation Score: **2.50**

Recommendations:

Dredge sediment bottom to required depths and area, and utilize cranberry farm irrigation control structures to maintain higher water levels within the water source during drought conditions.

Fire Department Water Supply Site #5 – W 2-10

The CFD draft from the surface of Muddy Pond Brook. The site is accessible through an unpaved road off of Green St. The site has the potential for sedimentation and heavily restricted seasonal access due to dense bank vegetation.

- Waterbody Name: Muddy Pond Brook
- Estimated Surface Area: N/A
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 10.00

Drought Vulnerability Index Score: **10.00**
Implementation and Operation Score: **0.00**

Recommendations:

Dredge sediment bottom to required depths, utilize upstream cranberry farm irrigation control structures to maintain higher water levels within the water source, and clear banks of vegetation.

Fire Department Water Supply Site #6 – W 2-12

The CFD frequently draft from a conduit behind Shaw's shopping complex on North Main St. The conduit has minor bank vegetation but dense aquatic vegetation that may clog pumping apparatuses. There is the potential for future sedimentation within the conduit due to upstream agricultural land use and the land neighboring the site is heavily commercialized and is categorized as a potential future growth areas in the Town of Carver's Master Plan.

- Waterbody Name: Unnamed Conduit
- Estimated Surface Area: N/A
- Depth Near Shore: Less than 2 feet

Prioritization Score: 16.43

Drought Vulnerability Index Score: **10.00**
Implementation and Operation Score: **6.43**

Recommendations:

Dredge sediment bottom to required depths and area, clear bank and aquatic vegetation to ensure seasonal access and prevent potential pumping obstructions.

Fire Department Water Supply Site #7 – W 2-19

The CFD draft from the surface of a large reservoir neighboring Leland Way. The reservoir is easily accessible via wide unpaved roads and is clear of any troublesome vegetation. However, this water supply has a history of algal blooms and has the potential for permitting complexity due to its location within a nonagricultural wetland.

- Waterbody Name: Unnamed Reservoir
- Estimated Surface Area: 298,000 sf
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 11.07

Drought Vulnerability Index Score: **5.00**
Implementation and Operation Score: **6.07**

Recommendations:

Dredge sediment bottom to required depths and area, and utilize upstream cranberry farm irrigation control structures to maintain higher water levels within the water source.

Fire Department Water Supply Site #8 – W 2-26

The CFD draft from the surface of Fuller Street Pond off of Fuller St. The site is accessible via an unpaved road. Dense bank vegetation and shallow water near the banks have the potential to restrict access to one firetruck and prevent serviceability seasonally. Additionally, the site has a history of algal blooms and the potential for future sedimentation due to the surrounding agricultural land use.

- Waterbody Name: Fuller Street Pond
- Estimated Surface Area: 970,000 sf
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 13.57

Drought Vulnerability Index Score: **10.00**
Implementation and Operation Score: **3.57**

Recommendations:

Dredge sediment bottom to required depths and area, use control structures to maintain high water levels, clear bank and aquatic vegetation, and plant new emergent aquatic vegetation.

Fire Department Water Supply Site #9 – W 2-28

The CFD draft from the surface of North Center Street Pond alongside Plymouth St after removing large stones that are blocking access. This water supply has been deepened once prior. Additionally, this water supply has a history of algal blooms and dense vegetation on the banks has the potential to restrict access seasonally.

- Waterbody Name: North Center Street Pond
- Estimated Surface Area: 515,000 sf
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 8.33

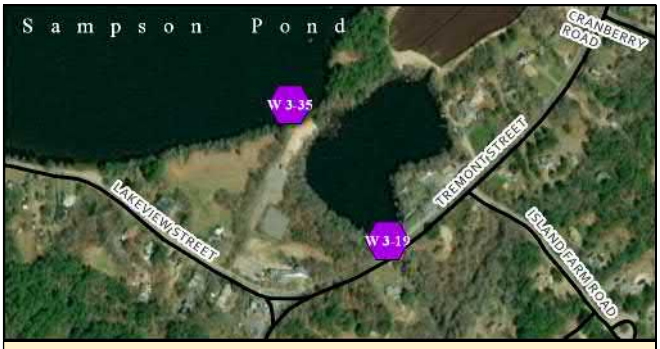
Drought Vulnerability Index Score: **3.33**
Implementation and Operation Score: **5.00**

Recommendations:

Dredge sediment bottom to required depths and area, clear bank vegetation to allow access year round, and plant new emergent aquatic vegetation.

Fire Department Water Supply Site #10 – W 3-19

The CFD draft from the surface of Lower Sampson Pond off of Tremont St. Lower Sampson Pond is fed directly from Sampson Pond and water levels are known to become very low during drought. Minor bank and aquatic vegetation exist at the drafting site and have the potential to prevent access or clog pumping apparatuses. Additionally, the site has a history of algal blooms and the potential for future sedimentation due to surrounding agricultural and impervious land use.



- Waterbody Name: Lower Sampson Pond
- Estimated Surface Area: 257,000 sf
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 9.52

Drought Vulnerability Index Score: **6.67**
Implementation and Operation Score: **2.86**

Recommendations:

Dredge sediment bottom to required depths and area, maintain higher water levels with control structures, clear bank and aquatic vegetation and plant new emergent aquatic vegetation.

Fire Department Water Supply Site #11 – W 3-28

The CFD draft from the surface of Clear Pond alongside Wareham St. Water levels within Clear Pond fluctuate greatly throughout a given year. There is adequate access to the site for a single firetruck. This water supply has a history of algal blooms and the potential for sedimentation due to surrounding agricultural land use.

- Waterbody Name: Clear Pond
- Estimated Surface Area: 480,000 sf
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 12.98

Drought Vulnerability Index Score: **8.33**
Implementation and Operation Score: **4.64**

Recommendations:

Dredge sediment bottom to required depths and area, use control structures to maintain high water levels, clear bank vegetation for additional access, and plant new emergent aquatic vegetation.

Fire Department Water Supply Site #12 – W 3-35

The CFD draft from the surface of Sampson Pond alongside Ridge Rd. Access to Sampson Pond is excellent with adequate room for multiple fire trucks simultaneously. Sampson Pond has aquatic vegetation that may clog pumping apparatuses, a history of algal blooms and is affected by phragmite, an invasive species.

- Waterbody Name: Sampson Pond
- Estimated Surface Area: 12,900,000 sf
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 7.14

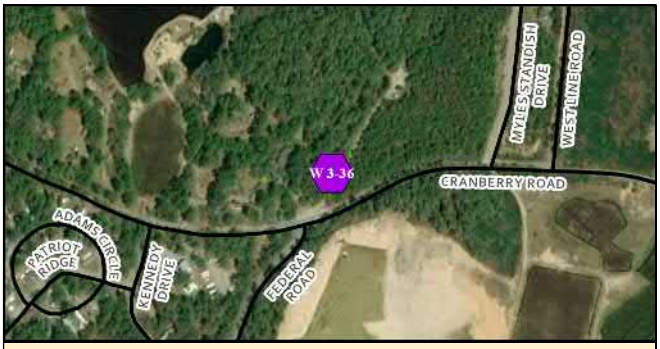
Drought Vulnerability Index Score: **5.00**
Implementation and Operation Score: **2.14**

Recommendations:

Dredge sediment bottom to required depths and area, maintain higher water levels within supply, remove aquatic vegetation and invasive species, and plant new emergent aquatic vegetation.

Fire Department Water Supply Site #13 – W 3-36

The CFD draft from a pressurized dry hydrant alongside Cranberry Road. The hydrant is interconnected with Cranberry Village's (mobile home community) water system which has an approximate capacity of 5000-10,000 gallons. When the CFD is drafting from this supply, the community has extremely limited access to water and the CFD has tapped this source completely dry in the past. This water source is especially valuable because it is one of the few water supplies bordering the Myles Standish State Forest.



- Waterbody Name: Unnamed Well
- Estimated Surface Area: N/A
- Depth Near Shore: N/A

Prioritization Score: 10.00

Drought Vulnerability Index Score: **0.00**
Implementation and Operation Score: **10.00**

Recommendations:

A detailed site-specific investigation is necessary. The preliminary recommendation is to increase capacity with an installation of an underground cistern or well system to improve the site's ability to supply water.

Fire Department Water Supply Site #14 – W 3-6

The CFD typically draft from the surface of Bates Pond alongside Meadow St. The site also features a secondary roadside dry hydrant, however its use is limited due to the potential for subsurface cracks in piping that lower drafting rates. Bates Pond has a history of algal blooms and bank vegetation that may prevent access to the drafting site. A neighboring cranberry bog draws from Bates Pond through a pump station and a diversion channel with flume boards.

- Waterbody Name: Bates Pond
- Estimated Surface Area: 925,000 sf
- Depth Near Shore: Less than 2 feet

Prioritization Score: 19.64

Drought Vulnerability Index Score: **10.00**
Implementation and Operation Score: **9.64**

Recommendations:

Dredge sediment bottom to required depths and area, use control structures to maintain high water levels, clear bank vegetation for additional access, and plant new emergent aquatic vegetation.

Fire Department Water Supply Site #15 – DH 3-38

The CFD draft from a dry hydrant connected to a small surface reservoir alongside Myles Standish Dr. Access to the dry hydrant is adequate and secondary access to the reservoir for direct drafting by at least 1 firetruck from the surface is possible. The surface reservoir has a history of algal blooms. This water supply is especially valuable because it is one of the few water supplies bordering the Myles Standish State Forest.

- Waterbody Name: Unnamed Reservoir
- Estimated Surface Area: 9,000 sf
- Depth Near Shore: Greater than 2 feet

Prioritization Score: 7.98

Drought Vulnerability Index Score: **3.33**
Implementation and Operation Score: **4.64**

Recommendations:

Dredge sediment bottom to required depths and area, and utilize cranberry farm irrigation control structures to maintain higher water levels within the water source.

Appendix F

Town-wide Firefighting Water Supply Source Groundwater Levels Under Drought of Record Conditions

Water Supply Site Identifier	Water Supply Location (Latitude)	Water Supply Location (Longitude)	USGS Simulated Groundwater Level Drop for Recurrence of the 1966 Record Drought (ft)	Maximum USGS Simulated Groundwater Level Drop for Recurrence of the 1966 Record Drought (ft)
W MS-12	-70.6877623286°W	41.8532295359°N	-4 to <-6	-6
DH 3-38	-70.7140408041°W	41.8462191477°N	-2 to <-4	-4
L1	-70.7913481474°W	41.9200920561°N	-2 to <-4	-4
L2	-70.7879047128°W	41.9180997741°N	-2 to <-4	-4
L25	-70.7405811769°W	41.8318822192°N	-2 to <-4	-4
L26	-70.6939155938°W	41.8459795899°N	-2 to <-4	-4
L27	-70.6922302469°W	41.8451757877°N	-2 to <-4	-4
L6	-70.7841209902°W	41.9050152571°N	-2 to <-4	-4
W 2-1	-70.7833452804°W	41.9361825113°N	-2 to <-4	-4
W 2-14	-70.8162622812°W	41.9177016323°N	-2 to <-4	-4
W 2-15	-70.8114172631°W	41.9188874608°N	-2 to <-4	-4
W 2-18	-70.7756688261°W	41.9238476956°N	-2 to <-4	-4
W 2-2	-70.7804551837°W	41.9364204339°N	-2 to <-4	-4
W 2-20	-70.7845350478°W	41.9055365073°N	-2 to <-4	-4
W 2-21	-70.7815047603°W	41.9070182918°N	-2 to <-4	-4
W 2-25	-70.7732911483°W	41.9365358852°N	-2 to <-4	-4
W 2-26	-70.811113428°W	41.9071650337°N	-2 to <-4	-4
W 2-27	-70.7893006464°W	41.9157146132°N	-2 to <-4	-4
W 2-28	-70.7853037034°W	41.9223003827°N	-2 to <-4	-4
W 2-3	-70.7696218934°W	41.9400262864°N	-2 to <-4	-4
W 2-4	-70.7859093397°W	41.9386999152°N	-2 to <-4	-4
W 2-8	-70.8103973654°W	41.9114487355°N	-2 to <-4	-4
W 2-9	-70.7885920556°W	41.9270436988°N	-2 to <-4	-4
W 3-11	-70.7225598141°W	41.83736784°N	-2 to <-4	-4
W 3-21	-70.730556792°W	41.8135040845°N	-2 to <-4	-4
W 3-23	-70.7450702585°W	41.8087412819°N	-2 to <-4	-4
W 3-27	-70.7412193541°W	41.832681327°N	-2 to <-4	-4
W 3-28	-70.7407978228°W	41.8306297729°N	-2 to <-4	-4
W 3-29	-70.7418866592°W	41.8247766412°N	-2 to <-4	-4
W 3-30	-70.7472424416°W	41.8027523298°N	-2 to <-4	-4
W 3-36	-70.718564495°W	41.8410568785°N	-2 to <-4	-4
W MS-10	-70.6914577524°W	41.8449553653°N	-2 to <-4	-4
W MS-11	-70.6947994668°W	41.8460373051°N	-2 to <-4	-4
W MS-4	-70.7138193986°W	41.8641799306°N	-2 to <-4	-4
W MS-6	-70.6978551846°W	41.8411989926°N	-2 to <-4	-4
W MS-9	-70.6900424518°W	41.8392856052°N	-2 to <-4	-4
DH 3-24	-70.7147026873°W	41.8286901866°N	-1 to <-2	-2
DH 3-37	-70.7300551932°W	41.844517841°N	-1 to <-2	-2
L0	-70.7983870263°W	41.9277580971°N	-1 to <-2	-2
L10	-70.7792123331°W	41.8921361503°N	-1 to <-2	-2
L11	-70.7805015636°W	41.8895911532°N	-1 to <-2	-2
L18	-70.7736084081°W	41.8379021215°N	-1 to <-2	-2
L3	-70.7971754545°W	41.9161891377°N	-1 to <-2	-2
L4	-70.7976177657°W	41.911086223°N	-1 to <-2	-2
L7	-70.7669799892°W	41.9161694299°N	-1 to <-2	-2
W 1-13	-70.7566211662°W	41.9241898445°N	-1 to <-2	-2
W 1-2	-70.7838279826°W	41.9003506959°N	-1 to <-2	-2
W 1-22	-70.7288274582°W	41.8999447886°N	-1 to <-2	-2
W 1-28	-70.7790875718°W	41.8923522503°N	-1 to <-2	-2
W 1-30	-70.7798688624°W	41.8909278339°N	-1 to <-2	-2
W 2-10	-70.7983539196°W	41.9180145235°N	-1 to <-2	-2
W 2-11	-70.7984913884°W	41.9109116769°N	-1 to <-2	-2

W 2-17	-70.7536129043°W	41.927743593°N	-1 to <-2	-2
W 2-29	-70.767285044°W	41.9289041271°N	-1 to <-2	-2
W 2-5	-70.7994580233°W	41.9288677586°N	-1 to <-2	-2
W 2-7	-70.7694949834°W	41.9156253697°N	-1 to <-2	-2
W 3-10	-70.7688678383°W	41.8438203135°N	-1 to <-2	-2
W 3-20	-70.7140093399°W	41.8229203079°N	-1 to <-2	-2
W 3-31	-70.7140185377°W	41.86870761°N	-1 to <-2	-2
W 3-4	-70.7412570319°W	41.8616499008°N	-1 to <-2	-2
W 3-43	-70.7300121858°W	41.8428023186°N	-1 to <-2	-2
W 3-5	-70.7801093246°W	41.8414142685°N	-1 to <-2	-2
W 3-6	-70.7739949981°W	41.8356104535°N	-1 to <-2	-2
W MS-2	-70.728317363°W	41.8512240894°N	-1 to <-2	-2
W MS-5	-70.7096923681°W	41.8320384038°N	-1 to <-2	-2
W MS-8	-70.6940837521°W	41.837122537°N	-1 to <-2	-2
DH 1-29	-70.7652544335°W	41.8892266843°N	0 to <-1	-1
DH 1-35	-70.7668898707°W	41.8925604374°N	0 to <-1	-1
DH 2-30	-70.8122263989°W	41.9281413531°N	0 to <-1	-1
DH 3-16	-70.7549989859°W	41.841967703°N	0 to <-1	-1
L12	-70.778493916°W	41.8625410569°N	0 to <-1	-1
L13	-70.7682725899°W	41.8633947155°N	0 to <-1	-1
L14	-70.7626151455°W	41.8566977329°N	0 to <-1	-1
L15	-70.7302444199°W	41.8668442327°N	0 to <-1	-1
L16	-70.7166473844°W	41.8744782144°N	0 to <-1	-1
L17	-70.707583619°W	41.8713957623°N	0 to <-1	-1
L19	-70.7493758943°W	41.8457190153°N	0 to <-1	-1
L20	-70.7437727274°W	41.8529100047°N	0 to <-1	-1
L21	-70.7451213324°W	41.8448663364°N	0 to <-1	-1
L22	-70.7427326578°W	41.8484093536°N	0 to <-1	-1
L23	-70.7561033761°W	41.856124148°N	0 to <-1	-1
L24	-70.7316962533°W	41.8518194578°N	0 to <-1	-1
L29	-70.7865479479°W	41.8720835805°N	0 to <-1	-1
L8	-70.7619314608°W	41.9190369373°N	0 to <-1	-1
L9	-70.7474761579°W	41.9187360895°N	0 to <-1	-1
W 1-1	-70.7646116384°W	41.8813849391°N	0 to <-1	-1
W 1-10	-70.7249082562°W	41.8957731186°N	0 to <-1	-1
W 1-11	-70.8029109633°W	41.8713339876°N	0 to <-1	-1
W 1-12	-70.7616542123°W	41.9192912465°N	0 to <-1	-1
W 1-14	-70.7767796319°W	41.8850122408°N	0 to <-1	-1
W 1-15	-70.7888816799°W	41.8603843721°N	0 to <-1	-1
W 1-16	-70.8031856169°W	41.8811981538°N	0 to <-1	-1
W 1-17	-70.7979630487°W	41.8749246689°N	0 to <-1	-1
W 1-18	-70.7914989231°W	41.8772193229°N	0 to <-1	-1
W 1-19	-70.7899440619°W	41.8794489714°N	0 to <-1	-1
W 1-20	-70.7483314162°W	41.8927613496°N	0 to <-1	-1
W 1-21	-70.7413526506°W	41.8964672354°N	0 to <-1	-1
W 1-23	-70.7649375136°W	41.8752408274°N	0 to <-1	-1
W 1-24	-70.8076077053°W	41.879081048°N	0 to <-1	-1
W 1-25	-70.7904804161°W	41.8828112734°N	0 to <-1	-1
W 1-26	-70.7465338905°W	41.9032195014°N	0 to <-1	-1
W 1-27	-70.7487958412°W	41.918278314°N	0 to <-1	-1
W 1-29	-70.8010248703°W	41.8747528832°N	0 to <-1	-1
W 1-3	-70.7668882015°W	41.8719182212°N	0 to <-1	-1
W 1-31	-70.8012892852°W	41.8797095697°N	0 to <-1	-1
W 1-32	-70.8020012746°W	41.8670880306°N	0 to <-1	-1
W 1-33	-70.7872779698°W	41.8727144159°N	0 to <-1	-1
W 1-34	-70.7615066243°W	41.8797449589°N	0 to <-1	-1

W 1-4	-70.7757083106°W	41.8698781611°N	0 to <-1	-1
W 1-5	-70.7704633525°W	41.8979076542°N	0 to <-1	-1
W 1-6	-70.7631002059°W	41.9018268086°N	0 to <-1	-1
W 1-7	-70.7539560829°W	41.8984441836°N	0 to <-1	-1
W 1-8	-70.7618441687°W	41.8863817147°N	0 to <-1	-1
W 1-9	-70.7403860459°W	41.8866101802°N	0 to <-1	-1
W 2-12	-70.8094023132°W	41.9238065169°N	0 to <-1	-1
W 2-13	-70.8172693043°W	41.9264147128°N	0 to <-1	-1
W 2-19	-70.8056494759°W	41.8905872891°N	0 to <-1	-1
W 2-22	-70.8214759043°W	41.9245637744°N	0 to <-1	-1
W 2-23	-70.8058310762°W	41.8870864997°N	0 to <-1	-1
W 2-24	-70.8092983291°W	41.8848563157°N	0 to <-1	-1
W 2-6	-70.8050711135°W	41.9388776416°N	0 to <-1	-1
W 3-1	-70.770806996°W	41.846977305°N	0 to <-1	-1
W 3-12	-70.7582975632°W	41.8487071716°N	0 to <-1	-1
W 3-13	-70.7566805974°W	41.8562245847°N	0 to <-1	-1
W 3-14	-70.7332859686°W	41.8566891533°N	0 to <-1	-1
W 3-15	-70.7394314065°W	41.8490593998°N	0 to <-1	-1
W 3-17	-70.7499173817°W	41.8352164189°N	0 to <-1	-1
W 3-18	-70.753479112°W	41.8302846813°N	0 to <-1	-1
W 3-19	-70.7439659853°W	41.843741222°N	0 to <-1	-1
W 3-2	-70.7550268091°W	41.8395856236°N	0 to <-1	-1
W 3-22	-70.735095996°W	41.8439323652°N	0 to <-1	-1
W 3-25	-70.7535846195°W	41.826711977°N	0 to <-1	-1
W 3-26	-70.7500562551°W	41.8450798984°N	0 to <-1	-1
W 3-3	-70.7638022144°W	41.8355451157°N	0 to <-1	-1
W 3-32	-70.7266978942°W	41.8744163791°N	0 to <-1	-1
W 3-33	-70.7299782924°W	41.8667200304°N	0 to <-1	-1
W 3-34	-70.7368648752°W	41.8558555336°N	0 to <-1	-1
W 3-35	-70.7428246752°W	41.8530841737°N	0 to <-1	-1
W 3-40	-70.7187688191°W	41.88679779°N	0 to <-1	-1
W 3-42	-70.7439133587°W	41.8365108425°N	0 to <-1	-1
W 3-7	-70.7815675482°W	41.8477126133°N	0 to <-1	-1
W 3-8	-70.7174129962°W	41.8777835469°N	0 to <-1	-1
W 3-9	-70.7719558114°W	41.8300706157°N	0 to <-1	-1
W MS-1	-70.7273415816°W	41.8581260552°N	0 to <-1	-1
W MS-13	-70.7060115873°W	41.8718444184°N	0 to <-1	-1
W MS-14	-70.7046547505°W	41.8784100295°N	0 to <-1	-1
W MS-3	-70.7244211288°W	41.8624419632°N	0 to <-1	-1
W MS-7	-70.6971079162°W	41.8347615893°N	0 to <-1	-1
DH 2-31	-70.8142389489°W	41.9327018343°N	Out of Simulated Area	Out of Simulated Area
W 2-16	-70.822182339°W	41.9188803941°N	Out of Simulated Area	Out of Simulated Area

Source: Fig 26, Masterson, J.P., Carlson, C.S., and Walter, D.A., 2009

Appendix G

Task 2 Report – Firefighting Source Waters

Fire Department Water Supply Source Assessment

Photo credit: © Susan Cole Kelly 2018

Town of Carver

Municipal Vulnerability Preparedness (MVP)

Action Grant

Climate Change Water Resources Vulnerability and Adaptation Strategy Assessment

Technical Report – Task 2

May 2019

FUSS & O'NEILL

Project No. 20170390.A51

Table of Contents

Appendices

1 Introduction and Purpose

Members of the Carver Municipal Vulnerability Preparedness (MVP) Core Team and additional stakeholders participated in a Community Resilience Building (CRB) workshop on April 19, 2018 to identify the top natural hazards of concern for the Town of Carver and identified Wind, Wildfire, Excessive Precipitation or Drought, and Extreme Temperatures. Of these, Excessive Precipitation or Drought directly relates to the sustainability of Carver's water resources and Wildfire represents a potential significant stressor on water supplies for firefighting. As a result, the Town is undertaking a Climate Change Water Resources Vulnerability and Adaptation Strategy Assessment with assistance from a MVP Action Grant.

Through the MVP planning process, the Town of Carver has recognized potential vulnerabilities to the availability and quality of surface and groundwater within the town. With the absence of a public water supply and town-wide distribution system, dependable water availability and access is critical not only for the Carver Fire Department (CFD) as it primarily relies on scattered surface water for firefighting, but also for the cranberry growing industry within Carver. Sedimentation and aquatic vegetation growth within surface water sources threaten their ability to provide sufficient water to meet firefighting needs. The prolonged drought during summer 2016 further underscored the susceptibility of these water supplies, particularly under a changing climate where high temperature and drought extremes are predicted to worsen and potential for forest fires within the Myles Standish State Forest may also increase. Thus it is crucial that the Town of Carver efficiently pursue adaption strategies and specific adaptation actions that will enhance the climate resiliency of their water infrastructure to protect their public, economic, and environmental health.

This report outlines the elements of the Water Resources Vulnerability and Adaptation Strategy Assessment that characterize water supplies identified as both critical for firefighting and representative of the types of surface water supplies used for firefighting throughout the Town of Carver. An approach to prioritizing the water supplies for improvements to increase resiliency is described and demonstrated for the 15 priority water supplied identified through the assessment process. This approach and methodology is applicable to all surface water supplies and can be expanded to include prioritization beyond the initial subset of water supplies that are the focus of this study.

2 Approach to the Assessment

A key task in the Climate Change Water Resources Vulnerability and Adaptation Strategy Assessment project focused on conducting a detailed vulnerability and risk assessment of surface water supplies focused on supporting fire suppression activities under current and future climate conditions. The assessment was carried out through a four step approach outlined in Figure 1.

In the first step of the assessment, Fuss & O'Neill coordinated with the CFD's Fire Chief Officer Craig Weston to identify a high priority subset of the previously identified and mapped potential water sources within town boundaries. As outlined in Section 3, a water source was categorized as a priority source based on its geographic location, its importance to the CFD due to its size or proximity to fire threats, and how representative it was of typical firefighting water supplies in the community.

In the second step of the assessment, these priority water supplies were physically inspected by Fuss & O'Neill staff to assess physical characteristics such as water depth, ease of access, history of algal blooms, potential for sedimentation, etc. This information was collected for each water source inspected as described in Section 4.

In the third step of the assessment, data gathered from field inspections, as well as GIS and town data assembled in the previous desktop assessment in Task 1, and data gathered from correspondence with CFD's Chief Officer and other members of the community were used to develop a list of key characteristics that could identify a water supply's vulnerabilities under future drought conditions based on currently available climate projections. This vulnerability assessment is outlined in Section 5.

The fourth and final step of the assessment utilized the information gathered to develop a specialized prioritization spreadsheet tool. This tool allows each water source to receive a relative prioritization ranking and allows for prioritization of adaptation options by the Town and provides a methodology that can be expanded to additional water resources in Carver. The work outlined in this task advances the goal of allowing identification of specific priority actions and conceptual design of improvements that will increase long-term resilience to Carver's water infrastructure.

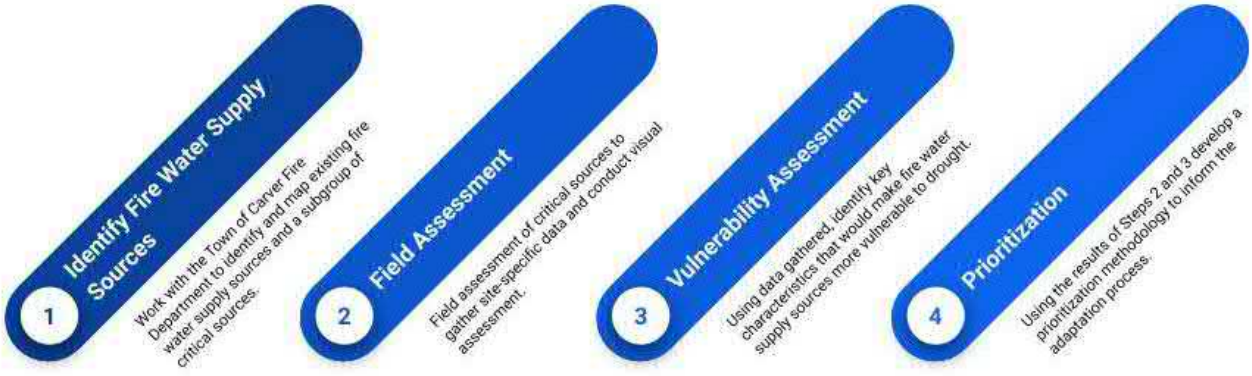


Figure 1. Approach to Fire Water Supply Vulnerability Assessment Task

3 Identification of Sources

Retrieval of Carver Fire Department Data

The CFD provided Fuss & O'Neill with a copy of the "2009 Carver Fire Department Map Book" depicting the location of the approximately 150 surface water sources identified as potential surface water supply sources for fire suppression. Locations of water supplies shown in the map book were subsequently digitized and the approximately150 water supply sources were spatially referenced in ArcGIS to create a GIS feature dataset of the existing water supply sources. This data set was used in conjunction with aerial imagery, mapped hydrography, and other publically-available geospatial data obtained from MassGIS to create maps that were reviewed by the CFD to confirm the accuracy of the water supply locations (see Appendix B).

Identification of Priority Sources

Using the map in Appendix B, Fuss & O'Neill staff worked with the CFD and the Town MVP Action Grant Steering Committee members to identify priority water supply sources in a conference call on November 8, 2018. Based on that meeting, 20 of the ~150 total water supply sources were identified as priority sources based on whether they had experienced issues with water availability during previous droughts, were located near population centers, or were of critical interest to the CFD. Of the 20 water supply sources identified as high priority, 15 water supplies were selected for field investigations due to their spatial variability and surrounding land use, so that they would be representative of other similar water sources located throughout the town (Table 1).

Table 1. Inspected Fire Department Water Supplies

Fire Department Water Supplies	Location (Latitude-Longitude)	Area (acres)	Descriptive Location (Street or Water Source)
DH 3-38	-70.7140408041°W, 41.8462191477°N	0.2	Grady Pond
W 1-1	-70.7646116384°W, 41.8813849391°N	N/A (River)	Route 58 Bridge
W 1-25	-70.7904804161°W, 41.8828112734°N	2.5	Beaver Dam Brook
W 1-33	-70.7872779698°W, 41.8727144159°N	32.0	South Meadow Brook Pond
W 1-5	-70.7704633525°W, 41.8979076542°N	0.1	Old Center Street
W 2-10	-70.7983539196°W, 41.9180145235°N	N/A (River)	Muddy Pond Brook
W 2-12	-70.8094023132°W, 41.9238065169°N	0.5	Behind Shaw's Grocery Store
W 2-19	-70.8056494759°W, 41.8905872891°N	14.6	Leland Way
W 2-26	-70.811113428°W, 41.9071650337°N	23.2	Fuller Street Pond
W 2-28	-70.7853037034°W, 41.9223003827°N	12.2	North Center Street Pond

Fire Department Water Supplies	Location (Latitude-Longitude)	Area (acres)	Descriptive Location (Street or Water Source)
W 3-19	-70.7439659853°W, 41.843741222°N	5.90	Lower Sampson Pond
W 3-28	-70.7407978228°W, 41.8306297729°N	11.7	Clear Pond
W 3-35	-70.7428246752°W, 41.8530841737°N	299.8	Sampson Pond
W 3-36	-70.718564495°W, 41.8410568785°N	N/A	Cranberry Road
W 3-6	-70.7739949981°W, 41.8356104535°N	20.5	Bates Pond

4 Field Assessment

The firefighting source water supplies were visited in the field by Fuss & O'Neill staff on November 19, 27, 28, and 29 (Table 2). During those site visits, data was collected regarding the number and condition of visible inlets and outlets or water control devices, quantity of bank and aquatic vegetation present, quantity of large trees, water depth near shore or depth at outlet, type of access paving, immediate surrounding land use, approximate number of fire trucks able to access water source at one time, potential for sedimentation, approximate area needed for sediment excavation, and potential obstacles to sediment excavation.. These field visits also included interviews with CFD Chief Officer Craig Weston to determine physical water source characteristics required for fire suppression, and the history, limitations, and importance of each of the 15 priority water sources in the context of fire suppression.

Table 2. Field Activities

Date of Field Work	Fire Department Water Supply Visited
11/19/2018	W 1-1, W 1-5, W 1-25, W 1-33, W 2-10, W 2-12, W 2-26, W 2-28, W 3-6, W 3-19, W 3-28, W 3-35, W 3-36, W 3-37, DH 1-35, DH 3-38
11/27/2018	W 1-1, W 1-5, W 1-25, W 1-33, W 2-10, W 2-12, W 2-19, W 2-26
11/28/2018	W 2-28, W 3-6, W 3-19, W 3-28, W 3-35, W 3-36, DH 1-35, DH 3-38
11/29/2018	W 1-33, W 2-10, W 3-19

Sediment Sampling

On November 29, 2018, Fuss & O'Neill staff obtained sediment samples at three of the priority firefighting water sources - Muddy Pond, Lower Sampson Pond, and South Meadow Brook. The sampling was intended to provide a screening level assessment[1] of sediment quality in representative water bodies within Carver. These water bodies were selected as representative based on geographic location in Carver, surrounding land use, and water body type (i.e., lake, pond, stream).

A description of the sediment sampling methods is included in Appendix C. In addition to grain size distribution, the samples were tested for constituents that could potentially affect disposal options of any dredged sediment, including metals, total organic carbon, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs).

Assessment of Sediment Results

In Massachusetts, dredged sediment is typically considered to be soil once it is removed from a water body and dewatered. Consequently, options for disposal or beneficial reuse at locations other than the source of the sediment are governed by the same regulations and guidance used for soil disposal or reuse (310 CMR 40.00). The options for sediment disposal or reuse depend on the existing and proposed uses of the disposal site (i.e., residential, industrial, etc.) as well as the presence of other resources such as wetlands or drinking water supplies. Since permitting for dredging of sediment in Massachusetts requires assessment of sediment quality consistent with 314 CMR 09, sediment collected as part of these project was tested for the constituents described above and found at 314 CMR 09.07(2)(b)(6). Although the specific criteria for disposal or reuse would depend on the anticipated reuse or disposal location, it is notable that the screening assessment determined the presence of metals above laboratory detection limits in all three samples. In general, the sample from South Meadow Brook had a greater number of SVOCs and EPHs present above lab detection limits compared to the other two sample locations. A summary of laboratory results is included in Appendix C.

The sediment sampling sites were selected to be representative of water body types and the geographic distribution of water bodies throughout Carver and this initial assessment indicates that metals in concentrations that may limit disposal or reuse options are likely to be detected regardless of location in in the town. If dredging of a water source or other actions that would require sediment disposal are considered to improve resiliency, specific consideration of potential disposal options should be pursued, and additional site-specific testing performed, regardless of geographic location, surrounding land use, or water body type.

[1] It is important to note that these sediment samples are intended for screening purposes only. Additional sediment quality analyses may be required before or during future construction, dredging, or other maintenance projects.

5 Drought Vulnerability Assessment

Concepts of drought hazard (the probability of a drought occurring on any given year) and drought vulnerability (the susceptibility of a system or community to the impact of drought hazards given its condition as determined by various physical, social ,economic, and environmental factors (Neri and Magana, 2018) are well established within hydrologic literature (e.g., Rajsekhar et al., 2015). Drought risk is defined as the product of drought hazard and drought vulnerability. There are three "types" of drought – meteorological drought, agricultural drought, and hydrologic drought (Wilhite and Glantz, 1985). Our focus in this study is assessing vulnerability to hydrologic drought, which occurs when extended dry weather patterns greatly diminish water supplies and impacts of reduced streamflow and groundwater recharge become apparent.

In order to effectively assess drought vulnerability for the purposes of prioritizing resiliency actions, we developed a simplified drought vulnerability index (DVI) for firefighting water supplies within Carver (SpDIVF). The SpDVIF serves as a comparative classification system for drought vulnerability, incorporating various readily measurable factors as they relate to firefighting water supplies (Table 3). A high SpDVIF score corresponds to a water supply that is more vulnerable to drought impacts. The calculation of the SpDVIF for a water supply is given in Appendix D.

Table 4 presents the results of the SpDVIF for the 15 water bodies selected for assessment as part of this Action Grant project. Among this group, W 3-6, W 2-12, W 2-26, and W-10 ranked as the most vulnerable water supplies, receiving a maximum Drought Vulnerability Score of 10. These sites either share the water source with an agricultural farm or are in close proximity to population centers and future growth areas which increases their vulnerability to drought impacts. W 3-36 ranked as the least vulnerable water supply, receiving a minimum Drought Vulnerability Score of 0. This site does not share the water source with an agricultural farm which aids its resilience to drought impacts.

Table 3. Drought Vulnerability Index Metrics

Factor	Description	Rationale	Scoring
Normal Water Depth (ND)	Approximate average water depth in the water supply under typical conditions	Deeper ponds have larger capacities and are less vulnerable to drying during drought conditions.	1 = > 5 ft. 2 = 2 - 5 ft. 3 = < 2 ft.
Estimated Water Source Surface Area (WSA)	Approximate surface area of the water supply site under typical conditions	The larger the surface area, typically the larger the total capacity of the water source, and the less vulnerable the water source may be to becoming dry under drought conditions.	1 = > 50 acres 2 = 10 - 50 acres 3 = < 10 acres

Factor	Description	Rationale	Scoring
Proximity to Vulnerable Areas (PVA)	Proximity of the water supply site to the nearest potentially vulnerable area, (e.g. centralized neighborhood, commercial area, or forest)	The closer a water source is to a vulnerable area, the more critical the site is for fire protection.	1 = > 1 mile 2 = 0.5 - 1 miles 3 = < 0.5 miles
Proximity to Other Water Supply Sites (PWS)	Number of other firefighting water supplies that are within a 1-mile radius	An isolated water supply results in greater vulnerability, especially in drought conditions.	1 = > 13 other water supply sites 2 = 7 - 13 other water supply sites 3 = < 7 other water supply sites
Number of Nearby Addresses (NA)	Number of building/floor/unit addresses that are within a 1-mile radius	During drought conditions, a highly populated area would be more vulnerable if a water supply is impacted by drought.	1 = < 250 nearby addresses 2 = 250 - 500 nearby addresses 3 = > 500 nearby addresses
Potential Future Growth Area (FGA)	Estimated future build out of residential units and commercial ft^2	Water supply sites that service a potential growth area may experience more use and greater stress under future drought conditions. Minor Growth = 1-10 residential units or 58,000-200,000 ft^2 commercial Significant Growth = >25units or >200,000 ft^2 commercial	1 = No Growth 2 = Minor Growth 3 = Significant Growth
Shared Use with Agriculture (AG)	Is the water potentially also needed for agricultural use?	A water source with a shared use will experience more use and greater stress during drought conditions.	1 = No 2 = Shared with one cranberry farm 3 = Shared with multiple cranberry farms
Estimated Source Groundwater/ Surface Water (SOURCE)	Does the firefighting water supply site receive input from groundwater, surface water, or a combination of the two?	A water source receiving only one type of input is more vulnerable than one receiving a combination. Additionally, impacts of drought are usually first apparent in surface water flows compared to groundwater which typically has a slower response to drought conditions.	1 = Surface water and groundwater inputs 2 = Groundwater inputs only 3 = Surface water inputs only

Table 4. Calculated SpDVIF for Fire Department Water Supplies

Fire Department Water Supplies	Descriptive Location (Street or Water Source)	SpDVIF
W 2-10	Muddy Pond Brook	10.00
W 2-12	Shaw's Grocery Store	10.00
W 2-26	Fuller Street Pond	10.00
W 3-6	Bates Pond	10.00
W 3-28	Clear Pond	8.33
W 1-25	Beaver Dam Brook	6.67
W 1-5	Old Center Street	6.67
W 3-19	Lower Sampson Pond	6.67
W 1-1	Route 58 Bridge	5.00
W 2-19	Leland Way	5.00
W 3-35	Sampson Pond	5.00
W 1-33	South Meadow Brook Pond	5.00
DH 3-38	Grady Pond	3.33
W 2-28	North Center Street Pond	3.33
W 3-36	Cranberry Road	0.00

The results of this index, together with the assessments of feasibility and practicability of measures to reduce drought vulnerability as part of the prioritization tool described below, complete a prioritization scheme that can inform decision makers for the Town of Carver and allow for targeted mitigation and adaption actions. The approach described in this section and in Appendix D can readily be extended beyond the 15 firefighting water supplies considered in this study to assess drought vulnerability of firefighting water supplies throughout the town and can also be updated should additional factors beyond those in Table 3 be identified as important to characterizing vulnerability to drought.

6 Preliminary Prioritization & Recommendations

Prioritization Tool

The Prioritization Tool was developed by Fuss & O'Neill to provide a systematic, consistent, and transparent method of prioritizing actions to increase resiliency to drought for firefighting water supplies within Carver. Implemented with a Microsoft Excel spreadsheet, the tool is designed with flexibility and adaptability in mind and is able to be used at a watershed, municipal, jurisdictional, or regional scale. It incorporates information on drought vulnerability, as described in Section 5, with information on the feasibility, potential challenges, and potential benefits of taking action to increase resiliency to drought. A combination of professional engineering judgment regarding technical feasibility and stakeholder input on more subjective factors associated with community priorities and opportunities is incorporated into the tool. The tool is designed to be transparent in its weighting of factors and calculations and is readily adaptable to changing conditions. As local conditions, stakeholder priorities, or funding opportunities may change, the prioritization can be revisited and updated accordingly. It is important to note, however, that the Tool is designed specifically for situations where water supplies, both location and type, are already identified and is not intended to ascertain appropriate resiliency actions for currently unidentified locations.

Factors Considered

Two general categories or domains were included in the Tool: Drought Vulnerability and Implementation and Operation Considerations (Table 5). The Drought Vulnerability domain is the SpDVIF described in Section 5 and reflects environmental and community conditions relative to each water supply. The Implementation and Operation Considerations domain incorporates stakeholder input and engineering judgement regarding feasibility and challenges of implementing drought resiliency improvement projects at a particular location. Tables in Appendix D provide a more-detailed description of these metrics.

Design of the Tool

The Tool converts input from for each metric into a prioritized list. The list is based on scores for each water supply generated by the model. The score for a particular water supply should be considered in relation to other water supplies under consideration for drought resiliency improvements. Each water supply receives a score for each metric based on the rationale provided in the metric descriptions. These metric scores are modified by the metric's weight, or importance as determined by the Tool users. Weights should be carefully selected and reflect stakeholder priorities and values. Higher weights reflect greater importance to stakeholders or users of the Tool. Scores are then summed for all metrics within a domain to provide a domain score. Domain scores contribute equally to a water supply's total score by default, although this can be modified as part of the Tool's flexibility. Higher total scores indicate a higher priority for resiliency improvement measures based on a combination of vulnerability, feasibility of implementation, and surrounding environmental conditions. A more detailed description of calculations used in the prioritization tool spreadsheet is included in Appendix D.

Table 5. List of Domains and Metrics Incorporated Into the Tool

Domain #1: Drought Vulnerability		Domain #2: Implementation and Operation Considerations	
Metric	Weight	Metric	Weight
Normal Water Depth (AD)	2.00	Operational Ease	3.00
Estimated Water Source Surface Area (WSA)	2.00	Permitting Complexity	2.50
Proximity to Vulnerable Areas (PVA)	2.00	Control Devices for Inlets/Outlets	1.00
Proximity to Other Water Supply Sites (PWS)	2.00	Site Accessibility	2.00
Number of Nearby Addresses (NA)	2.00	Land Ownership	1.50
Potential Future Growth Area (FGA)	2.00	Public Acceptance for Improvements	1.00
Shared Use with Agriculture (AG)	2.00	Sedimentation Potential	3.00
Estimated Source - Groundwater/Surface Water (SOURCE)	2.00	Multi-Benefit Opportunities	2.50

Preliminary Prioritization Results

The output of the spreadsheet tool is summarized to rank the water supply for upgrade and/or replacement. The results of the preliminary prioritization process are presented in Table 6. Figure 2 shows the spatial location of each priority firefighting water supply as well as the relative ratio of each domain contributing to its total prioritization score. Using the preliminary results of the prioritization tool as a guide, Town of Carver stakeholders should consider the following recommended actions to advance the Climate Change Water Resources Vulnerability and Adaptation Strategy Assessment and improve resiliency of their water infrastructure.

Table 6. Preliminary Prioritization Results

Water Supply Site Identifier	Descriptive Location (Street or Water Source)	Domain #1: DVI Score (0-10)	Domain #2: Implementation Score (0-10)	PRIORITIZATION SCORE (MAX = 20)	PRIORITIZATION SCORE (0-10)	PRIORITY RATING High (Dark Green) Medium (Light Green) Low (Gray)
W 3-6	Bates Pond	10.00	9.64	19.64	10.0	10.00
W 2-12	Shaw's Grocery Store	10.00	6.43	16.43	7.4	7.43
W 2-26	Fuller Street Pond	10.00	3.57	13.57	5.1	5.14
W 1-1	Route 58 Bridge	5.00	8.21	13.21	4.9	4.86
W 3-28	Clear Pond	8.33	4.64	12.98	4.7	4.67
W 2-19	Leland Way	5.00	6.07	11.07	3.1	3.14
W 1-33	South Meadow Brook Pond	5.00	6.07	11.07	3.1	3.14
W 2-10	Muddy Pond Brook	10.00	0.00	10.00	2.3	2.29
W 3-36	Cranberry Road	0.00	10.00	10.00	2.3	2.29
W 1-25	Beaver Dam Brook	6.67	3.21	9.88	2.2	2.19
W 3-19	Lower Sampson Pond	6.67	2.86	9.52	1.9	1.90
W 1-5	Old Center Street	6.67	2.50	9.17	1.6	1.62
W 2-28	North Center Street Pond	3.33	5.00	8.33	1.0	0.95
DH 3-38	Grady Pond	3.33	4.64	7.98	0.7	0.67
W 3-35	Sampson Pond	5.00	2.14	7.14	0.0	0.00

Figure 2. Firefighting Water Supplies Prioritization Scores Map

Recommendations

Recommendations for Drought Resilience

- Dredge Firefighting Water Supply Sediment Bottom Minimum Area.
  Dredging an approximate 20' by 40' wide area neighboring the shore will improve drought resilience by increasing the capacity of the water supplies and increasing the likelihood that these water supplies satisfy the minimum depth requirements for fire suppression via surface drafting (CFD minimum of 2 feet) under future drought conditions. Dredged depths depend on individual site assessments with special consideration paid to potential changes in groundwater level during drought under climate change conditions.[2]

- Dredge Firefighting Water Supply Sediment Bottom Minimum Depth.
  Dredging the water supply bottom to a depth that will provide the CFD minimum depth of 2 feet during drought conditions will improve the resiliency of these supplies to drought conditions. The 2016 drought was observed to cause water levels in water supplies to drop approximately 1 foot. The record 1960s drought conditions are anticipated to cause water levels to drop from 1 to 4 feet, so a conservative drop of 4 feet can be assumed to represent the drought of record for the area. Sedimentation from aquatic plant and algae die off, leaf accumulation, and mineral sediment accumulation will also result in a shallowing of these supplies over time. It is therefore recommended to provide additional depth to accommodate some shallowing by sedimentation while still providing adequate depth and volume of water. Assuming a typical average depth to current bottom of 2 feet, dredging 3 feet of sediment will provide resilience to a 2016 magnitude drought and dredging 6 feet of sediment will provide resilience to a 1960s magnitude drought. The Town should consider dredging to accomplish resilience to the 1960s magnitude drought where feasible, but at least to a depth that is anticipated to provide resilience to the 2016 magnitude drought. Any dredge area also should create the minimum 20' by 40' area at the selected resilience level discussed in the recommendation above.

- Maintain Normal Water Levels At Higher Levels Where Control Structures Exist.
  Certain Fire Department water supplies are also agricultural water sources that have control structures that consist of flume boards that can be removed and installed as necessary to make water available for agricultural uses. Some of these water supplies may have the ability to raise normal water levels by installing an additional flume board(s) without having any negative consequence such as flooding of upstream farms, or infrastructure, or causing water to overtop a containment berm or roadway. These water supplies can be evaluated on a case by case basis, and where appropriate additional storage can be provided by installing additional flume board(s). It is understood that this additional storage may be consumed by agricultural uses, however there may be occasions where firefighting needs occur when water has not yet been lowered substantially for agricultural uses, leaving substantial water to draw from for firefighting needs without endangering the agricultural operations. The consideration to raise the water level in a water supply should contemplate potential flooding impacts, the relative importance as a fire fighting water supply versus an agricultural water supply.

[2] USGS modeled groundwater levels dropped between 1-4 feet throughout Carver when simulated with 1960's conditions, a time period in which the area experienced its record drought (Matterson, 2009).

- Engage Private Property Owners or Residential Communities Where Water Supply Improvements are Planned.
  Based on the application of the prioritization tool, several water supplies on private property ranked higher than some on publically-owned or controlled land. In order to take advantage of potentially valuable/impactful improvements, we recommend that these property owners are engaged as early as possible in the planning stages to determine what type projects these owners would support.

- Continue to Engage the Farming Community.
  Where agricultural farms utilize water supplies that also provide fire protection (as is the case with 10 of the 15 priority supplies in Table 1), intentional collaboration efforts should be made to promote shared-use, drought resiliency goals through implementation of recommended improvements and continued maintenance.

  In addition, agriculture is a significant source of nutrients supporting aquatic growth and sediment that contribute to the vulnerability of Carver's water supplies to drought impacts. NRCS (Natural Resources Conservation Service), Plymouth County Conservation District (PCCD), and the Cape Cod Cranberry Growers Association provide programs to both educate and support farmers with technical and financial resources. Active promotion of these programs should continue.

- Identify Implementation Sustainable Funding Sources.
  While this initial phase of prioritization was included as part of the MVP Action Grant, additional significant investment will be required to fully implement improvements at the priority firefighting water supplies throughout Carver. Appendix E provides a list of potential funding sources for the design and construction of the type of resiliency actions identified in this report.

<u>Other Recommendations for Continuing Maintenance & Ecological Enhancement Opportunities</u>

- Clear Banks of Vegetation.
  Small trees and unwanted brush vegetation should be removed from areas where the CFD intend to access the water supply. These cleared area would serve as a "staging area" that would allow for access of at least one and, ideally, multiple fire trucks. The staging area would be maintained regularly to be clear of brush and other potential obstructions so that the fire department can access the water supply with relative ease year round. Establish signage to indicate that the area is a fire department water supply site to prevent the possibility of future obstructions.

- Remove Aquatic Vegetation.
  Remove any aquatic vegetation within water source that lies in close proximity to shore to prevent this unwanted vegetation from potentially clogging fire department drafting apparatuses. Actions should be taken to ensure that waters from which the CFD draft are maintained and remain clear of aquatic vegetation.

- Planting Emergent Aquatic Vegetation.
  The ecological value of these water supply sources can be increased by the planting of select aquatic vegetation to create varied habitats for wildlife and aquatic organisms. Emergent aquatic vegetation can be planted at appropriate water depths within the impoundments to provide habitat diversity. The selection of aquatic plants should recognize the anticipated drop in water level over time due to climate change and should therefore focus on plants that have the ability to recolonize to deeper water as water depths diminish. In addition, plant species that are tolerant

of a wider range of water depths would have greater resiliency to anticipate drops in surface water level. Riparian vegetation can be planted along the shoreline to further enhance habitat diversity and overall habitat value of the waterbody and adjacent uplands and reduce potential for sedimentation due to bank erosion. The planting areas should be located such that they will not encroach upon the areas required for water supply or access from the shoreline. For these reasons, the very small waterbodies may not be good candidates for this enhancement due to limited area and potential encroachment on the needed area of water storage and fire truck access.

- Remove Invasive Plant Species.
  The Town of Carver has convened an Invasives Species Committee that is striving to control, reduce and, if possible, eradicate the invasive species that have colonized within the Town. They have identified invasive plant species that have colonized some of the water supplies and some of the uplands adjacent to the water supplies. An opportunity exists to identify and eradicate invasive species within these areas as part of the resiliency measures for the firefighting water supplies. Up front screening and identification of the invasives that exist within and adjacent to the water supplies would allow their eradication to become part of an overall project to deepen these water supplies and increase the storage and access areas by dredging and clearing vegetation, and plant desirable vegetation for improvement and enhancement of habitat value.

Permitting Requirements for Water Supply Resiliency Recommendations

New construction including expanding pond area, deepening ponds beyond the original constructed depth, deepening diversions beyond their original constructed depths, installation of new wells, raising the berms on existing ponds to store more water, would likely require some level of permitting or regulatory approval. Depending on the exact nature and location of a proposed activity, permits may be required in accordance with the following local, state and/or federal regulations:

- US Army Corps of Engineers Section 404
- Massachusetts
  - Water Quality Certification (314 CMR 9.00)
  - Waterways (310 CMR 9.00)
  - Wetlands Protection Act (310 CMR 10.00)
  - Water Management Act (310 CMR 36.00)
  - Well Drilling (310 CMR 46.00)
  - Environmental Policy Act (301 CMR 11.00)
  - Renovation of Cranberry Bogs (310 CMR 23.00)
- Carver Conservation Commission Wetland By-Law

Maintenance of existing ponds by simply removing sediments to the original pond bottom and removing vegetation and debris to restore pond areas, as well as channels and diversion ditches, should be covered as a maintenance activity. It is recommended however that this be confirmed with the Carver Conservation Commission before such activity is undertaken since it will also keep the Town's Conservation Agent aware of activities affecting wetland, waterbodies and watercourses in the Town of Carver.

Appendix A

References

Massachusetts Executive Office of Energy & Environmental Affairs, 2017, "MCP Numerical Standards." Massachusetts Department of Environmental Protection

Masterson, J.P., Carlson, C.S., and Walter, D.A., 2009, Hydrogeology and simulation of groundwater flow in the Plymouth-Carver-Kingston-Duxbury aquifer system, southeastern Massachusetts: U.S. Geological Survey Scientific Investigations Report 2009–5063, 110 p.

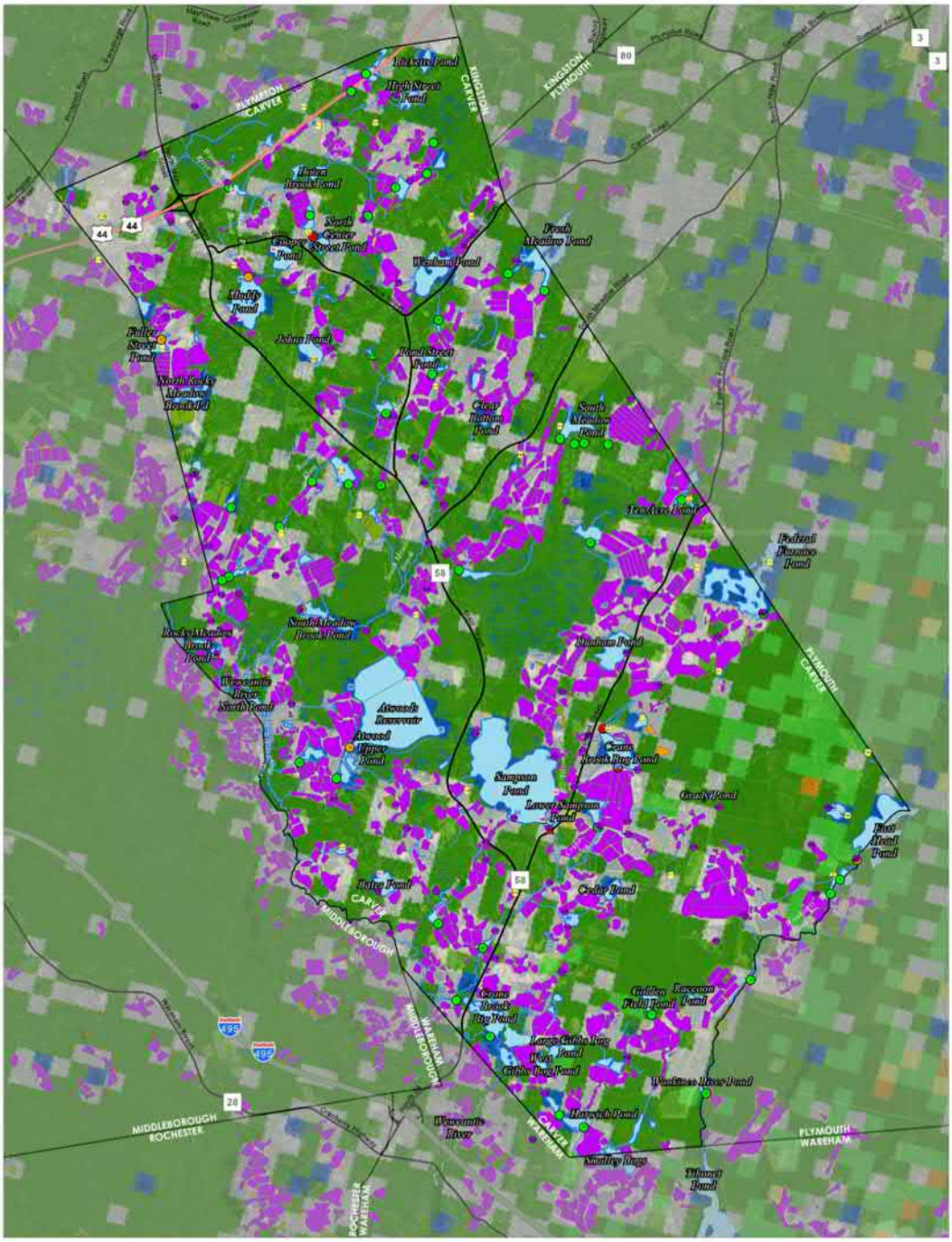
Neri, Carolina, and Víctor Magaña., 2016, "Estimation of Vulnerability and Risk to Meteorological Drought in Mexico." Weather, Climate, and Society, vol. 8, no. 2, pp. 95–110., doi:10.1175/wcas-d-15-0005.1.

Rajsekhar, Deepthi, et al., 2015, "Integrated Drought Causality, Hazard, and Vulnerability Assessment for Future Socioeconomic Scenarios: An Information Theory Perspective." Journal of Geophysical Research: Atmospheres, vol. 120, no. 13, pp. 6346–6378., doi:10.1002/2014jd022670.

Wilhite, D.A.; and M.H. Glantz., 1985, "Understanding the Drought Phenomenon: The Role of Definitions." Water International, vol. 10, no. 3, pp. 111–120.

Appendix B

Firefighting Water Supplies Map



Appendix C

Sediment Sampling Method and Results

Sediment Sampling Plan Summary

During evaluation of water supply sites, sediment samples were collected in the field to determine the gradation of the soil and test for the presence of chemicals of concern. The location of each sample collected was determined based on observed site conditions in order to sample sediments expected to be typical of water sources within the watershed. Three samples were collected at three sites (Muddy Pond, Lower Sampson Pond, and South Meadow Brook), and submitted to a laboratory for analysis.

It is important to note that these sediment samples are intended for screening purposes only. Additional sediment quality analyses may be required before or during future construction, dredging, or other maintenance projects since potential disposal facilities that receive sediment often require a characterization sample for each 1,000 cubic yards of material. In addition, if the due diligence search identifies additional constituents of concern, further sampling may be required.

Sediment samples collected for soil quality and gradation were delivered to an analytical laboratory for analysis of the following parameters:

- Total organic carbon
- EPA 8 priority metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Zn)
- MADEP EPH
- VOCs 8260B
- PAHs 8270
- PCBs 8082
- Grain size distribution (wet sieve, ASTM D422)

The results of the sediment quality and grain size analyses will be used to perform a screening-level assessment of how the material may be reused or disposed.

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Table C-1. Sediment Testing Results

Constituents	Muddy Pond 0130220181129-04	Lower Sampson Pond 0130220181129-05	South Meadow Brook 0130220181129-06
	29-Nov-2018	29-Nov-2018	29-Nov-2018
Semivolatile Organic Compounds (mg/kg)			
Acenaphthene	<0.016	<0.012	<0.019
Acenaphthylene	<0.016	<0.012	0.051
Anthracene	<0.011	<0.0087	0.033
Benzo(a)anthracene	0.0065	0.0064	0.067
Benzo(a)pyrene	0.0091	0.0055	0.075
Benzo(b)fluoranthene	0.013	0.011	0.09
Benzo(g,h,i)perylene	<0.028	<0.021	0.047
Benzo(k)fluoranthene	<0.011	<0.0087	0.033
Chrysene	<0.011	0.014	0.089
Dibenz(a,h)anthracene	<0.011	<0.0087	<0.013
Fluoranthene	<0.028	0.025	0.13
Fluorene	<0.049	<0.037	<0.056
Indeno(1,2,3-cd)pyrene	<0.011	<0.0087	0.055
2-Methylnaphthalene	<0.049	<0.037	<0.056
Naphthalene	<0.049	<0.037	<0.056
Phenanthrene	0.0085	0.0094	0.1
Pyrene	<0.049	<0.037	0.15
Polychlorinated Biphenyls (mg/kg)			
Aroclor-1016	<0.13	<0.097	<0.14
Aroclor-1221	<0.13	<0.097	<0.14
Aroclor-1232	<0.13	<0.097	<0.14
Aroclor-1242	<0.13	<0.097	<0.14
Aroclor-1248	<0.13	<0.097	<0.14
Aroclor-1254	<0.13	<0.097	<0.14
Aroclor-1260	<0.13	<0.097	<0.14
Aroclor-1262	<0.13	<0.097	<0.14
Aroclor-1268	<0.13	<0.097	<0.14
Total PCBs	---	---	---
Extractable Petroleum Hydrocarbons (mg/kg)			
C9-C18 Aliphatics	<16	<12	<18
C19-C36 Aliphatics	<16	<12	48
Unadjusted C11-C22 Aromatics	<16	<12	50
C11-C22 Aromatics	<16	<12	45
Acenaphthene	<0.16	<0.12	<0.18

Constituents	Muddy Pond 0130220181129-04	Lower Sampson Pond 0130220181129-05	South Meadow Brook 0130220181129-06
	29-Nov-2018	29-Nov-2018	29-Nov-2018
Acenaphthylene	<0.16	<0.12	<0.18
Anthracene	<0.16	<0.12	<0.18
Benzo(a)anthracene	<0.16	<0.12	0.36
Benzo(a)pyrene	<0.16	<0.12	1.1
Benzo(b)fluoranthene	<0.16	<0.12	0.39
Benzo(g,h,i)perylene	<0.16	<0.12	<0.18
Benzo(k)fluoranthene	<0.16	<0.12	<0.18
Chrysene	<0.16	<0.12	0.67
Dibenz(a,h)anthracene	<0.16	<0.12	<0.18
Fluoranthene	<0.16	<0.12	0.55
Fluorene	<0.16	<0.12	<0.18
Indeno(1,2,3-cd)pyrene	<0.16	<0.12	0.63
2-Methylnaphthalene	<0.16	<0.12	<0.18
Naphthalene	<0.16	<0.12	<0.18
Phenanthrene	<0.16	<0.12	0.62
Pyrene	<0.16	<0.12	0.7
Volatile Petroleum Hydrocarbons (mg/kg)			
Unadjusted C5-C8 Aliphatics	---	---	<27
C5-C8 Aliphatics	---	---	<27
Unadjusted C9-C12 Aliphatics	---	---	<27
C9-C12 Aliphatics	---	---	<27
C9-C10 Aromatics	---	---	<27
Benzene	---	---	<0.14
Ethylbenzene	---	---	<0.14
Methyl tert-Butyl Ether (MTBE)	---	---	<0.14
Naphthalene	---	---	<0.68
Toluene	---	---	<0.14
m+p Xylene	---	---	<0.27
o-Xylene	---	---	<0.14
Total Metals (mg/kg)			
Arsenic	3.9	<2.1	6.3
Barium	21	5.2	40
Cadmium	0.55	<0.21	0.37
Chromium	5.0	1.2	10
Lead	13	3.5	190
Mercury	<0.043	<0.031	0.2
Selenium	<5.4	<4.1	<6.1
Silver	<0.54	<0.41	<0.61

Constituents	Muddy Pond 0130220181129-04	Lower Sampson Pond 0130220181129-05	South Meadow Brook 0130220181129-06
	29-Nov-2018	29-Nov-2018	29-Nov-2018
Other Parameters			
Total Organic Carbon (mg/kg)	13,000	5,100	19,000
% Solids (% wt)	61.4	79.7	53.5

Notes: --- = Constituent not analyzed

Appendix D

Prioritization Tool Calculations and Results

The Prioritization Tool utilizes a weighted scoring method to prioritize firefighting water supplies for resiliency improvements. The tool utilizes factors related to drought vulnerability and operational feasibility for implementation of improvements to priority water supply characteristics, professional judgement and stakeholder input. This appendix outlines the calculation methods used in the Prioritization Tool.

Prioritization Tool Metrics

The Prioritization Tool is designed to consider previously identified water sources and their priority for resiliency improvements, rather than identify new firefighting water supplies.

Each previously identified water source receives a score for prioritization in relation to metrics that are divided into 2 domains: Drought Vulnerability (which describes the vulnerability of the water source to drought impacts), and Implementation and Operation considerations (which describe feasibility and challenges of implementing drought resiliency improvement projects at that particular location). Description of the metrics and the rationale for scoring categories is provided **Tables D.1 and D.2**.

Metric Weighting

Each metric receives a weight, or contribution, to the domain score. This weight is assigned by the user. Assignment of weights and can be based on user judgement or stakeholder input. The higher the weight, the greater the relative influence of a particular metric to a domain score. All metrics are given a weight of one (1) by default, reflecting equal input from each metric in a domain as a starting point.
A metric's score is the product of the weight and a coded numeric response associated with the possible values of that metric. For any single metric *j*, the score is calculated as:

$$b_i = c_{i,j} \times w_j$$

where:

$b_{i,j}$ = the score of the i-th water supply
$c_{i,j}$ = the coded numeric response for the *j*-th metric for the *i*-th water supply
w_j = the weight assigned to metric j

For example, for the metric that assesses the site accessibility of water supply the possible responses "Only accessible seasonally," "Readily accessible year round. Room for 1 firetruck." and "Readily accessible year round. Room for at least 2 firetrucks." are associated with the numeric response (1, 2, and 3, respectively). While the numeric response depends on the metric, for all metrics included in this tool, a larger number reflects higher priority water supply. If site accessibility is determined to be an important consideration, the metric might receive a weight of 2.5. Therefore, using the formula above a water supply that is accessible by 1 firetruck would receive a score of 5 for that metric.

Calculating the Domain Score

The domain score for each water supply is the sum of all metric scores within that domain:

$$C_i = \sum_{i=1}^{n_k} b_i$$

where:

C_i = the domain raw score for the *i*-th water supply

n_k = the number of metrics in the k-th domain (here k = 2, because there are 2 domains of metrics)

b_i = the water supply score of the *i*-th water supply for an individual metric

After all water supplies have received scores in a particular domain those scores are normalized to a 0-10 range. This step equalizes the influence of domains independent of the number of metrics each contains, providing each water supply a score between 0 and 10 for each of the two domains, proportional to its score between the minimum and maximum domain score:

$$S_i = \frac{C_j - \min(C)}{\max(C) - \min(C)} \times 10$$

Where, for a particular domain:

S_i = the normalized domain score (0-10) for the i-th water supply

C_i = the domain score for the i-th water supply

C = the set of scores in that domain for all water supply

Calculating the Total Prioritization Score

The total prioritization score is sum of standardized scores across all domains.

$$R_i = \sum_{1}^{k} S_i$$

where:

R_i = the total raw score of the i-th water supply

k = the number of domains (here k = 2 because there are 2 domains of metrics)

S_i = the domain score (0-10) of the i-th water supply

For ease of comparison, the total scores (which have a maximum value of 20) are also normalized to a 0 – 10 scale, proportional to their value between the minimum and maximum total scores:

$$T_i = \frac{R_i - \min(R)}{\max(R) - \min(R)}$$

where:

T_i = the normalized total prioritization score (0-10) of the i-th water supply

R_i = the raw total score of the i-th water supply

R = the set of raw total scores for all water supply

Table D.1. Description of Drought Vulnerability Metrics

Watershed Metric	Metric description	Source
Normal Water Depth (AD)	What is the approximate average water depth in the water supply under typical conditions? Deeper ponds have larger capacities and are less vulnerable to drying during drought conditions. Average normal depth in the waterbody during typical conditions as estimated by the conic approximation method. The conic approximation method calculates the volume between two sectional areas; the two areas being added along with the square root of their produce and multiplied by a third of distance between the areas to determine the volume. The depth is categorized as follows: 1 > 5 ft. 2 2 - 5 ft. 3 < 2 ft.	Field Observations Town Data Desktop GIS Analysis
Estimated Water Source Surface Area (WSA)	What is the approximate surface area of the water supply site under typical conditions? The larger the surface area, typically the larger the total capacity of the water source, and the less vulnerable the water source may be to becoming dry under drought conditions. Approximate surface areas of water supply sites, calculated through desktop GIS analysis are categorized as follows: 1 > 50 acres 2 10 - 50 acres 3 < 10 acres	Desktop GIS Analysis

Watershed Metric	Metric description	Source
Proximity to Vulnerable Areas (PVA)	What is the proximity of the water supply site to the nearest potentially vulnerable area, such as a centralized neighborhood, commercial area, or forest. The closer a water source is to a vulnerable area, the more critical the site is for fire protection. The estimated proximity to the nearest vulnerable area is categorized as follows: 1 > 1 mile 2 0.5 - 1 miles 3 < 0.5 miles	Desktop GIS Analysis
Proximity to Other Water Supply Sites (PWS)	How many other firefighting water supplies are within a 1-mile radius of the site? An isolated water supply results in greater vulnerability, especially in drought conditions. The number of nearby water supply site categories are: 1 > 13 other water supply sites 2 7 - 13 other water supply sites 3 < 7 other water supply sites	Desktop GIS Analysis
Number of Nearby Addresses (NA)	How many building/floor/unit addresses that are within a 1-mile radius of the water supply site? During drought conditions, a highly populated area would be more vulnerable if a water supply is impacted by drought. Addresses were obtained from Nextgen's 911 Master Address geodatabase. The approximate number of number of nearby addresses are categorized as follows: 1 < 250 nearby addresses 2 250 - 500 nearby addresses 3 > 500 nearby addresses	Nextgen 911 Master Address List
Potential Future Growth Area (FGA)	Is the firefighting water supply site within a 0.5 mile radius of an area with planned future development as determined by the Town of Carver's Master plan? Water supply sites that service a potential growth area may experience more use and greater stress under future drought conditions. The thresholds categories for potential future growth are: Minor Growth = 1-10 residential units or 58,000-200,000 ft2 commercial Significant Growth= > 25units or > 200,000 ft2 commercial 1 No Growth 2 Minor Growth 3 Significant Growth	Town of Carver Master Plan
Shared Use with Agriculture (AG)	Does one or more nearby cranberry farms rely on the firefighting water supply site? A water supply site with a shared use will potentially experience more use and greater stress during drought conditions. Additionally, water supply sites with a shared use present an opportunity for maintenance however may be more difficult to access during the growing or harvesting season. The shared use categories are: 1 No 2 Shared with one cranberry farm 3 Shared with multiple cranberry farms	Field Observations Stakeholder Input Desktop GIS Analysis
Estimated Source Groundwater/ Surface Water (SOURCE)	Does the firefighting water supply site receive input from groundwater, surface water, or a combination of the two? A water source receiving only one type of input is more vulnerable than one receiving a combination. Additionally, impacts of drought are usually first apparent in surface water flows compared to groundwater which typically has a slower response to drought conditions. The categories of water input source are: 1 Surface water and groundwater inputs 2 Groundwater inputs only 3 Surface water inputs only	Field Observations Stakeholder Input Desktop GIS Analysis

Table D.2. Description of Implementation and Consideration Metrics

Watershed Metric	Metric description	Source
Operational Ease	Does the water supply meet the necessary fire department requirements for operational use? The minimum desired depth required to draw from the water source using the fire department's pumping apparatus is 2 feet. Does the approximate depth of water near the shoreline meet this minimum desired depth? During drought conditions, the depth of water available near the access point of the water supply site may not be great enough for use. Additionally, is there aquatic vegetation within the water supply that may obstruct the pumping apparatus? The operational ease categories are as follows for typical hydrologic conditions (i.e., not during drought or flood): 1 Depth near shore > 2ft. No aquatic vegetation 2 Depth near shore > 2ft. Aquatic vegetation present 3 Depth near shore < 2ft. Aquatic vegetation present	Town Data Field GIS Observation
Permitting Complexity	How complex is the permitting process for any available improvements? The effort, coordination, and fees required for permitting vary greatly depending on the challenges presented for a particular site or improvement alternative. This metric takes into account NHESP endangered species habitats, certified vernal pools, outstanding resource waters, dredged sediment disposal requirements, as well other critical issues, and is a screening level assessment only: 1 Permits required. Complex or unique site challenges. 2 Permits required. Moderate site challenges. 3 Minimal permits or only notifications required.	Federal Regulation State Regulations Local Regulations Professional Judgement
Control Devices for Inlets/Outlets	Do the inlets and/or outlets to the water supply source have any control devices or structures? Control devices allow flexibility for the water supply levels during periods of extreme weather. For example, more water may be retained during drought, or more water may be released during flood conditions. The control device categories are: 1 No 2 Yes - No Current Improvements Available 3 Yes - Improvements Available	Field Observation Professional Judgement
Site Accessibility	Is non-aquatic vegetation present at the fire department water supply site that reduces the usability of the site? If water supply sites are overgrown with non-aquatic vegetation, the water source becomes difficult to access, and eventually becomes impossible to access without vegetation removal. Additionally, how many fire department vehicles (e.g. firetrucks or water trucks) can park side-by-side in the staging area at the water supply site? During the event of a fire emergency, trucks draw water in a cyclic manner to quickly transport large volumes of water to the fire site. The more area available at a water supply site, the more fire department vehicles can utilize the water supply site for water intake. Typically, the fire department recommends area available for two firetrucks side-by-side. This metric is measured by the accessibility of the fire department water supply site. The site accessibility categories are: 1 Only accessible seasonally. 2 Readily accessible year round. Room for 1 firetruck. 3 Readily accessible year round. Room for at least 2 firetrucks.	Field Observation Aerial Photographs Professional Judgement

Watershed Metric	Metric description	Source
Land Ownership	Is the water supply source or access road to the fire department water supply located on private or public land? While the fire department is allowed access to these sites for the purposes of emergency use or maintenance, land ownership is an important component of the planning of repairs, recurring maintenance considerations, and permitting. This metric is measured by land owner entity type. The land ownership categories are: 1 Private 2 Mixed - Private/Public 3 Public	Town Parcel GIS Database or Tax Assessors Data Field Observations Local Stakeholder Input
Public Acceptance for Improvements	Are there any challenges associated with public acceptance for improvements at a water supply site? Depending on the potential repairs for and the location of water supply sites, the general public may express concern about improvements. This metric takes into account the location of a fire department water supply site (e.g. residential community), aesthetic impacts of improvements, and overall areal scale of improvements at a site. This metric is measured by the estimated level of public acceptance for the potential improvement alternatives for a fire department water supply site. 1 Low or no public acceptance 2 Moderate public acceptance 3 Full public acceptance	Local Stakeholder Input
Sedimentation Potential	What is the level of vulnerability to sedimentation at the fire department water supply site? Sedimentation can reduce volume in a water supply and create more potential for clogging of firefighting equipment. This metric takes into consideration surrounding land use, impervious cover, neighboring terrain slopes, field observations, soil types, water control types, water source type, in addition to other factors. The sedimentation potential categories are: 1 High sedimentation potential 2 Medium sedimentation potential 3 Low sedimentation potential	Desktop GIS Analysis Professional Judgement Town Data Field Observations
Multi-Benefit Opportunities	Are there any opportunities to increase both the water capacity and the natural habitat of the water supply? Are there invasive species present at the water supply site? Does the water supply have a history of algal blooms? Invasive species and algal blooms are detrimental to the overall water supply habitat and present clogging issues with fire department pumping equipment. If vegetation is removed from a water supply site for fire department access purposes, it is essential to ensure invasive species will not replace the previously removed vegetation. During scheduled improvements, can additional actions be taken to address other issues present within the water supply? The opportunities categories are: 1 Limited or no opportunities 2 Some opportunities 3 Significant opportunities	Town Data Field Observations Local Stakeholder Input

Table D.3. Firefighting Water Supply Prioritization Results

Water Supply Site Identifier	Descriptive Location (Street or Water Source)	Domain #1: DVI Raw Score	Domain #1: DVI Score (0-10)	Domain #2: Implementation Raw Score	Domain #2: Implementation Score (0-10)	PRIORITIZATION SCORE (MAX = 20)	PRIORITIZATION SCORE (0-10)	PRIORITY RATING High (Dark Green) Medium (Light Green) Low (Gray)
W 3-6	Bates Pond	40.00	10.00	39.50	9.64	19.64	10.0	10.00
W 2-12	Shaw's Grocery Store	40.00	10.00	35.00	6.43	16.43	7.4	7.43
W 2-26	Fuller Street Pond	40.00	10.00	31.00	3.57	13.57	5.1	5.14
W 1-1	Route 58 Bridge	34.00	5.00	37.50	8.21	13.21	4.9	4.86
W 3-28	Clear Pond	38.00	8.33	32.50	4.64	12.98	4.7	4.67
W 2-19	Leland Way	34.00	5.00	34.50	6.07	11.07	3.1	3.14
W 1-33	South Meadow Brook Pond	34.00	5.00	34.50	6.07	11.07	3.1	3.14
W 2-10	Muddy Pond Brook	40.00	10.00	26.00	0.00	10.00	2.3	2.29
W 3-36	Cranberry Road	28.00	0.00	40.00	10.00	10.00	2.3	2.29
W 1-25	Beaver Dam Brook	36.00	6.67	30.50	3.21	9.88	2.2	2.19
W 3-19	Lower Sampson Pond	36.00	6.67	30.00	2.86	9.52	1.9	1.90
W 1-5	Old Center Street	36.00	6.67	29.50	2.50	9.17	1.6	1.62
W 2-28	North Center Street Pond	32.00	3.33	33.00	5.00	8.33	1.0	0.95
DH 3-38	Grady Pond	32.00	3.33	32.50	4.64	7.98	0.7	0.67
W 3-35	Sampson Pond	34.00	5.00	29.00	2.14	7.14	0.0	0.00

Table D.4. Drought Vulnerability Data

Domain:	Drought Vulnerability							
Contribution to Domain Score:	13%	13%	13%	13%	13%	13%	13%	13%
Fire Department Water Supply Site ID	**AD**	**WSA**	**PVA**	**PWS**	**NA**	**FGA**	**AG**	**SOURCE**
DH 3-38	N/A	0.2	0.3	7	322	No Growth	Shared with one cranberry farm	Groundwater inputs only
W 1-1	3.6	0.17	0.51	8	486	Minor Growth	No	Surface water inputs only
W 1-25	0.8	2.5	0.58	14	593	Minor Growth	Shared with multiple cranberry farms	Surface water and groundwater inputs
W 1-33	1.6	32	0.24	10	189	Minor Growth	Shared with multiple cranberry farms	Surface water and groundwater inputs
W 1-5	2.4	0.1	0.45	11	793	Minor Growth	Shared with one cranberry farm	Surface water and groundwater inputs
W 2-10	1.6	0.1	0.27	11	631	No Growth	Shared with one cranberry farm	Surface water inputs only
W 2-12	1.2	0.5	0.03	10	437	Significant Growth	No	Surface water inputs only
W 2-19	2.4	14.6	0.39	6	564	No Growth	Shared with one cranberry farm	Surface water and groundwater inputs
W 2-26	1.6	23.2	0.7	6	567	Minor Growth	Shared with multiple cranberry farms	Groundwater inputs only
W 2-28	1.6	12.2	0.5	7	598	Minor Growth	No	Surface water and groundwater inputs
W 3-19	1.6	5.9	0.25	15	470	Minor Growth	Shared with multiple cranberry farms	Surface water and groundwater inputs
W 3-28	2.4	11.7	0.43	9	673	Minor Growth	Shared with multiple cranberry farms	Groundwater inputs only
W 3-35	1.6	299.8	0.15	14	387	Significant Growth	Shared with multiple cranberry farms	Surface water and groundwater inputs
W 3-36	N/A	NA	0.5	8	421	Significant Growth	No	Groundwater inputs only
W 3-6	0.8	20.5	0.15	6	322	Significant Growth	Shared with one cranberry farm	Groundwater inputs only

Table D.5. Implementation and Operation Considerations Data

Domain:	Implementation Considerations							
Contribution to Domain Score:	18%	15%	6%	12%	9%	6%	18%	15%

Fire Department Water Supply Site ID	Operational Ease	Permitting Complexity	Control Devices for Inlets/Outlets	Site Accessibility	Land Ownership	Public Acceptance for Improvements	Sedimentation Potential	Multi-Benefit Opportunities
DH 3-38	Depth near shore > 2ft. No aquatic vegetation	Minimal permits or only notifications required.	No	Readily accessible year round. Room for 1 firetruck.	Mixed - Private/Public	Full public acceptance	Medium sedimentation potential	Some opportunities
W 1-1	Depth near shore > 2ft. Aquatic vegetation present	Minimal permits or only notifications required.	No	Readily accessible year round. Room for 1 firetruck.	Public	Full public acceptance	Low sedimentation potential	Limited or no opportunities
W 1-25	Depth near shore < 2ft. Aquatic vegetation present	Permits required. Complex or unique site challenges.	Yes - Improvements Available	Only accessibly seasonally.	Mixed - Private/Public	Full public acceptance	High sedimentation potential	Some opportunities
W 1-33	Depth near shore > 2ft. Aquatic vegetation present	Permits required. Complex or unique site challenges.	Yes - Improvements Available	Only accessibly seasonally.	Mixed - Private/Public	Full public acceptance	Medium sedimentation potential	Some opportunities
W 1-5	Depth near shore > 2ft. No aquatic vegetation	Permits required. Moderate site challenges.	Yes - Improvements Available	Readily accessible year round. Room for at least 2 firetrucks.	Private	Full public acceptance	High sedimentation potential	Some opportunities
W 2-10	Depth near shore > 2ft. No aquatic vegetation	Minimal permits or only notifications required.	No	Only accessibly seasonally.	Private	Full public acceptance	High sedimentation potential	Some opportunities
W 2-12	Depth near shore < 2ft. Aquatic vegetation present	Minimal permits or only notifications required.	No	Only accessibly seasonally.	Private	Full public acceptance	Medium sedimentation potential	Some opportunities
W 2-19	Depth near shore > 2ft. No aquatic vegetation	Permits required. Moderate site challenges.	Yes - No Current Improvements Available	Readily accessible year round. Room for at least 2 firetrucks.	Private	Full public acceptance	Low sedimentation potential	Some opportunities
W 2-26	Depth near shore > 2ft. Aquatic vegetation present	Minimal permits or only notifications required.	No	Readily accessible year round. Room for 1 firetruck.	Private	Full public acceptance	High sedimentation potential	Some opportunities
W 2-28	Depth near shore > 2ft. No aquatic vegetation	Permits required. Moderate site challenges.	Yes - Improvements Available	Only accessibly seasonally.	Mixed - Private/Public	Full public acceptance	Low sedimentation potential	Some opportunities
W 3-19	Depth near shore > 2ft. Aquatic vegetation present	Permits required. Moderate site challenges.	Yes - Improvements Available	Only accessibly seasonally.	Mixed - Private/Public	Full public acceptance	High sedimentation potential	Some opportunities
W 3-28	Depth near shore > 2ft. No aquatic vegetation	Minimal permits or only notifications required.	No	Readily accessible year round. Room for 1 firetruck.	Mixed - Private/Public	Full public acceptance	Medium sedimentation potential	Some opportunities
W 3-35	Depth near shore > 2ft. Aquatic vegetation present	Permits required. Complex or unique site challenges.	Yes - No Current Improvements Available	Readily accessible year round. Room for at least 2 firetrucks.	Private	Full public acceptance	High sedimentation potential	Some opportunities
W 3-36	Depth near shore < 2ft. Aquatic vegetation present	Permits required. Complex or unique site challenges.	Yes - Improvements Available	Readily accessible year round. Room for 1 firetruck.	Public	Full public acceptance	Low sedimentation potential	Some opportunities
W 3-6	Depth near shore < 2ft. Aquatic vegetation present	Permits required. Moderate site challenges.	Yes - No Current Improvements Available	Only accessibly seasonally.	Public	Full public acceptance	Low sedimentation potential	Some opportunities

Appendix E

Potential Funding Sources

The following programs were identified for further consideration from the list of grants/programs provided in the MVP Action Grant application.

1. Dam and Seawall Repair or Removal Program Grants and Funds
   This may apply to the berms that impound some of the water supplies, however this program prioritizes those dams that pose a High or Significant hazard to downstream area should they fail.
2. Local Acquisitions for Natural Diversity (LAND) Grant Program
   This program is for the purchase and preservation of natural areas, and unique natural, cultural, or historic resources, and in some cases farmland. The land has to be identified in the Town's Open Space Plan as land important to be preserved. If there were some water supplies that were located on farmland that the Town has identified for preservation, then there could be some funding to purchase the land, but likely not to improve the resiliency of the water supply. If such supplies exist, then inquiry into this program would be worthwhile.
3. Drinking Water Supply Protection Grant Program
   This is intended to purchase land within approved drinking water supply protection areas, or land in estimated protection areas of identified and planned future water supply wells or intakes. This is for potable water sources, so if a fire department water supply exists within one of these areas, it could be part of a land purchase grant to preserve it. However funds would likely not be available to make the fire department supply more resilient.
4. Landscape Partnership Grant Program
   This program seeks to protect large blocks of conservation land. Local, state, and federal government agencies and non-profit groups can use this grant to work together to protect at least 500 acres of land. Eligible projects include purchase of land in fee simple for conservation, forestry, agriculture, or water supply purposes, purchase of a Conservation Restriction, Agricultural Preservation Restriction, or Watershed Preservation Restriction, or construction of a park or playground. If there was a water supply associated with an agricultural property that was no longer being farmed, there is the potential that this property could be purchased and then the land be subject to a project to restore open waters as part of the Division of Ecological Restoration Grant program. See below.
5. Division of Ecological Restoration
   This Department of Fish & Game division undertakes ecological restoration projects such as restoration of wetlands from cranberry bogs that have been permanently taken out of production. A cranberry farm, if it were voluntarily out of production, and if no interest existed for its continued use in cranberry production, the Landscape Partnership Grant Program might help fund its purchase, and then the DER might fund its ecological restoration and as part of that project maintain a fire department water supply.
6. MET Drive for a Better Environment (DFBE) Grants Program
   The DFBE Grants Program provides funding to innovative and well-designed projects that support the advancement of marine animal conservation efforts and restoration and enhancement of aquatic ecosystems within Massachusetts.

This program could be contacted to determine if the dredging of existing water supplies to provide deeper water habitat, coupled with the planting of aquatic plant and riparian plant species to increase habitat diversity and value would qualify it for funding.

7. Agricultural Environmental Enhancement Program (AEEP)
   This program funds actions that mitigate or prevent negative impacts to the state's natural resources that may result from agricultural practices. Practices funded include those that prevent direct impacts on water quality, ensure efficient use of water, and address agricultural impacts on air quality. This may potentially apply to the dredging of agricultural water supplies to make them more resilient as well as the planting of riparian and aquatic plant species if they can be seen to improve water quality.
8. Agricultural Preservation Restriction (APR) Program
   This is a farmland preservation program. In the case where an important agricultural water supply source could be abandoned upon sale and decommissioning of a farm, this program may potentially provide a way to preserve the farm and the source of water. Funds for making the supply more resilient however are not obvious.
9. State Revolving Fund (SRF) Loan Program
   This program might apply tangentially if improvements to the health of a pond could be deemed as satisfying specific watershed management priorities, storm water management, and green infrastructure goals for potable water supply protection in Carver.
10. Conservation Partnership Grant Program
    This is for purchase of land for conservation and recreation purposes, so it is not clear if this program could support the resiliency cause except perhaps by preserving a water supply that might otherwise be decommissioned if the property were to be sold.

Other potential grant programs include:

- The MassWildlife Habitat Management Grant Program
  This DFG program is designed to provide financial assistance to private and municipal landowners of protected lands to support active habitat management while fostering partnerships to encourage landscape scale habitat management and expand public recreation on conserved lands. This program may provide funding for the ecological enhancement aspects of the water supply resiliency recommendations that could result in a better fishery from providing deeper water habitat, ecological diversity associated with aquatic and riparian plantings. https://www.mass.gov/service-details/masswildlife-habitat-management-grant-program
- DER Culvert Replacement Municipal Assistance Grant Program
  This DFG program is intended to enable or enhance aquatic connectivity and improve flood resiliency by replacement of culverts with properly sized and designed culverts. This program may provide tangential funding, although very few of the fire department water sources contain culverts. https://www.mass.gov/how-to/culvert-replacement-municipal-assistance-grant-program

Appendix H

Task 3 Report – Cranberry Growing Source Waters

Agricultural Water Source Assessment

Photo credit: © Susan Cole Kelly 2018

Town of Carver

Municipal Vulnerability Preparedness (MVP)

Action Grant

Climate Change Water Resources Vulnerability and Adaptation Strategy Assessment

Technical Report – Task 3

May 2019

FUSS & O'NEILL

Project No. 20170390.B51

Table of Contents

Appendices

1 Introduction and Purpose

Members of the Carver Municipal Vulnerability Preparedness (MVP) Core Team and additional stakeholders participated in a Community Resilience Building (CRB) workshop on April 19, 2018 to identify the top natural hazards of concern for the Town of Carver and identified Wind, Wildfire, Excessive Precipitation or Drought, and Extreme Temperatures. Of these, Excessive Precipitation or Drought directly relates to the sustainability of Carver's water resources and the Town's cranberry growing industry that can be profoundly impacted due to reduced water availability for agricultural operations. As a result, the Town is undertaking a Climate Change Water Resources Vulnerability and Adaptation Strategy Assessment with assistance from an MVP Action Grant.

The Town has many cranberry farming operations that rely heavily upon water for irrigation, frost protection, and for harvesting of the cranberry crop. Projected climate change is anticipated to result in several changes impacting cranberry growing, with drought being one of them. Seasonal freshwater flushing of the bogs in the fall, winter and spring is necessary for harvest and protection from frost and pests. The cranberry growers in the Town of Carver primarily use surface water from nearby ponds, swamps, or streams for this flushing. Increased annual and summer temperatures may result in an increased number of droughts. A drought comparable to the record-holding drought of the 1960s could result in decreased water levels throughout the region and depletion of surface and groundwater supplies may result in limited access to water for flushing the bogs. The water storage and water management systems already associated with these farms may provide an opportunity to develop a more resilient water supply system for existing cranberry farming operations and in addition provide an opportunity for natural systems restoration.

This report outlines the elements of the Water Resources Vulnerability and Adaptation Strategy Assessment that assess a variety of types of agricultural water sources representative of the types of surface water supplies used for the cranberry growing industry throughout the Town of Carver.

2 Approach to the Assessment

The goal of this portion of the Water Resources Vulnerability and Adaptation Strategy Assessment is to work with the agricultural community to further define their current water supply challenges and to identify adaptation measures to reduce water use, manage existing water resources and provide additional sources of water. Understanding how water is used and the manner in which it is stored and distributed is critical to an assessment of opportunities for developing more resilient water supplies for cranberry growers. The framework of the four step assessment is outlined in Figure 1.

In the first step of the assessment, a file review of the Massachusetts Department of Conservation and Recreation (MADCR) Office of Dam Safety (ODS) and town databases was performed to gather applicable information regarding non-jurisdictional agricultural dams or hydraulic control structures. Using available data, Fuss & O'Neill coordinated with the MVP Core Team and the Cape Cod Cranberry Growers Association to select six (6) agricultural water sources for a detailed field review. The intent was that the selected water sources be representative of the common types of agricultural water sources within the town, with priority placed on those that historically experienced water shortages. The specifics of this review and selection process are described in Section 3.

In the second step of the assessment, the selected agricultural water sources were visually examined by Fuss & O'Neill staff to gain an understanding of the relative integrity of the water impoundment structures. For water sources with dams and dikes, the examination followed standard Office of Dam Safety inspection protocols addressing hazard classification information and structural condition as outlined in Section 4. When available, farm owners were consulted and information pertaining to operational procedures and specific site challenges was gathered and documented.

In the third step of the assessment, an online survey was distributed to the cranberry community within the Town of Carver with assistance from the Cape Cod Cranberry Growers Association. The survey gathered information about the specifics of a farm's water use needs, practices, challenges, and potential opportunities. The information collected from this survey is detailed in Section 5.

In the fourth and final step of the assessment utilizing information gained from steps 1 through 3, potential management alternatives were evaluated and potential recommendations were developed for agricultural water sources. Recommendations consist of repairs, modifications or additions of water sources to increase drought resiliency and a worksheet developed to help guide the evaluation of potential resiliency measures.

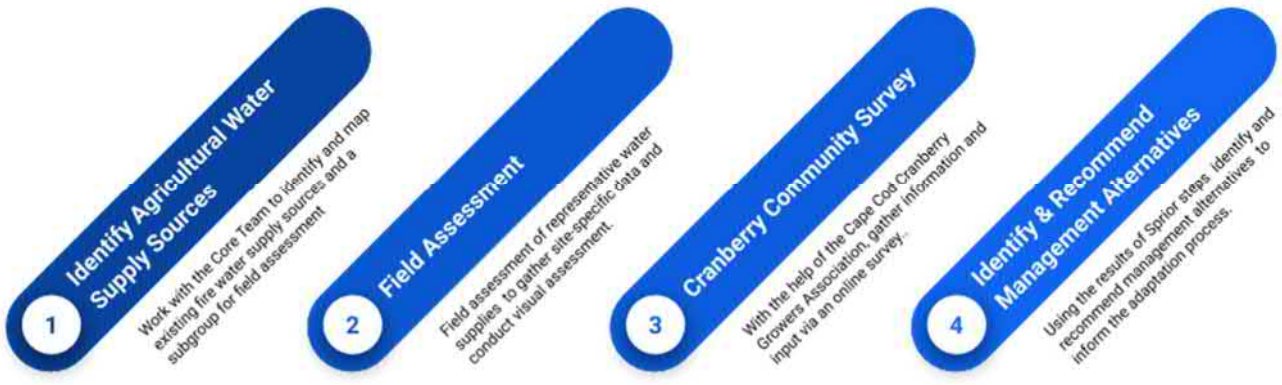

Figure 1. Approach to Agricultural Water Supply Vulnerability Assessment Task

3 Identification of Sources

Retrieval of Massachusetts Department of Environmental Protection (MassDEP) Cranberry Farm Data

As part of the Water Management Act (WMA M.G.L. 21G; 310 CMR 36.00), any cranberry grower with a cumulative total of 4.66 acres of bog in Massachusetts is subject to water use regulations. MassDEP has compiled this information on regulated cranberry growing operations into a cranberry bog GIS data layer. This data layer contains information regarding the current permit ID and status, owner's information, and permitted acreage. The latest release of this data layer (dated July 13, 2018) was obtained from the MassDEP Southeast Region office and was used as a baseline inventory of cranberry bogs within Carver. Table 1 summarizes the total number and surface area coverage of registered cranberry farms within Carver, which covers approximately 14% of the land area of the town.

Table 1. MassDEP Registered Cranberry Bogs in Carver, MA

Number of Registered Bogs	216 Bogs
Number of Inactive/Abandoned Bogs	17 Bogs
Total Acres of Cranberry Bogs	3740 Acres

Massachusetts Office of Dam Safety File Review

The Massachusetts Office of Dam Safety (ODS) within the Department of Conservation and Recreation (MADCR) maintains a dam safety database containing information such as the location, ownership, regulation authority (i.e., is it regulated by the Office of Dam Safety under CMR 302 10.00), and the hazard classification of the dam if it is regulated. A review of the DCR Office of Dam Safety database was performed to determine if any jurisdictional dams existed as part of a cranberry farm water source .Additionally, the Town and the Cape Cod Cranberry Growers Association were consulted but neither maintains any additional information on dams or hydraulic control structures used for agricultural operations.

The query of the ODS database shows that four (4) dams within Carver are owned by the Town, and the remaining 52 are privately owned (Appendix A). Ten dams are regulated by ODS under CMR 302 10.00 (four (4) significant hazard dams and six (6) low hazard dams), including two (2) owned by the Town of Carver, and the remaining 46 are non-jurisdictional. The significant hazard dams are:

- Tremont Street Dam
- Crane Brook Upper Dam
- Mayflower Road Dam
- Plymouth Road Dam.

The ODS database along with MassDEP's cranberry and hydrography GIS data layers were combined to create the Agricultural Water Supply Map in Figure 2 which depicts the total inventory of registered dams, cranberry farms and associated water sources within Carver.

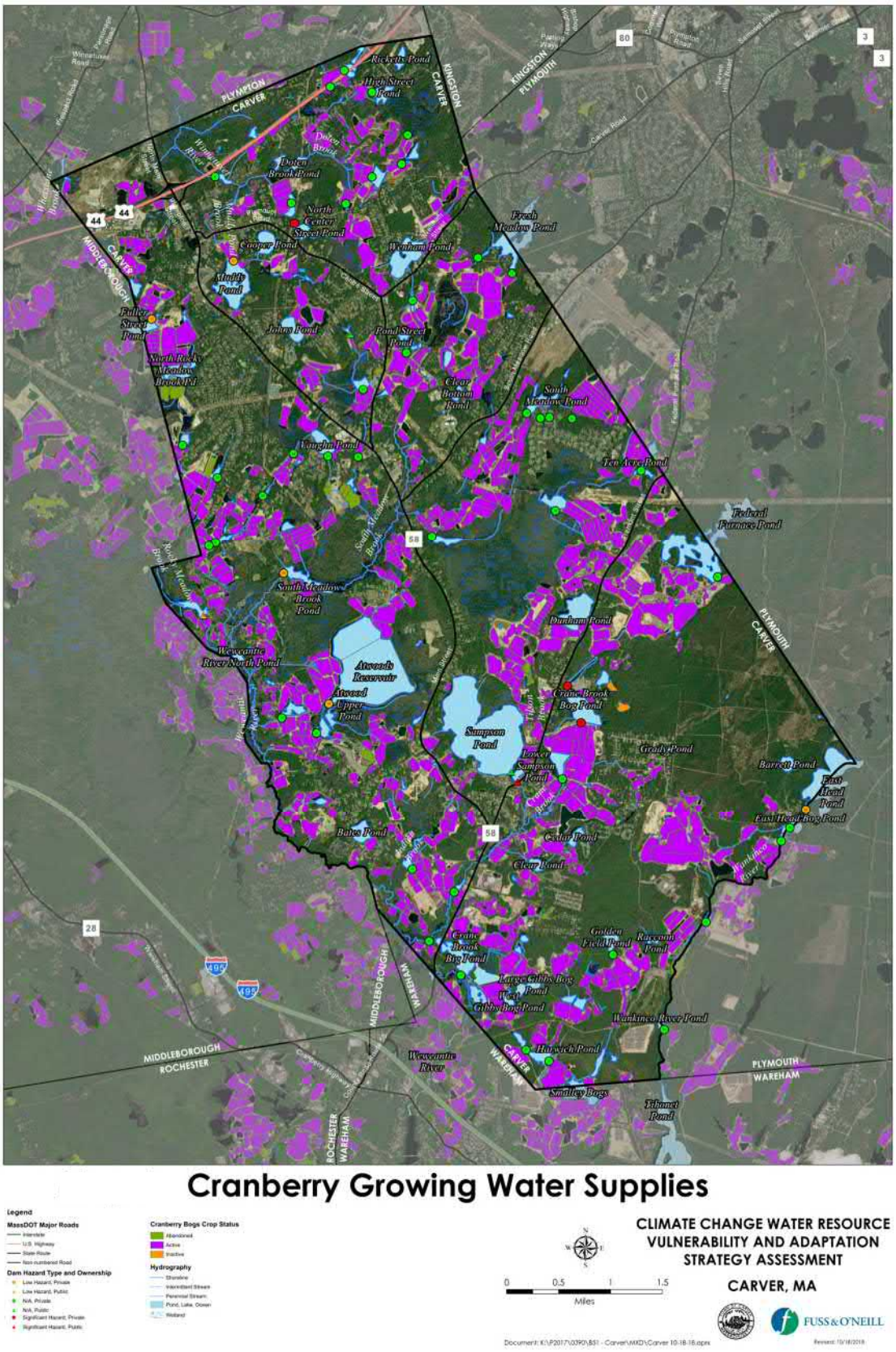

Figure 2. Cranberry Growing Water Supplies

Identification of Representative Agricultural Water Sources

The selection of agricultural water supplies to visit in the field was initially discussed at the MVP Action Grant Project Initiation Meeting on October 17, 2018 with the goal of developing a priority short list of 5 water sources/hydraulic structures for field review. The intent was that the water sources be representative of the common types of agricultural water sources and those that historically experienced water shortages. Additionally, owners/operators of the bogs would need to provide access and information on the nature of impacts during the 2016 drought and a description of the operation of the farm and the normal use of water in the agricultural activity. Brian Wick, Executive Director of the Cape Cod Cranberry Growers Association developed a short list of cranberry farms to visit that would represent the various supply types: dams, swamps, flumes, etc. With assistance from the Cape Cod Cranberry Growers, the following sites were selected from the MassDEP inventory of cranberry bogs in Carver (Table 2):

Table 2. Sites of Cranberry Growing Water Supply Site Visits

Cranberry Water Supplies	Location (Address)
Center St. Bog	20 Center Street
Flax Pond Bog	58 Pond Street
Godfrey Bog	24 Gate Street
Mayflower Road Bog	Mayflower Road
Shaw Bog	157 MA-58
South Carver Bog	41 Cranberry Road

4 Limited Visual Condition Assessment

Field visits to each of the six (6) agricultural water sources were performed to gather information on the details of the water use, storage and transmission, as well as the condition of the infrastructure in regards to the need for maintenance to assure greater reliability in relation to source and transmission, as well as safety and/or long term viability in relation to dams or earthen embankments storing water. An important component of the field assessment was meeting with the representatives of the Cape Cod Cranberry Growers Association as well as the cranberry grower on site to understand the details of the water operations, the degree of impacts from the 2016 drought and the ongoing maintenance and repair activities undertaken for the system. The goals of the field assessment were to identify the distinct types of agricultural water sources, develop a clear understanding of their operations, the vulnerability of these systems to low water, and the practical solutions that growers have employed to address water availability so that this information would then be applied to identifying potential management and infrastructure improvements or modifications that could be made to improve the resiliency of these water sources.

Operability of the agricultural water sources is dependent on the functionality of the associated dams and dikes impounding these water bodies. As part of the agricultural water source field visits, notable dam systems were visually observed for deficiencies and overall conditions. Per Massachusetts Department of

Conservation and Recreation (MADCR) Office of Dam Safety (ODS) 302 CMR 10.04, the agricultural dams observed in the field are excluded from the State's defined classification of a "Dam." However, it is recommended that operation, maintenance, and emergency procedures are developed for agricultural dams to remediate deficiencies, and to improve overall conditions of the water sources.

The five observed dams include Godfrey Bog Dam #1 (MA00382), Old Center Street Dam (MA02073), an unnamed dam located on Clear Bottom Pond within Flax Pond Bog, Shaw Bog Dam (MA00089), and an unnamed bog located on Dunham Pond within Mayflower Road Bog. The Commonwealth of Massachusetts DCR Dam Safety Inspection Checklist was used as a template for visual observation of each dam visited in the field. The inspection checklists are presented within Appendix B.

In general, the agricultural dams within Carver are small-sized, grass-covered, earthen embankments adjacent to cranberry bogs. Dams observed in the field and through desktop research range from two (2) feet in structural height, to greater than six (6) feet. The hydraulic heights observed are typically low, and greatly vary at the water sources depending on the cranberry growing operations and groundwater conditions. The primary measures of controlling flow include short lengths of flume boards (timber, extruded aluminum, stainless steel, etc.) contained within concrete channels, corrugated metal pipe (CMP) drop-inlet structures, agricultural pump systems, among other means of conveying flow to bogs. Regardless of the composition of the dam, appurtenances, and control devices, it is essential that the system is properly maintained in order to sustain the critical agricultural water supplies, and provide greater resilience for the farm during extreme climate conditions, such as severe drought and heavy rains.

The agricultural dam embankments are typically well-maintained due to the dams' dual use for water impoundment and for serving as access and haul roads for the growing operations. However, because of the frequent truck and heavy machinery traffic on the dam crests, the most common deficiencies observed included bare areas and rutting on the dam crest. Additionally, the shallow depths, slopes, and low velocities of the typical impoundments observed, the approach areas to the dam primary spillways are susceptible to vegetation overgrowth, sedimentation, and collection of debris. Due to the intentional flooding of bogs during wet cranberry harvesting, the agricultural dams experience intermittent flows of various depth and velocity along the embankment toe, leaving these areas susceptible to erosion and potential undermining of the dam embankment. It is common practice for growers to place soils on the dam or internal dike system crests during intentional flooding to protect the embankments from overtopping.

The estimated overall condition of the observed dams appeared to be "Satisfactory", as defined by MADCR ODS 302 CMR 10. These condition ratings do not constitute as MADCR ODS-approved ratings for Dams, but provide an estimation of overall condition if a formal ODS Phase I Visual Dam Safety Inspection were to be performed.

5 Information Gathering from the Cranberry Growing Community

With assistance from the Cape Cod Cranberry Growers Association, an online survey was developed to gather additional information from cranberry growers in Carver about their water supplies, water use practices, impacts to their operation by the 2016 drought, and their ability to manage water for their

growing operations. The goal of the survey was to gather additional information to inform potential resiliency recommendations. A copy of the survey questions is located in Appendix C. The survey was open from April 24, 2019-May 5, 2019 and again from May 8, 2019-May 13, 2019. Of the growers in Carver contacted by email for the survey, 6 responded (Appendix C). Highlights of the survey include the following:

- Bog size varied from 1 to 100 acres.
- Number of water supplies varied from 1 to 6, with the majority reporting 2 water supplies.
- Of the 5 growers that responded to the question, 3 had the ability to move water around their farm, 2 did not.
- Only 1 of the growers had a water supply that was also used for firefighting purposes.
- While one grower used both dry and wet picking methods, all others used wet picking exclusively.
- Surface water sources included a mix of ponds, swamps, streams, and reservoirs.
- Only 2 of 5 growers reported having groundwater as a backup water source.
- Adequate water for harvesting was a greater concern than for frost protection.
- For growers impacted by recent drought (2016), water level declines of up to 4 feet were reported.
- 3 of the 5 responding to the question indicated they would like to be able to manage their water differently.

6 Evaluation of Management Alternatives

The Agricultural Water Sources are of varying ages and construction type and have a wide range of storage and water yield capacities. They are all subject to a decrease in available capacity and yield over time from a variety of causes - some related to reductions in storage capacity, others related to reduced water conveyance capacity or greater loss of water due to increases in rates of leakage. The design of these water sources may also make them vulnerable to the anticipated potential substantial reduction of available water due to projected climate change impacts including reduced surface water flows, and surface water drop due to drought. Causes of the major challenges facing these water sources include:

- Decreased storage occurs as a result of gradual accumulation of mineral sediments deposits, from silts and sands carried in diversion water or river water flows. Accumulation of organic sediments due to die off of algae and aquatic plants will also result in a loss of storage.

- Inadequate storage due to ponds not having been constructed deep enough to intercept the diminished groundwater levels that have and are anticipated to occur during severe droughts. The absence of deep wells to tap the lowered groundwater levels that will occur in a severe drought.

- The normal wear and tear of the manmade infrastructure associated with the water extraction, conveyance and storage components of water use results in the system not operating at its highest capacity, which becomes much more critical during times of reduced water availability.

In addition to addressing these major challenges, there are also measures that may be taken to improve the resiliency of agricultural water sources to the potential impacts of climate change. They include:

- Opportunities to reduce the demand for raw irrigation water may exist and can augment the capacity of the existing water infrastructure.

- Sources of water that have shown to have surpluses and are expected to have surpluses during extreme drought may be able to provide the additional capacity to meet the demand of specific agricultural operations.

Following is a discussion of the measures that may improve the resiliency of the agricultural water sources to anticipated climate change-induced drought and warm weather. Permitting and approval requirements of these measures will vary and can be determined on a site-specific basis. Table 3 summarizes these measures and the questions used to assess their feasibility. While most of the resiliency measures identified and discussed in the following section will be obvious to the growers who own and manage these cranberry farms, this is written for the understanding of a wider audience who may not have the knowledge and experience that these growers have. It is important for decision makers, including the regulatory agencies and the funding agencies, to have an understanding of the variety of measures that may exist for increasing the water use resiliency of these agricultural operations, as well as some of the challenges to their implementation.

Dredge to Remove Sediment or Increase Capacity

For those water sources that have had their storage volumes diminished there are numerous actions that may be appropriate to restore and even increase available storage.

- The most obvious means of increasing storage capacity is to dredge accumulated sediments from storage ponds to restore the original dimensions of the ponds. This would be allowed without permit approval since it is maintenance of an existing farm pond.

- Similarly diversion channels and natural watercourses may have sediment accumulation that restricts the ability to withdraw water. Dredging of these channels and watercourses will restore their original conveyance capacity. Dredging of existing diversion channels would be allowed without permit approval since it is maintenance of an existing farm water management system, however dredging of natural watercourses could require permit approval, if not considered ongoing maintenance of a historical component of the farm water management system.

- Debris accumulation may restrict the flow of water within diversion channels, and rivers. Removing this debris from diversion channels will help restore the original diversion capacity. Debris removal would not require permits as long as part of ongoing farm maintenance activities.

- Ponds should be sufficiently deep to contain enough water for critical water use during drought conditions. Ponds could be over excavated to deepen them to at least 12 foot overall depth to intercept anticipated severe drought condition groundwater levels. The cranberry grower survey indicated that pond levels dropped as much as 4 feet during the 2016 drought. Predictions for impacts due to the 1960's era record drought in the Carver aquifer predict water levels dropping up to 6 feet, with most areas in Town up to 4 feet under current withdrawal conditions. There is a minimum volume of storage that is required to be available for the most critical water use which is wet harvesting. Assuming the minimum depth required to provide an adequate minimum storage amount is 6 feet, then add 4 feet for 2016 and 1960's drought and get 10 feet. Then provide an additional 2 feet for surplus

depth for sediment storage, lengthening the time between required maintenance dredging activities. This totals a depth of 12 feet. Excavating ponds to a normal depth of at least 12 feet should provide resiliency to those critical droughts, and will provide additional storage for anticipated sedimentation. Over dredging beyond the historic depth of the pond would likely require permit approvals.

- Some farms have the room to either expand the surface area of existing ponds, or to excavate additional storage ponds where they currently do not exist. Typically growers can excavate as far as their equipment can reach from the berm, so there could be limitations on reaching the full area of the larger ponds. Larger equipment would have to be brought in to undertake large pond deepening efforts. Expansion of the surface area of an existing pond would require permit approvals.

- For swamps that are bermed on their downstream side and are used for storage of water, typically only a small area near the berm is kept excavated of sediments to allow an area to install a pump and draw water from the swamp storage area. Permitting through MassDEP would be required for expansion of the pond surface area since that would not be considered a maintenance of an existing excavated area, but excavation of an existing naturally vegetated wetland area. If the deepening/expansion was permitted, it is anticipated that there would still be greater cost associated with this as opposed to excavating an existing pond deeper that is located in an area of sandy soil. In the latter case, the sand/gravel has some value for re-use, while the mucky organic materials likely excavated from a swamp will have no or minimal value for re-use.

- If raising the berm on an existing natural swamp water source could be undertaken without unacceptably flooding upstream areas, it would still require permit from MassDEP for the new berm material to be placed in order to raise its height.

- Excavation of a new pond would provide additional storage for ground and potentially surface water. MassDEP wetland permitting has setbacks and therefore if a new pond is proposed to be excavated within the regulatory setbacks of a wetland area, then MassDEP would require permits.

Augment With Groundwater

For those agricultural water sources that are known to be insufficient during times of drought, and no effective alternatives are known to exist to make those water sources more resilient to drought, then providing a direct groundwater source may be appropriate. The groundwater aquifer in Carver is known to have substantial capacity and represents a massive reservoir of water that is relatively easily withdrawn with the installation of a gravel packed well.

It is critical that the well is installed to elevations that are substantially below the anticipated drawdown level of the 1960's record drought including the maximum drawdown that would occur during the pumping and withdrawal of water through that well. These are calculations that are relatively easily performed. For instance, if it is expected that groundwater levels will diminish by up to 4 feet from normal levels due to a drought of the magnitude of the 1960's drought, and the desired pumping rate from the

well will create a drawdown level at the pump of 10 feet, then the depth of the well below normal groundwater level must be at least the sum of those dimensions plus the screened opening of the well.

Installation of any well must recognize the potential impact to adjacent water sources and wells, and an emergency back-up water supply well is not an exception. It is important to understand the potential drawdown cone associated with the well pumping at the design rate to determine if this will substantially impact the availability of water from adjacent waterbodies, water courses, or wells. An emergency back up well must be an additional source of water that is not diminishing the availability of water from other sources during a drought emergency. Installation of a new well would require a MassDEP Well Drilling Application.

Increase Water Control Options

For those water sources that have a history of having been impacted by the 2016 drought, or that do not have the minimum recommended depths as referenced above for dredging of ponds (12 feet), or do not have the flow capacity to allow a sufficient diversion from existing water courses, then other maintenance or operational measures may be available to increase the resiliency of the water source.

Earthen berms are critical to the water storage and conveyance systems on the farms, so being maintained in good condition is important to assure water availability. Leaking berms will allow water to be lost. Leakage through earthen berms also has the potential to cause those berms to fail by breaching through a process known as piping erosion where soils that comprise the berm are eroded with the leaking water. Trees growing on berms can weaken the berms and provide preferential seepage paths for water to leak and potentially result in failure through piping erosion failures. Berms with uneven crest elevations could result in an overtopping of low spots during high water conditions and resulting erosion and potentially failure due to overtopping flow. Maintaining these berms properly by repairing leaks, properly removing trees and root systems and maintaining level crest elevations, will provide greater assurance that the water stored and conveyed by these berms is not being lost gradually or suddenly and is available for agricultural uses. Similarly, flume board structures need to be properly maintained to assure water is stored and conveyed to where it is needed and not lost due to leakage or sudden failure. Maintenance of these berms should be allowed without specific permit approvals, however contacting the DCR Office of Dam Safety and the Carver Conservation Commission would be advised to inform both of the proposed activities.

Farms that rely partly upon wells for their water source will find that well capacity may diminish over time due to biofouling or blocking of well screens with finer mineral soils. Restoring the capacity of wells on an as needed basis will assure that water is available when needed. Redeveloping wells can be accomplished by a variety of means and a well driller will be able to advise as to the feasibility, and if found feasible, the most appropriate measures to take and whether specific permits are required.

An obvious operational measure that may have application to improve the resiliency of these water sources is that additional storage may be available in certain ponds by raising the water level with addition of flume boards. If upstream bogs, or infrastructure is not impacted by these higher water levels then this may be one way of providing additional storage with existing infrastructure. This may already be part of the ongoing water management measures at many bogs.

Flume sizing should also be evaluated for adequacy. Some of these flumes are old structures that pre-date the Water Management Plan approvals, and may not have the capacity to fully utilize the amount of water allowed in the approved plan. There is evidence that at least one case, the flows from upstream have increased due to development and the flumes need to be modified to handle the increased flows.

Increase Water Conservation/Reuse

For those water sources that are losing water due to equipment malfunction or poor condition, and obvious means of reducing water demand is conservation of water by minimizing water loss from leaking pumps and pipes. For storage ponds that due to their size cannot be excavated to intercept groundwater, consideration might be given to lining these ponds to minimize loss through infiltration of water into underlying soils during drought conditions. Careful consideration should be given to this approach, since lining of a pond bottom will preclude groundwater infiltration when water levels are higher than the pond bottom, or ambient water level in the pond.

There may be additional water sources that are not readily available due to lack of certain infrastructure. One of the obvious means of providing additional resiliency is to reduce the overall demand of raw water. This can be accomplished by recycling water that has already passed through the bogs and returning it to the area where water is needed. This could be accomplished through the installation of pumps at the most downgradient outlet of the farm to pump water and convey with piping to the head of the farm where the water is being stored for future use. This recycling infrastructure could be augmented by the installation of a tail pond that captures the excess water at the downgradient end of the farm, and stores it for future use. Future use would be enabled by a pumping and piping system to return the water to the upgradient extent of the farm. Recycling of water needs to consider the impact it may have on downstream areas including downstream farms that may rely upon the flow of water from the upgradient farm operation. Recycling would have to be coordinated at all farms in series to be assured that no downgradient farms are deprived of water that they have come to rely upon during periods of low flow where their sources or other off line sources may not provide the needed water. In general, water recycling should be encouraged and therefore opportunities sought since it not only diminishes the demand for raw water, it minimizes the potential for pollution to natural waters from fertilizer, herbicide and pesticide use.

“New type” bogs use considerably less water than ”old type” bogs, so it follows that changing to new type bog would result in substantial water conservation. The percentage of old versus new types of bogs in Carver is approximately 50/50. The primary obstacle to converting from old to new style bogs is the financial impact on the grower. The Cape Cod Cranberry Growers Association reports that it initially costs approximately $50,000 per acre to convert from old style to new style. The conversion also takes the farm out of production for approximately 3 years, so there is the additional cost of that lost revenue. It takes another 5 to 6 years to return to full production. Overall, the return on investment can be a 12 to 15 year timeframe. So due to this substantial financial impact, many growers cannot afford to make this conversion without outside financial assistance.

The greatest water use by volume is in the winter, for winter flooding of the entire bog acreage to protect the plants and roots from freezing. Wet harvesting uses less water than winter flooding. Most of the larger bogs are compartmentalized with berms and flumes so that discrete bog sections can be watered for wet harvest and then the water is sluiced to the next compartment(s) in a farm’s system of bogs. In this manner, the entire bog area of a farm does not have to be filled completely all at once. Water is

efficiently used several times in the larger bogs to allow the wet harvest to proceed. In the smaller bogs that are not compartmentalized, the entire bog has to be filled entirely to allow the wet harvest to proceed.

Dry harvesting is a method that by its name requires little to no water for completion. For those farms where the ability to dry harvest could be achieved by having the proper equipment available, then farms may consider cooperating in the purchase of the necessary equipment to assure some backup capacity to harvest during drought emergencies where insufficient water is available for the traditional wet harvest utilized at most farms. In most cases however, switching to a dry harvest is not feasible during the growing season once the berries have begun to grow. Dry harvesting requires plants to be manually pruned so the harvesting equipment can move though the plants without breaking the vines and causing extensive damage to the plants. Conversion to dry harvesting is only effective as a permanent strategy such that the conversion can be undertaken in the fall after the harvest, and certainly no later than the spring when the plants are just beginning to grow back. Additionally dry harvesting involves 3-4 times more people than wet harvesting, and wet harvesters don't have dry harvesting equipment on hand and would need to rent/invest in them. Switching to dry harvesting should be seen as more of a permanent conversion applicable mainly to small acreage growers.

A proven method of water conservation that substantially reduces water use is autostart technology for irrigation. This refers the pumps that are controlled by software that, with the use of temperature and/or soil moisture probes, controls when the water is pumped for irrigation or frost control and when it is shut off. Temperature probes have been shown to substantially reduce water use. Soil moisture probe use is being perfected by the USDA-ARS (Agricultural Research Service) Hydrology Program at the UMass Cranberry Station at Amherst and should provide further reduction in water use in the future. According to the Cape Cod Cranberry Grower Association, approximately70% of the cranberry industry uses autostart technology with temperature probes. Expanding this to all of the cranberry growers in Carver could reduce water demand and provide greater drought resiliency.

Water Sharing/Diversion

For those water sources that have had insufficient water availability during drought conditions, there may be other farms that have a surplus of water availability. These farms may have major sources of water which have substantial excess capacity to be able supply additional farms during high water demand periods. The water distribution systems may not exist to allow that excess water to be shared with farms in need. This may be accomplished by increasing the capacity of existing diversions and by construction of new diversion systems to reach farms in need of additional water. These diversion systems could be one or a combination of diversion channels or pipes for gravity flow, or pumping systems to feed channels or piping systems to convey available water.

Trucking of Emergency Water

The concept of purchasing water and having it trucked to a farm in a drought emergency was evaluated and it was determined that is not a feasible option. It would be very expensive since it would require over thirty (30) 10,000 gallon tanker trucks to provide enough water for a 1 acre bog for harvesting. While this option may be a last resort measure in a dire drought emergency, it is not a reasonable resiliency measure to rely upon or adopt.

Permitting Requirements for Water Supply Resiliency Recommendations

Some of these resiliency measures could require permits or regulatory approvals if they are not considered maintenance activities, and water management activities that are included in the farm's current MassDEP approved Water Management Plan. Other measures such as dredging of accumulated sediments to original pond bottom, removal of debris, repairs to components that may be leaking, all can be undertaken as maintenance activities.

New construction including expanding pond area, deepening ponds beyond the original constructed depth, deepening diversions beyond their original constructed depths, installation of new wells, installation of water recycling systems, raising the berms on existing ponds to store more water, enlarging the size of flumes, construction of new diversions systems to bring new sources of water to a farm, all would likely require some level of permitting or regulatory approval. Depending on the exact nature and location of a proposed activity, permit may be required in accordance with the following local, state and/or federal regulations:

- US Army Corps of Engineers Section 404
- Massachusetts
    - Water Quality Certification (314 CMR 9.00)
    - Waterways (310 CMR 9.00)
    - Wetlands Protection Act (310 CMR 10.00)
    - Water Management Act (310 CMR 36.00)
    - Well Drilling (310 CMR 46.00)
    - Environmental Policy Act (301 CMR 11.00)
    - Renovation of Cranberry Bogs (310 CMR 23.00)
- Carver Conservation Commission Wetland By-Law

Maintenance of existing ponds by simply removing sediments to the original pond bottom and removing vegetation and debris to restore pond areas, as well as channels and diversion ditches, should be covered as a maintenance activity. It is recommended however that this be confirmed with the Carver Conservation Commission before such activity is undertaken since it will also keep the Town's Conservation Agent aware of activities affecting wetland, waterbodies and watercourses in the Town of Carver.

During an emergency drought condition, it is possible that the permitting authorities could waive or streamline the approval process for certain permits. According to the Cape Cod Cranberry Growers Association, in 2016 the permitting agencies generally suspended the need for permits so emergency actions could be taken to save the crop. Some agencies still required approvals, but they were expedited.

Table 3. Carver Agricultural Water Sources Resiliency Recommendations – Potential Measures Summary

Dredge to Remove Sediment or Increase Capacity	
Applicable Question	Potential Resiliency Measure
Has pond lost substantial storage volume due to sediment accumulation?	Dredge accumulated sediments from storage ponds
Has capacity of diversion channels diminished over time due to debris and or sediment accumulation?	Remove debris from and dredge diversion channels to restore diversion capacity
Is there room for existing pond to be expanded in surface area?	Expand area of pond
Is normal pond depth only 3 feet or did pond go nearly dry in 2016?	Dredge accumulated sediment
Is there room to excavate a new storage pond into groundwater?	Over excavate to a 12 foot overall depth to intercept anticipated drought condition
Has pond lost substantial storage volume due to sediment accumulation?	Excavate new storage pond
Augment With Groundwater	
Applicable Question	Potential Resiliency Measure
Are there locations for the drilling of a gravel packed well given proper setbacks from existing on site sanitary waste disposal systems or other wells or surface water sources that could be influenced by well drawdown?)	Drill wells
Increase Water Control Options	
Applicable Question	Potential Resiliency Measure
Are earthen berms or dams in poor condition (such as leakage, erosion, covered in trees, etc.) or in need of maintenance?	Repair earthen berm to reduce leakage and enhance stability and durability
Are flume board structures in poor condition (such as leakage, erosion, corrosion, covered in trees, etc.) or in need of maintenance?	Repair flume board structure to reduce leakage and enhance useful life
Are flume board structures sized properly?	Evaluate hydraulic adequacy of flume board structures
Can water level be raised without causing upstream flooding of infrastructure or bogs?	Raise water level with additional flume boards
Are water sources with surplus storage located downstream?	Install pumps and piping systems
Has capacity of existing well(s) diminished over time?	Restore original well capacity by redeveloping existing well(s) by appropriate methodology
Increase Water Conservation/Reuse	
Applicable Question	Potential Resiliency Measure
Are pipes or pumps leaking?	Repair leaking pumps and pipes
Are wet harvesting methods currently employed?	Convert to dry harvesting
Is water not currently recycled for reuse?	Recycle water for reuse
Is the Bog currently an Old type bog?	Convert to New Type Bog
Does site currently irrigate manually?	Install autostart Irrigation Technology with temperature probes, and ultimately soil probes
Water Sharing/Diversion	
Applicable Question	Potential Resiliency Measure
Are there water sources with known surplus as evidenced by 2016 drought in reasonably close proximity?	Seek shared water sources
Are water sources with surplus storage located upstream?	Install diversions

7 Future Application

The methodology utilized in this task to develop applicable recommendations for improving the resiliency of agricultural water sources is available to be applied to the balance of the agricultural water sources in Carver. Information required to make the appropriate recommendations include desktop data readily available from the sources identified in background documentation completed in the first phase of this project. Additional information required would be obtained from field visits as explained in Section 3 and 4.

The questions in the Potential Resiliency Measures Recommendation worksheet (Appendix D and Table 3) would be asked and answered and would provide a list of potential resiliency measures that could be implemented on the particular agricultural water source. These would be a list of potential applicable measures whose ultimate applicability and then priority would be decided by the farmer in recognition of other factors not considered by the recommendation worksheet. They could include restrictions on access to implement the specific resiliency measures, insufficient land area for expansions of surface water sources or installation of additional water control structures, insufficient setback from adjacent wells or adjacent surface water sources, prior agreements with downstream farmers on the release of once through bog water, available funding to implement these measures, potential permitting challenges, and other considerations.

The best way to exhibit the use of the Potential Resiliency Measures Recommendation Worksheet tool is to provide an example agricultural water source and apply the worksheet to determine the list of potential resiliency measures that are recommended (Appendix D). Following is a hypothetical site that will be evaluated for potential resiliency measures.

Hypothetical Bog Resiliency Recommendations

Hypothetical Bog has two ponds that are relatively small, being a ½ acre each. They are both 6 feet deep, and are in series with an upper pond draining to a lower pond through a flume board structure that then drains to the lower pond. The upper pond is fed from a natural watercourse through a diversion structure that sluices some of the flow to the upper pond as it is needed. The sluice is a flume board structure. The lower pond has a flume board structure that allows water to drain to the cranberry bog. The cranberry bog has a flume board structure that drains back to the same natural watercourse. There is one cranberry bog located downstream after which the flow drains back to the natural watercourse. The downstream bog has sufficient sources of water on site so as to not have to rely upon the once flow through water from Hypothetical bog. The ponds are partially excavated into the ground, and partially impounded by earthen berms (dams) that retain the higher levels of water. The berms are covered with woody shrub vegetation, and several trees that are within 10 feet of the berms. Some leakage is occurring from the base of the earthen berms when water levels are high in the ponds. The flume board control structures are in good shape and do not leak.

The ponds both suffered from the 2016 drought, with water level having dropped approximately 4 feet in both ponds. The drop in water level was likely a combination of ground water levels dropping, evaporation from the ponds and the need to irrigate the bog during the long hot dry periods, and finally the lack of sufficient available flow to sluice from the natural watercourse. The remaining 2 feet of water in the ponds was not sufficient to provide adequate water for wet harvesting in the fall. The diversion

channel from the watercourse has grown in with woody vegetation, and debris as gotten hung up on the woody vegetation and this likely restricted the diversion capacity.

The farm is located on a very small parcel with the ponds relatively close to the property line, so there is not much room for expansion of the ponds. Access to the ponds for maintenance dredging is good and dredging had been undertaken in the past to restore the original 9 feet of depth. There is additional land below the bog on both sides of the ditch that conveys flow back to the natural stream. There is not sufficient land area to install a well without potentially inducing flow from the adjacent cranberry farm ponds.

Using the Potential Resiliency Measures Recommendation worksheet (Appendix D), the following would be determined for the Hypothetical Bog:

Dredge to Remove Sediment or Increase Capacity

- Has pond lost substantial storage volume due to sediment accumulation?
  - Yes - Dredge accumulated sediments from storage ponds.
- Has capacity of diversion channels diminished over time due to debris and or sediment accumulation?
  - Yes - Remove debris from and dredge diversion channels to restore diversion capacity.
- Is there room for existing pond to be expanded in surface area?
  - No
- Is normal pond depth only 3 feet or did pond go nearly dry in 2016?
  - Yes - Pond went nearly dry with only 2 feet of water left, where 4 feet minimum has been identified as the minimum water storage that is acceptable. Over excavate to a 12 foot overall depth to intercept anticipated drought condition ground water levels.
- Is there room to excavate a new storage pond into groundwater?
  - No

Augment With Groundwater

- Are there locations for the drilling of a gravel packed well given proper setbacks from existing on site sanitary waste disposal systems or other wells or surface water sources that could be influenced by well drawdown?
  - No

Increase Water Control Options

- Are earthen berms or dams in poor condition (such as leakage, erosion, covered in trees, etc.) or in need of maintenance?
  - Yes - Repair earthen berm to reduce leakage and enhance stability and durability.
- Are flume board structures in poor condition (such as leakage, erosion, corrosion, covered in trees, etc.) or in need of maintenance?
  - No
- Can water level be raised without causing upstream flooding of infrastructure or bogs?
  - No – raising water level in the ponds would flood upstream areas and cause the diversion channels between the watercourse and the upper pond, and between lower and upper pond to overflow and flood adjacent areas.
- Are water sources with surplus storage located downstream?
  - No

- Has capacity of existing well(s) diminished over time?
    - N/A

Increase Water Conservation/Reuse

- Are pipes or pumps leaking?
    - N/A
- Are wet harvesting methods currently employed?
    - Yes – Develop back up provisions for dry harvesting.
- Is water not currently recycled for reuse?
    - Yes - Recycle water for reuse.

Water Sharing/Diversion

- Are there water sources with known surplus as evidenced by 2016 drought in reasonably close proximity?
    - No
- Are water sources with surplus storage located upstream?
    - No

Based on the use of the Potential Resiliency Measures Recommendation worksheet the following Potential Resiliency Measures have been identified (Appendix D) for the Hypothetical Bog:

- Dredge accumulated sediments from storage ponds
    - This seems reasonable since it has been done historically so has been approved by the Carver Conservation Commission (ConCom) in the past.
- Remove debris from and dredge diversion channels to restore diversion capacity
    - This seems reasonable since the diversion channels have become partially occluded with growth that is restricting flows. Removal of vegetation, or at least trimming of vegetation may require authorization from the ConCom.
- Over excavate to a 12 foot overall depth to intercept anticipated drought condition groundwater levels
    - This seems reasonable since after maintenance dredging pond will only be nine feet deep. This over excavation may require specific approval of the ConCom since it is excavation beyond the original depth of the pond.
- Repair earthen berm to reduce leakage and enhance stability and durability
    - This clearly seems reasonable since the berms are an important component of the water storage system. Berms shall have all woody vegetation removed to within 20 feet of all portions of the berm and water control structure, including stumps and roots over 3 inches in diameter. A healthy stand of grass should be established on the berm crest and downstream slopes. If mowing of the berm slopes is difficult, consider obtaining the appropriate mowing equipment for steep slopes, or alternatively consider flattening the downstream slopes for easier access by conventional mowing equipment. These activities may require approval from the ConCom, and the DCR Office of Dam Safety.
- Develop back up provisions for dry harvesting
    - Farmers will know best how viable a resiliency measure is for their particular bog and agricultural operation. If deemed applicable, there may be cooperative agreements that can be entered into for the sharing of dry harvesting equipment and staffing to be able to accomplish dry harvesting within the critical harvesting window.
- Recycle water for reuse
    - This seems entirely reasonable given that the one bog located downstream has sufficient water source, and does not rely upon the once through water from the Hypothetical Bog. The installation of a pumping system to intercept flow discharging from the Hypothetical Bog and a piping system to allow that flow to be discharged back into the upper pond

would provide an overall reduction in demand for water from the natural watercourse. The construction of a small berm to create a small impoundment (tail pond) downstream from the bog would make pumping water easier for recycling.

The farmer can determine which of these resiliency measures to install and in what sequence based upon costs, permitting requirement, and potential disruption to their ongoing operations. Implementing all of these measures would optimize the resiliency of the farm to anticipated future drought conditions.

Implementing Resiliency Recommendations Town-wide

This example provides an illustration of how the Potential Resiliency Measures Recommendation worksheet would be used to identify potential resiliency measures for agricultural water supplies. This could be used town-wide to help guide the identification and implementation of measures to increase resiliency during drought conditions. In addition to the questions in the worksheet, consideration of individual farm operating and planning, as well as permitting requirements, would need to be considered to identify a final list of applicable and feasible resilience measures.

Appendix A

Office of Dam Safety Database

Table. Office of Dam Safety (ODS) Dam Database (1)

NATID	REGAUTH	Owner Type	OWNTYPE2	OWNTYPE3	MGMTUNIT	TOWN	DAMLAT	DAMLONG	LOCSTATUS	DAMNAME	HAZCODE
MA00083	Office of Dam Safety	Private	Private	Private		Carver	41.854468	-70.778776	NOT Verified	Atwood Upper Reservoir #2 Dam	Low Hazard
MA00084	Office of Dam Safety	Public	Municipality	Town of Carver	Board of Selectmen	Carver	41.866905	-70.80206	Verified	France Street Dam	Low Hazard
MA00086	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.816362	-70.754559	Verified	Slocum-Gibbs #1 Dam	N/A
MA00087	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.91433	-70.743868	Verified	Fresh Meadow Pond #1 Dam	N/A
MA00088	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.90332	-70.763735	Verified	Pond Street Dam	N/A
MA00089	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.877739	-70.759271	Verified	Shaw Bog Reservoir Dam	N/A
MA00090	Office of Dam Safety	Private	Private	Private		Carver	41.908334	-70.811253	Verified	Fuller Street Dam	Low Hazard
MA00267	Office of Dam Safety	Private	Private	Private		Carver	41.856652	-70.734216	Verified	Mayflower Road Dam	Significant Hazard
MA00268	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.871655	-70.705975	Verified	Federal Pond Dam	N/A
MA00269	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.836534	-70.692912	Verified	East Head Bog Dam #1	N/A
MA00270	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.823495	-70.708747	Verified	Wankinco River #1 Dam	N/A
MA00271	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.81906	-70.72615	Verified	Golden Field Pond Dam	N/A
MA00272	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.928216	-70.799194	Verified	Cole Mill Pond Dam	N/A
MA00328	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.942923	-70.774879	Verified	Bumpus No1 Dam	N/A
MA00329	Office of Dam Safety	Private	Private	Private		Carver	41.916453	-70.795887	Verified	Muddy Pond Dam	Low Hazard
MA00330	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.834688	-70.69456	Verified	East Head Bog Dam #2	N/A
MA00331	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.928008	-70.769879	Verified	Makepeace #4 Dam	N/A
MA00332	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.933822	-70.763147	Verified	Makepeace #2 Dam	N/A
MA00333	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.808543	-70.716728	Verified	Wankinco River #2 Dam	N/A
MA00376	Office of Dam Safety	Private	Private	Private		Carver	41.839131	-70.689914	Verified	East Head Pond Dam	Low Hazard
MA00377	Office of Dam Safety	Public	Municipality	Town of Carver	Town Administrator	Carver	41.843386	-70.743671	Verified	Tremont Street Dam	Significant Hazard
MA00378	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.850409	-70.781116	NOT Verified	Atwood Lower Reservoir #1 Dam	N/A
MA00379	Office of Dam Safety	Private	Private	Private		Carver	41.872713	-70.787017	Verified	Holmes Street Dam	Low Hazard
MA00380	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.894765	-70.74134	Verified	South Meadow Pond Dam	N/A

Table. Office of Dam Safety (ODS) Dam Database (2)

NATID	REGAUTH	Owner Type	OWNTYPE2	OWNTYPE3	MGMTUNIT	TOWN	DAMLAT	DAMLONG	LOCSTATUS	DAMNAME	HAZCODE
MA00381	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.939822	-70.769722	Verified	Makepeace #1 Dam	N/A
MA00382	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.924457	-70.784982	Verified	A. Godfrey Dam #1	N/A
MA00401	Office of Dam Safety	Private	Private	Private		Carver	41.92161	-70.78446	Verified	Plymouth Road Dam	Significant Hazard
MA00402	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.805884	-70.742551	Verified	Harwich Upper Reservoir Dam	N/A
MA00403	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.80428	-70.738272	Verified	Harwich Lower Reservoir Dam	N/A
MA01071	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.886641	-70.720065	NOT Verified	10 Acre Reservoir Dam	N/A
MA02067	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.8836	-70.79078	Verified	Beaver Dam Road Pond	N/A
MA02068	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.843738	-70.735293	NOT Verified	Crane Brook Lower Dam	N/A
MA02069	Office of Dam Safety	Private	Private	Private		Carver	41.851538	-70.731702	Verified	Crane Brook Upper Dam	Significant Hazard
MA02070	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.877117	-70.799686	NOT Verified	Beaver Brook #1 Dam	N/A
MA02071	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.876657	-70.800911	NOT Verified	Beaver Brook #2 Dam	N/A
MA02072	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.890748	-70.805695	Verified	Town Line Dam	N/A
MA02073	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.898291	-70.771872	NOT Verified	Old Center St. Dam	N/A
MA02074	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.910619	-70.76249	Verified	Sherman Pond Dam	N/A
MA02075	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.889435	-70.784994	Verified	John Atwood Pond Dam	N/A
MA02076	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.886188	-70.799237	Verified	Fosdick Road Dam	N/A
MA02077	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.821149	-70.760421	Verified	Slocum-Gibbs #2 Dam	N/A
MA02078	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.828016	-70.755674	Verified	Crane Brook Dam	N/A
MA02079	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.88117	-70.736173	Verified	Atwood Dam	N/A
MA02080	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.929769	-70.764307	Verified	Makepeace #3 Dam	N/A
MA02081	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.940648	-70.777522	NOT Verified	Bumpus #2 Dam	N/A
MA02082	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.916587	-70.750207	Verified	Fresh Meadow Pond #2 Dam	N/A
MA02083	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.924299	-70.774797	Verified	Alberghini Dam	N/A
MA02084	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.852579	-70.787565	Verified	Atwood Dam #3	N/A
MA02086	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.83123	-70.763461	Verified	Bartholomew Pond Dam	N/A
MA02087	Non-Jurisdictional - Other	Public	Municipality	Town of Carver	Town Administrator	Carver	41.90597	-70.774136	NOT Verified	Diamond Bog Reservoir Dam	N/A
MA02089	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.88906	-70.77856	Verified	Vaughn Pond Dam	N/A
MA02092	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.893976	-70.732921	NOT Verified	Fuller-Hammond Dam #1	N/A
MA02093	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.894185	-70.737103	Verified	Indian Brook Reservoir Dam	N/A
MA02094	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.894085	-70.738819	NOT Verified	Makepeace #5 Dam	N/A
MA03148	Non-Jurisdictional - Other	Private	Private	Private		Carver	41.88892	-70.772906	Verified	Shurtleff Pond Dam	N/A
MA03380	Non-Jurisdictional - Other	Public	Municipality	Town of Carver	Board of Selectmen	Carver	41.844782	-70.744849	Verified	Sampson Pond Dam	N/A

Appendix B

Dam Safety Inspection Checklists

Dam Evaluation Summary Detail Sheet

1. NID ID:	NA	4. Inspection Date:	November 19, 2018
2. Dam Name:	A. Godfrey Bog Dam #1	5. Last Insp. Date:	NA
3. Dam Location:	Carver, MA	6. Next Inspection:	NA
7. Inspector:	Sage Hardesty, Fuss & O'Neill, Inc.		
8. Consultant:	Fuss & O'Neill, Inc.		
9. Hazard Code:	Non-Juris.	9a. Is Hazard Code Change Requested?:	No
10. Insp. Frequency:	NA	11. Overall Physical Condition of Dam:	SATISFACTORY
12. Spillway Capacity (%SDF)	0-50% of the SDF or Unknown		(No H&H)

E1. Design Methodology:	1	E7. Low-Level Discharge Capacity:	5
E2. Level of Maintenance:	5	E8. Low-Level Outlet Physical Condition:	5
E3. Emergency Action Plan:	1	E9. Spillway Design Flood Capacity:	1
E4. Embankment Seepage:	5	E10. Overall Physical Condition of the Dam:	4
E5. Embankment Condition:	4	E11. Estimated Repair Cost:	N/A
E6. Concrete Condition:	N/A		

Evaluation Description

E1: DESIGN METHODOLOGY
1. Unknown Design – no design records available
2. No design or post-design analyses
3. No analyses, but dam features appear suitable
4. Design or post design analysis show dam meets most criteria
5. State of the art design – design records available & dam meets all crite

E2: LEVEL OF MAINTENANCE
1. Dam in disrepair, no evidence of maintenance, no O&M manual
2. Dam in poor level of upkeep, very little maintenance, no O&M manual
3. Dam in fair level of upkeep, some maintenance and standard procedur
4. Adequate level of maintenance and standard procedures
5. Dam well maintained, detailed maintenance plan that is executed

E3: EMERGENCY ACTION PLAN
1. No plan or idea of what to do in the event of an emergency
2. Some idea but no written plan
3. No formal plan but well thought out
4. Available written plan that needs updating
5. Detailed, updated written plan available and filed with MADCR, annual t

E4: SEEPAGE (Embankments, Foundations, & Abutments)
1. Severe piping and/or seepage with no monitoring
2. Evidence of monitored piping and seepage
3. No piping but uncontrolled seepage
4. Minor seepage or high volumes of seepage with filtered collection
5. No seepage or minor seepage with filtered collection

E5: EMBANKMENT CONDITION (See Note 1)
1. Severe erosion and/or large trees
2. Significant erosion or significant woody vegetation
3. Brush and exposed embankment soils, or moderate erosion
4. Unmaintained grass, rodent activity and maintainable erosion
5. Well maintained healthy uniform grass cover

E6: CONCRETE CONDITION (See Note 2)
1. Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns
2. Cracks with misalignment inclusive of transverse cracks with no misalignment but with potential for significant structural degradation
3. Significant longitudinal cracking and minor transverse cracking
4. Spalling and minor surface cracking
5. No apparent deficiencies

E7: LOW-LEVEL OUTLET DISCHARGE CAPACITY
1. No low level outlet, no provisions (e.g. pumps, siphons) for emptying
2. No operable outlet, plans for emptying pond, but no equipment
3. Outlet with insufficient drawdown capacity, pumping equipment availa
4. Operable gate with sufficient drawdown capacity
5. Operable gate with capacity greater than necessary

E8: LOW-LEVEL OUTLET PHYSICAL CONDITION
1. Outlet inoperative needs replacement, non-existent or inaccessible
2. Outlet inoperative needs repair
3. Outlet operable but needs repair
4. Outlet operable but needs maintenance
5. Outlet and operator operable and well maintained

E9: SPILLWAY DESIGN FLOOD CAPACITY
1. 0 - 50% of the SDF or unknown
2. 50-90% of the SDF
3. 90 - 100% of the SDF
4. >100% of the SDF with actions required by caretaker (e.g. open outle
5. >100% of the SDF with no actions required by caretaker

E10: OVERALL PHYSICAL CONDITION OF DAM
1. UNSAFE – Major structural, operational, and maintenance deficiencies exist under normal operating conditions
2. POOR - Significant structural, operation and maintenance deficiencies are clearly recognized under normal loading conditions
3. FAIR - Significant operational and maintenance deficiencies, no struc deficiencies. Potential deficiencies exist under unusual loading condi that may realistically occur. Can be used when uncertainties exist a critical parameters
4. SATISFACTORY - Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result In deficiencies.
5. GOOD - No existing or potential deficiencies recognized. Safe perforr is expected under all loading including SDF

E11: ESTIMATED REPAIR COST

Estimation of the total cost to address all identified structural, operationa maintenance deficiencies. Cost shall be developed utilizing standard estimating guides and procedures

1.1 Summary Data Table

Required Phase I Report Data	Data Provided by the Inspecting Engineer
National ID #	NA
Dam Name	A. Godfrey Bog Dam #1
Dam Name (Alternate)	A. Godfrey Bog Reservoir Dam
River Name	Doten Brook (Tributary to the Weweantic River)
Impoundment Name	A. Godfrey Bog Reservoir
Hazard Class	Non-juridictional
Size Class	Small
Dam Type	Earth Embankment
Dam Purpose	Agriculture
Structural Height of Dam (feet)	5.5 ±
Hydraulic Height of Dam (feet)	4 ±
Drainage Area (sq. mi.)	0.3
Reservoir Surface Area (acres)	9
Normal Impoundment Volume (acre-feet)	12 ±
Max Impoundment Volume ((top of dam) acre-feet)	16.5 ±
SDF Impoundment Volume* (acre-feet)	Unknown SDF or SDF Impoundment Volume
Spillway Type	Sharp-crested weir
Spillway Length (feet)	6 ± (2 weirs @ 3 ft each)
Freeboard at Normal Pool (feet)	5
Principal Spillway Capacity* (cfs)	No H&H
Auxiliary Spillway Capacity* (cfs)	No H&H
Low-Level Outlet Capacity* (cfs)	No H&H
Spillway Design Flood* (flow rate - cfs)	No H&H
Winter Drawdown (feet below normal pool)	NA
Drawdown Impoundment Vol. (acre-feet)	NA
Latitude	41.92438
Longitude	-70.785003
City/Town	Carver
County Name	Plymouth
Public Road on Crest	No
Public Bridge over Spillway	No
EAP Date (if applicable)	NA
Owner Name	Bayside Agricultural Inc.
Owner Address	77 Charlotte Furnace Road
Owner Town	Carver
Owner Type	Private
Date of Field Inspection	11/19/2018

*In the event a hydraulic and hydrologic analysis has not been completed for the dam, indicate "No H&H" in this table, recommendation section shall include specific recommendation to hire a qualified dam engineering consultant to conduct analysis to determine spillway adequacy in conformance with 302 CMR 10.00.

DAM SAFETY INSPECTION CHECKLIST

NAME OF DAM:	A. Godfrey Bog Dam #1	STATE ID #:	MA00382
REGISTERED:	☐ YES ☑ NO	NID ID #:	NA
STATE SIZE CLASSIFICATION:	Small	STATE HAZARD CLASSIFICATION:	Non-jurisdictional
		CHANGE IN HAZARD CLASSIFICATION REQUESTED?:	No

DAM LOCATION INFORMATION

CITY/TOWN:	Carver	COUNTY:	Plymouth
DAM LOCATION: (street address if known)	East of Gate Street, Godfrey Bog	ALTERNATE DAM NAME:	A. Godfrey Bog Reservoir Dam
USGS QUAD.:	Plympton	LAT.: 41.92438	LONG.: -70.785003
DRAINAGE BASIN:	Buzzards Bay	RIVER:	Doten Brook (Tributary to the Weweantic River)
IMPOUNDMENT NAME(S):	A. Godfrey Bog Reservoir		

GENERAL DAM INFORMATION

TYPE OF DAM:	Earth Embankment	OVERALL LENGTH (FT):	1600 ±
PURPOSE OF DAM:	Agriculture	NORMAL POOL STORAGE (ACRE-FT):	12 ±
YEAR BUILT:	Unknown	MAXIMUM POOL STORAGE (ACRE-FT):	16.5 ±
STRUCTURAL HEIGHT (FT):	5.5 ±	EL. NORMAL POOL (FT):	94.0
HYDRAULIC HEIGHT (FT):	4 ±	EL. MAXIMUM POOL (FT):	96.0

NAME OF DAM: A. Godfrey Bog Dam #1 | STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 | NID ID #: NA

INSPECTION SUMMARY

DATE OF INSPECTION: November 19, 2018 | DATE OF PREVIOUS INSPECTION: NA

TEMPERATURE/WEATHER: Overcast, 45 F | ARMY CORPS PHASE I: ☐ YES ☑ NO | If YES, date

CONSULTANT: Fuss & O'Neill, Inc. | PREVIOUS DCR PHASE I: ☐ YES ☑ NO | If YES, date

BENCHMARK/DATUM: NAD83, NAVD88

OVERALL PHYSICAL CONDITION OF DAM: SATISFACTORY | DATE OF LAST REHABILITATION: Unknown

SPILLWAY CAPACITY: 0-50% of the SDF or Unknown

EL. POOL DURING INSP. 95 ± | EL. TAILWATER DURING INSP.: 91 ±

PERSONS PRESENT AT INSPECTION

NAME	TITLE/POSITION	REPRESENTING
Shawn King, EIT	Project Engineer	Fuss & O'Neill, Inc.
Sage Hardesty	Project Engineer	Fuss & O'Neill, Inc.
Brian Wick	Executive Director	Cape Cod Cranberry Growers' Association

EVALUATION INFORMATION

		Click on box to select E-code
E1)	TYPE OF DESIGN	1
E2)	LEVEL OF MAINTENANCE	5
E3)	EMERGENCY ACTION PLAN	1
E4)	EMBANKMENT SEEPAGE	5
E5)	EMBANKMENT CONDITION	4
E6)	CONCRETE CONDITION	N/A
E7)	LOW-LEVEL OUTLET CAPACITY	5

		Click on box to select E-code
E8)	LOW-LEVEL OUTLET CONDITION	5
E9)	SPILLWAY DESIGN FLOOD CAPACIT	1
E10)	OVERALL PHYSICAL CONDITION	4
E11)	ESTIMATED REPAIR COST	N/A
	ROADWAY OVER CREST	NO
	BRIDGE NEAR DAM	NO

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

OWNER:		CARETAKER:	
ORGANIZATION	Bayside Agricultural Inc.	ORGANIZATION	Bayside Agricultural Inc.
NAME/TITLE		NAME/TITLE	
STREET	77 Charlotte Furnace Road	STREET	77 Charlotte Furnace Road
TOWN, STATE, ZIP	Carver	TOWN, STATE, ZIP	Carver
PHONE		PHONE	
EMERGENCY PH. #		EMERGENCY PH. #	
FAX		FAX	
EMAIL		EMAIL	
OWNER TYPE	Private		

PRIMARY SPILLWAY TYPE Sharp-crested weirs

SPILLWAY LENGTH (FT) 6 ± (2 weirs @ 3 ft each) SPILLWAY CAPACITY (CFS) 20 ±

AUXILIARY SPILLWAY TYPE NA AUX. SPILLWAY CAPACITY (CFS) NA

NUMBER OF OUTLETS 1 OUTLET(S) CAPACITY (CFS) Unknown (No H&H)

TYPE OF OUTLETS Agricultural Pump System TOTAL DISCHARGE CAPACITY (CFS) Unknown (No H&H)

DRAINAGE AREA (SQ MI) 0.3 SPILLWAY DESIGN FLOOD (PERIOD/CFS) Unknown (No H&H)

HAS DAM BEEN BREACHED OR OVERTOPPED ☐ YES ☐ NO IF YES, PROVIDE DATE(S) Unknown

FISH LADDER (LIST TYPE IF PRESENT) No

DOES CREST SUPPORT PUBLIC ROAD? ☐ YES ☑ NO IF YES, ROAD NAME: NA

PUBLIC BRIDGE WITHIN 50' OF DAM? ☐ YES ☑ NO IF YES, ROAD/BRIDGE NAME: NA

MHD BRIDGE NO. (IF APPLICABLE NA

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	1. SURFACE TYPE	Earth embankment		X*	
	2. SURFACE CRACKING	No issues observed.	X		
	3. SINKHOLES, ANIMAL BURROWS	No issues observed.		X	
	4. VERTICAL ALIGNMENT (DEPRESSIONS)	Some rutting due to frequent vehicular use. Maintained as necessary.		X	
	5. HORIZONTAL ALIGNMENT	Good.	X		
	6. RUTS AND/OR PUDDLES	Some rutting due to frequent vehicular use. Maintained as necessary.		X	
	7. VEGETATION (PRESENCE/CONDITION)	Grass on crest edges. Bare in vehicle tire paths**			X
	8. ABUTMENT CONTACT	Good.	X		

ADDITIONAL COMMENTS: *The crest of the dam also serves as a primary access and haul road within the agricultural bog.

**Due to the frequency of vehicular traffic on the dam crest, it is unlikely healthy grass can be maintained in the bare areas.

**Fill in vehicle ruts to avoid substantial ponding of water

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (D/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S SLOPE	1. WET AREAS (NO FLOW)	No wet areas (NO FLOW) observed. Agricultural channels present along dam toe.		X*	
	2. SEEPAGE	No issues observed.	X		
	3. SLIDE, SLOUGH, SCARP	Minor vertical scarp observed at dam toe along the the agricultural channels.		X*	
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. SINKHOLE/ANIMAL BURROWS	No issues observed.		X	
	6. EROSION	No issues observed on d/s face of dam.	X		
	7. UNUSUAL MOVEMENT	No issues observed.	X		
	8. VEGETATION (PRESENCE/CONDITION)	Grass-covered. Well maintained.	X		

ADDITIONAL COMMENTS: *While the wet areas along the dam toe are intentional for agricultural purposes, the condition of the dam embankment should be monitored for erosion or undermining caused by the varying flows and tailwater elevations along the dam toe.

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (U/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	No issues observed on observable surface.	X		
	2. SLOPE PROTECTION TYPE AND COND.	No slope protection observed.	X		
	3. SINKHOLE/ANIMAL BURROWS	No issues observed on observable surface.	X		
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. EROSION	No issues observed on observable surface.	X		
	6. UNUSUAL MOVEMENT	No issues observed on observable surface.	X		
	7. VEGETATION (PRESENCE/CONDITION)	Satisfactory. Minor areas of low-cut woody vegetation.		X	

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	None observed.	X		
	2. OBSERVATION WELLS	None observed.	X		
	3. STAFF GAGE AND RECORDER	None observed.	X		
	4. WEIRS	None observed.	X		
	5. INCLINOMETERS	None observed.	X		
	6. SURVEY MONUMENTS	None observed.	X		
	7. DRAINS	None observed.	X		
	8. FREQUENCY OF READINGS	None observed.	X		
	9. LOCATION OF READINGS	None observed.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S WALLS	1. WALL TYPE				
	2. WALL ALIGNMENT				
	3. WALL CONDITION				
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: max: avg:			
	5. SEEPAGE OR LEAKAGE				
	6. ABUTMENT CONTACT				
	7. EROSION/SINKHOLES BEHIND WALL				
	8. ANIMAL BURROWS				
	9. UNUSUAL MOVEMENT				
	10. WET AREAS AT TOE OF WALL				

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

UPSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS			NO ACTION	MONITOR	REPAIR
U/S WALLS	1. WALL TYPE						
	2. WALL ALIGNMENT						
	3. WALL CONDITION						
	4. HEIGHT: TOP OF WALL TO MUDLINE	min:	max:	avg:			
	5. ABUTMENT CONTACT						
	6. EROSION/SINKHOLES BEHIND WALL						
	7. ANIMAL BURROWS						
	8. UNUSUAL MOVEMENT						

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM AREA

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S AREA	1. ABUTMENT LEAKAGE	No issues observed on observable portions of embankment.	X		
	2. FOUNDATION SEEPAGE	Unobservable.	X		
	3. SLIDE, SLOUGH, SCARP	See Downstream Slope		X	
	4. WEIRS	NA	X		
	5. DRAINAGE SYSTEM	See Outlet Works	X		
	6. INSTRUMENTATION	None observed.	X		
	7. VEGETATION	Agricultural. Well maintained.	X		
	8. ACCESSIBILITY	Good.	X		
	9. DOWNSTREAM HAZARD DESCRIPTION	Primarily low-lying agricultural and forested wetland areas.			
	10. DATE OF LAST EAP UPDATE	No formal EAP developed for the dam. The water supply impounded by the dam is used for agricultural purposes as part of the grower's farm plan.			

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

MISCELLANEOUS

AREA INSPECTED	CONDITION	OBSERVATIONS
MISC.	1. RESERVOIR DEPTH (AVG)	Unknown. Estimated 3 feet.
	2. RESERVOIR SHORELINE	See Upstream Slope.
	3. RESERVOIR SLOPES	Shallow.
	4. ACCESS ROADS	Dam crest is used as access road and haul road for farm.
	5. SECURITY DEVICES	None at dam. Private property.
	6. VANDALISM OR TRESPASS	☐ YES ☑ NO WHAT:
	7. AVAILABILITY OF PLANS	☐ YES ☑ NO DATE:
	8. AVAILABILITY OF DESIGN CALCS	☐ YES ☑ NO DATE:
	9. AVAILABILITY OF EAP/LAST UPDATE	☐ YES ☑ NO DATE:
	10. AVAILABILITY OF O&M MANUAL	☐ YES ☑ NO DATE:
	11. CARETAKER/OWNER AVAILABLE	☐ YES ☑ NO DATE:
	12. CONFINED SPACE ENTRY REQUIRED	☐ YES ☑ NO PURPOSE:

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

PRIMARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	Sharp-crested weir	X		
	WEIR TYPE	Flume board drop inlets to corrugated metal discharge pipes.	X		
	SPILLWAY CONDITION	Good.	X		
	TRAINING WALLS	Good.	X		
	SPILLWAY CONTROLS AND CONDITION	Flume boards in good condition.	X		
	UNUSUAL MOVEMENT	None observed.	X		
	APPROACH AREA	Shallow impoundment susceptible to aquatic vegetation growth, sediment, & debris		X	
	DISCHARGE AREA	Well-maintained agricultural farm.	X		
	DEBRIS	None observed.	X		
	WATER LEVEL AT TIME OF INSPECTION	Approximately 1.5 feet of freeboard.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

AUXILIARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE				
	WEIR TYPE				
	SPILLWAY CONDITION				
	TRAINING WALLS				
	SPILLWAY CONTROLS AND CONDITION				
	UNUSUAL MOVEMENT				
	APPROACH AREA				
	DISCHARGE AREA				
	DEBRIS				
	WATER LEVEL AT TIME OF INSPECTION				

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

OUTLET WORKS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
OUTLET WORKS	TYPE	Pump intake structure*	X		
	INTAKE STRUCTURE	Primary intake appears to be approximately 24" diameter pipe.	X		
	TRASHRACK	Trash rack present at outlet structure/headwall.	X		
	PRIMARY CLOSURE	Unknown			
	SECONDARY CLOSURE	Unknown			
	CONDUIT	Subsurface conduit unobservable.			
	OUTLET STRUCTURE/HEADWALL	Concrete headwall in fair condition. Flume logs present to control discharge.		X	
	EROSION ALONG TOE OF DAM	NA			
	SEEPAGE/LEAKAGE	No issues observed.	X		
	DEBRIS/BLOCKAGE	No issues observed.	X		
	UNUSUAL MOVEMENT	No issues observed.	X		
	DOWNSTREAM AREA	Earthen open-channel used for agricultural purposes.		X**	
	MISCELLANEOUS				

ADDITIONAL COMMENTS: *The main components of the pump intake structure contained within the pump house were not observed.

**Monitor for and maintain accumulated sediments or debris observed in the channel.

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
GENERAL	TYPE				
	AVAILABILITY OF PLANS				
	AVAILABILITY OF DESIGN CALCS				
	PIEZOMETERS				
	OBSERVATION WELLS				
	INCLINOMETERS				
	SEEPAGE GALLERY	NOT APPLICABLE			
	UNUSUAL MOVEMENT				

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	HORIZONTAL ALIGNMENT				
	VERTICAL ALIGNMENT				
		NOT APPLICABLE			

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (DOWNSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S FACE	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	ABUTMENT CONTACT				
	LEAKAGE	NOT APPLICABLE			

ADDITIONAL COMMENTS:

NAME OF DAM: A. Godfrey Bog Dam #1 STATE ID #: MA00382

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (UPSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S FACE	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	ABUTMENT CONTACTS	NOT APPLICABLE			

ADDITIONAL COMMENTS:

Dam Evaluation Summary Detail Sheet

1. NID ID:	NA	4. Inspection Date:	November 19, 2018
2. Dam Name:	Dunham Pond Dam	5. Last Insp. Date:	NA
3. Dam Location:	Carver, MA	6. Next Inspection:	NA
7. Inspector:	Sage Hardesty, Fuss & O'Neill, Inc.		
8. Consultant:	Fuss & O'Neill, Inc.		
9. Hazard Code:	Non-Juris.	9a. Is Hazard Code Change Requested?:	No
10. Insp. Frequency:	NA	11. Overall Physical Condition of Dam:	SATISFACTORY
12. Spillway Capacity (%SDF)	0-50% of the SDF or Unknown		

E1. Design Methodology:	1	E7. Low-Level Discharge Capacity:	5
E2. Level of Maintenance:	5	E8. Low-Level Outlet Physical Condition:	5
E3. Emergency Action Plan:	1	E9. Spillway Design Flood Capacity:	1
E4. Embankment Seepage:	5	E10. Overall Physical Condition of the Dam:	4
E5. Embankment Condition:	4	E11. Estimated Repair Cost:	N/A
E6. Concrete Condition:	4		

Evaluation Description

E1: DESIGN METHODOLOGY
1. Unknown Design – no design records available
2. No design or post-design analyses
3. No analyses, but dam features appear suitable
4. Design or post design analysis show dam meets most criteria
5. State of the art design – design records available & dam meets all crite

E2: LEVEL OF MAINTENANCE
1. Dam in disrepair, no evidence of maintenance, no O&M manual
2. Dam in poor level of upkeep, very little maintenance, no O&M manual
3. Dam in fair level of upkeep, some maintenance and standard procedur
4. Adequate level of maintenance and standard procedures
5. Dam well maintained, detailed maintenance plan that is executed

E3: EMERGENCY ACTION PLAN
1. No plan or idea of what to do in the event of an emergency
2. Some idea but no written plan
3. No formal plan but well thought out
4. Available written plan that needs updating
5. Detailed, updated written plan available and filed with MADCR, annual t

E4: SEEPAGE (Embankments, Foundations, & Abutments)
1. Severe piping and/or seepage with no monitoring
2. Evidence of monitored piping and seepage
3. No piping but uncontrolled seepage
4. Minor seepage or high volumes of seepage with filtered collection
5. No seepage or minor seepage with filtered collection

E5: EMBANKMENT CONDITION (See Note 1)
1. Severe erosion and/or large trees
2. Significant erosion or significant woody vegetation
3. Brush and exposed embankment soils, or moderate erosion
4. Unmaintained grass, rodent activity and maintainable erosion
5. Well maintained healthy uniform grass cover

E6: CONCRETE CONDITION (See Note 2)
1. Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns
2. Cracks with misalignment inclusive of transverse cracks with no misalignment but with potential for significant structural degradation
3. Significant longitudinal cracking and minor transverse cracking
4. Spalling and minor surface cracking
5. No apparent deficiencies

E7: LOW-LEVEL OUTLET DISCHARGE CAPACITY
1. No low level outlet, no provisions (e.g. pumps, siphons) for emptying
2. No operable outlet, plans for emptying pond, but no equipment
3. Outlet with insufficient drawdown capacity, pumping equipment availa
4. Operable gate with sufficient drawdown capacity
5. Operable gate with capacity greater than necessary

E8: LOW-LEVEL OUTLET PHYSICAL CONDITION
1. Outlet inoperative needs replacement, non-existent or inaccessible
2. Outlet inoperative needs repair
3. Outlet operable but needs repair
4. Outlet operable but needs maintenance
5. Outlet and operator operable and well maintained

E9: SPILLWAY DESIGN FLOOD CAPACITY
1. 0 - 50% of the SDF or unknown
2. 50-90% of the SDF
3. 90 - 100% of the SDF
4. >100% of the SDF with actions required by caretaker (e.g. open outle
5. >100% of the SDF with no actions required by caretaker

E10: OVERALL PHYSICAL CONDITION OF DAM
1. UNSAFE – Major structural, operational, and maintenance deficiencies exist under normal operating conditions
2. POOR - Significant structural, operation and maintenance deficiencies are clearly recognized under normal loading conditions
3. FAIR - Significant operational and maintenance deficiencies, no struc deficiencies. Potential deficiencies exist under unusual loading condi that may realistically occur. Can be used when uncertainties exist a critical parameters
4. SATISFACTORY - Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result In deficiencies.
5. GOOD - No existing or potential deficiencies recognized. Safe perforr is expected under all loading including SDF

E11: ESTIMATED REPAIR COST

Estimation of the total cost to address all identified structural, operationa maintenance deficiencies. Cost shall be developed utilizing standard estimating guides and procedures

1.1 Summary Data Table

Required Phase I Report Data	Data Provided by the Inspecting Engineer
National ID #	NA
Dam Name	Dunham Pond Dam
Dam Name (Alternate)	NA
River Name	NA
Impoundment Name	Dunham Pond
Hazard Class	Non-jurisdictional
Size Class	Small
Dam Type	Earth embankment
Dam Purpose	Agricultural Water Supply
Structural Height of Dam (feet)	5 ±
Hydraulic Height of Dam (feet)	4 ±
Drainage Area (sq. mi.)	Unknown
Reservoir Surface Area (acres)	7.52
Normal Impoundment Volume (acre-feet)	60
Max Impoundment Volume ((top of dam) acre-feet)	110
SDF Impoundment Volume* (acre-feet)	Unknown (No H&H)
Spillway Type	Sharp-crested weir
Spillway Length (feet)	6 ± (2 weirs @ 3ft each)
Freeboard at Normal Pool (feet)	3
Principal Spillway Capacity* (cfs)	20 ±
Low-Level Outlet Capacity* (cfs)	Unknown (No H&H)
Spillway Design Flood* (flow rate - cfs)	Unknown (No H&H)
Winter Drawdown (feet below normal pool)	NA
Drawdown Impoundment Vol. (acre-feet)	NA
Latitude	41.864911°
Longitude	-70.734434°
City/Town	Carver
County Name	Plymouth
Public Road on Crest	No
Public Bridge over Spillway	No
EAP Date (if applicable)	NA
Owner Name	Cecas Cranberry Co. Inc.
Owner Address	Mayflower Road
Owner Town	Carver, Massachusetts
Owner Type	Private
Caretaker Emergency Phone	0
Date of Field Inspection	11/19/2018

*In the event a hydraulic and hydrologic analysis has not been completed for the dam, indicate "No H&H" in this table, recommendation section shall include specific recommendation to hire a qualified dam engineering consultant to conduct analysis to determine spillway adequacy in conformance with 302 CMR 10.00.

DAM SAFETY INSPECTION CHECKLIST

NAME OF DAM:	Dunham Pond Dam	STATE ID #:	NA
REGISTERED:	☐ YES ☑ NO	NID ID #:	NA
STATE SIZE CLASSIFICATION:	Small	STATE HAZARD CLASSIFICATION:	Non-Jurisdictional
		CHANGE IN HAZARD CLASSIFICATION REQUESTED?:	No

DAM LOCATION INFORMATION

CITY/TOWN:	Carver	COUNTY:	Plymouth
DAM LOCATION: (street address if known)	Mayflower Road	ALTERNATE DAM NAME:	NA
USGS QUAD.:	Plympton	LAT.: 41.864911°	LONG.: -70.734434°
DRAINAGE BASIN:	Buzzards Bay	RIVER:	NA
IMPOUNDMENT NAME(S):	Dunham Pond		

GENERAL DAM INFORMATION

TYPE OF DAM:	Earth embankment	OVERALL LENGTH (FT):	900
PURPOSE OF DAM:	Agricultural Water Supply	NORMAL POOL STORAGE (ACRE-FT):	60
YEAR BUILT:	Unknown	MAXIMUM POOL STORAGE (ACRE-FT):	110
STRUCTURAL HEIGHT (FT):	5 ±	EL. NORMAL POOL (FT):	92.0
HYDRAULIC HEIGHT (FT):	4 ±	EL. MAXIMUM POOL (FT):	94.5

NAME OF DAM Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

INSPECTION SUMMARY

DATE OF INSPECTION: November 19, 2018 DATE OF PREVIOUS INSPECTION: Unknown

TEMPERATURE/WEATHER: Overcast, 45 F ARMY CORPS PHASE I: ☐ YES ☑ NO If YES, date NA

CONSULTANT: Fuss & O'Neill, Inc. PREVIOUS DCR PHASE I: ☐ YES ☑ NO If YES, date NA

BENCHMARK/DATUM: NAD83, NAVD88

OVERALL PHYSICAL
CONDITION OF DAM: SATISFACTORY DATE OF LAST REHABILITATION: Unknown

SPILLWAY CAPACITY: 0-50% of the SDF or Unknown

EL. POOL DURING INSP. EL. TAILWATER DURING INSP.: 92.5 ±

PERSONS PRESENT AT INSPECTION

NAME	TITLE/POSITION	REPRESENTING
Shawn King, EIT	Project Engineer	Fuss & O'Neill, Inc.
Sage Hardesty	Project Engineer	Fuss & O'Neill, Inc.
Craig Weston	Fire Chief	Town of Carver - Fire Department

EVALUATION INFORMATION

		Click on box to select E-code
E1)	TYPE OF DESIGN	1
E2)	LEVEL OF MAINTENANCE	5
E3)	EMERGENCY ACTION PLAN	1
E4)	EMBANKMENT SEEPAGE	5
E5)	EMBANKMENT CONDITION	4
E6)	CONCRETE CONDITION	4
E7)	LOW-LEVEL OUTLET CAPACITY	5

		Click on box to select E-code
E8)	LOW-LEVEL OUTLET CONDITION	5
E9)	SPILLWAY DESIGN FLOOD CAPACIT	1
E10)	OVERALL PHYSICAL CONDITION	4
E11)	ESTIMATED REPAIR COST	N/A
	ROADWAY OVER CREST	NO
	BRIDGE NEAR DAM	NO

NAME OF DAM: Dunham Pond Dam | STATE ID #: NA

INSPECTION DATE: November 19, 2018 | NID ID #: NA

OWNER:		CARETAKER:	
ORGANIZATION	Cecas Cranberry Co. Inc.	ORGANIZATION	Cecas Cranberry Co. Inc.
NAME/TITLE		NAME/TITLE	
STREET	Mayflower Road	STREET	
TOWN, STATE, ZIP	Carver, Massachusetts	TOWN, STATE, ZIP	Carver, Massachusetts
PHONE		PHONE	
EMERGENCY PH. #		EMERGENCY PH. #	
FAX		FAX	
EMAIL		EMAIL	
OWNER TYPE	Private		

PRIMARY SPILLWAY TYPE: Sharp-crested weir

SPILLWAY LENGTH (FT): 6 ± (2 weirs @ 3ft each) | SPILLWAY CAPACITY (CFS): 20 ±

NUMBER OF OUTLETS: 4 (see type of outlets below) | OUTLET(S) CAPACITY (CFS): Unknown (No H&H)

TYPE OF OUTLETS: Agricultural Pump (2), Diversion Channel (2) | TOTAL DISCHARGE CAPACITY (CFS): Unknown (No H&H)

DRAINAGE AREA (SQ MI): Unknown | SPILLWAY DESIGN FLOOD (PERIOD/CFS): Unknown (No H&H)

HAS DAM BEEN BREACHED OR OVERTOPPED ☐ YES ☐ NO | IF YES, PROVIDE DATE(S): Unknown

FISH LADDER (LIST TYPE IF PRESENT): NA

DOES CREST SUPPORT PUBLIC ROAD? ☐ YES ☑ NO | IF YES, ROAD NAME: NA

PUBLIC BRIDGE WITHIN 50' OF DAM? ☐ YES ☑ NO | IF YES, ROAD/BRIDGE NAME: NA

MHD BRIDGE NO. (IF APPLICABLE): NA

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	1. SURFACE TYPE	Earth embankment		X*	
	2. SURFACE CRACKING	No issues observed.	X		
	3. SINKHOLES, ANIMAL BURROWS	No issues observed.	X		
	4. VERTICAL ALIGNMENT (DEPRESSIONS)	Minor rutting due to frequent vehicular use. Maintained as necessary.		X	
	5. HORIZONTAL ALIGNMENT	Good. Crest width fairly uniform in width, alignment good.	X		
	6. RUTS AND/OR PUDDLES	Minor rutting due to frequent vehicular use. Maintained as necessary.		X	
	7. VEGETATION (PRESENCE/CONDITION)	Vegetation presence is fair. Grass-covered crest. Bare areas in tire ruts.**			X
	8. ABUTMENT CONTACT	Good.	X		

ADDITIONAL COMMENTS: *The crest of the dam also serves as a primary access and haul road within the agricultural bog.

**Due to the frequency of vehicular traffic on the dam crest, maintaining a healthy grass-covered surface may be difficult.

**Fill ruts as necessary to prevent significant ponding of water

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (D/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S SLOPE	1. WET AREAS (NO FLOW)	No wet areas (NO FLOW) observed. Agricultural channels present along dam toe.		X*	
	2. SEEPAGE	No issues observed in observerable portion of dam embankment.	X		
	3. SLIDE, SLOUGH, SCARP	Embankment material loss in vicinity of primary spillway structure.			X
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. SINKHOLE/ANIMAL BURROWS	No issues observed.		X	
	6. EROSION	Some bare areas present on d/s face. Erosion noted along primary spillway structure.			X
	7. UNUSUAL MOVEMENT	No issues observed.	X		
	8. VEGETATION (PRESENCE/CONDITION)	Grass-covered. Mowed regularly. Some bare areas present on d/s face.	X		

ADDITIONAL COMMENTS: *While the wet areas along the dam toe are intentional for agricultural purposes, the condition of the dam embankment should be monitored for erosion or undermining caused by the varying flows and tailwater elevations along the dam toe.

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (U/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	Majority of slope submerged at the time of the inspection. Shallow but varying slope	X		
	2. SLOPE PROTECTION TYPE AND COND.	No slope protection observed.	X		
	3. SINKHOLE/ANIMAL BURROWS	No issues observed in the exposed portions of the embankment.	X		
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. EROSION	Varying shallow slopes may indicate past erosion. Vegetation indicates no recent notable erosion.		X	
	6. UNUSUAL MOVEMENT	No issues observed.	X		
	7. VEGETATION (PRESENCE/CONDITION)	Grass-covered slope. Mowed regularly. Large trees along some lengths.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	None observed.	X		
	2. OBSERVATION WELLS	None observed.	X		
	3. STAFF GAGE AND RECORDER	None observed.	X		
	4. WEIRS	None observed.	X		
	5. INCLINOMETERS	None observed.	X		
	6. SURVEY MONUMENTS	None observed.	X		
	7. DRAINS	None observed.	X		
	8. FREQUENCY OF READINGS	None observed.	X		
	9. LOCATION OF READINGS	None observed.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S WALLS	1. WALL TYPE				
	2. WALL ALIGNMENT				
	3. WALL CONDITION				
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: max: avg:			
	5. SEEPAGE OR LEAKAGE				
	6. ABUTMENT CONTACT				
	7. EROSION/SINKHOLES BEHIND WALL				
	8. ANIMAL BURROWS				
	9. UNUSUAL MOVEMENT				
	10. WET AREAS AT TOE OF WALL				

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

UPSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S WALLS	1. WALL TYPE				
	2. WALL ALIGNMENT				
	3. WALL CONDITION				
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: max: avg:			
	5. ABUTMENT CONTACT				
	6. EROSION/SINKHOLES BEHIND WALL				
	7. ANIMAL BURROWS				
	8. UNUSUAL MOVEMENT				

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM AREA

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S AREA	1. ABUTMENT LEAKAGE	No issues observed on observable portions of embankment.	X		
	2. FOUNDATION SEEPAGE	No issues observed on observable portions of embankment.	X		
	3. SLIDE, SLOUGH, SCARP	No issues observed on observable portions of embankment.	X		
	4. WEIRS	None observed.	X		
	5. DRAINAGE SYSTEM	None observed.	X		
	6. INSTRUMENTATION	None observed.	X		
	7. VEGETATION	Agricultural. Well maintained.	X		
	8. ACCESSIBILITY	Good.	X		
	9. DOWNSTREAM HAZARD DESCRIPTION	Low-lying agricultural areas, forested wetlands, some residential properties, and two public roadways.			
	10. DATE OF LAST EAP UPDATE	No formal EAP developed for the dam. The water supply impounded by the dam is used for agricultural purposes as part of the grower's farm plan.			

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

MISCELLANEOUS

AREA INSPECTED	CONDITION	OBSERVATIONS
MISC.	1. RESERVOIR DEPTH (AVG)	
	2. RESERVOIR SHORELINE	See Upstream Slope.
	3. RESERVOIR SLOPES	Varying shallow slopes.
	4. ACCESS ROADS	Dam crest is used as access road and haul road for farm.
	5. SECURITY DEVICES	Surveillance
	6. VANDALISM OR TRESPASS	☐ YES ☑ NO WHAT:
	7. AVAILABILITY OF PLANS	☐ YES ☑ NO DATE:
	8. AVAILABILITY OF DESIGN CALCS	☐ YES ☑ NO DATE:
	9. AVAILABILITY OF EAP/LAST UPDATE	☐ YES ☑ NO DATE:
	10. AVAILABILITY OF O&M MANUAL	☐ YES ☑ NO DATE:
	11. CARETAKER/OWNER AVAILABLE	☑ YES ☐ NO DATE: November 19, 2018
	12. CONFINED SPACE ENTRY REQUIRED	☐ YES ☑ NO PURPOSE:

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

PRIMARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	Sharp-crested weir	X		
	WEIR TYPE	Flume boards		X*	
	SPILLWAY CONDITION	Satisfactory. Minor leakage of flume boards. Embankment deficiencies.			X**
	TRAINING WALLS	Satisfactory.	X		
	SPILLWAY CONTROLS AND CONDITION	See Spillway Condition			
	UNUSUAL MOVEMENT	No issues observed.	X		
	APPROACH AREA	Shallow impoundment susceptible to aquatic vegetation growth, sediment, & debris		X	
	DISCHARGE AREA	Well-maintained agricultural farm.	X		
	DEBRIS	None observed.	X		
	WATER LEVEL AT TIME OF INSPECTION	Approximately 1 foot of freeboard.	X		

ADDITIONAL COMMENTS: *Monitor leakage and replace flume boards as required to reduce flow through or around boards.
**See Downstream Slope

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

AUXILIARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE				
	WEIR TYPE				
	SPILLWAY CONDITION				
	TRAINING WALLS	NOT APPLICABLE			
	SPILLWAY CONTROLS AND CONDITION				
	UNUSUAL MOVEMENT				
	APPROACH AREA				
	DISCHARGE AREA				
	DEBRIS				
	WATER LEVEL AT TIME OF INSPECTION				

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

OUTLET WORKS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
OUTLET WORKS	TYPE	Pump intake structures (2)*, Agricultural diversion channel (1)	X		
	INTAKE STRUCTURE	Primary intakes appear to be approximately 12" diameter pipe.	X		
	TRASHRACK	No trash racks observed.	X		
	PRIMARY CLOSURE	Unknown			
	SECONDARY CLOSURE	Unknown			
	CONDUIT	Diversion channel is earthen open channel and maintained. Susceptible to sediment		X	
	OUTLET STRUCTURE/HEADWALL	See Primary Spillway			
	EROSION ALONG TOE OF DAM	No erosion issues associated with outlet works were observed.	X		
	SEEPAGE/LEAKAGE	No issues observed.	X		
	DEBRIS/BLOCKAGE	No issues observed.	X		
	UNUSUAL MOVEMENT	No issues observed.	X		
	DOWNSTREAM AREA	Earthen open-channels used for agricultural purposes.		X**	
	MISCELLANEOUS				

ADDITIONAL COMMENTS: *The main components of the pump intake structure contained within the pump house were not observed.

**Monitor for and maintain accumulated sediments or debris observed in the channel.

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
GENERAL	TYPE				
	AVAILABILITY OF PLANS				
	AVAILABILITY OF DESIGN CALCS				
	PIEZOMETERS	NOT APPLICABLE			
	OBSERVATION WELLS				
	INCLINOMETERS				
	SEEPAGE GALLERY				
	UNUSUAL MOVEMENT				

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	TYPE	NOT APPLICABLE			
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	HORIZONTAL ALIGNMENT				
	VERTICAL ALIGNMENT				

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (DOWNSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S FACE	TYPE	NOT APPLICABLE			
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	ABUTMENT CONTACT				
	LEAKAGE				

ADDITIONAL COMMENTS:

NAME OF DAM: Dunham Pond Dam STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (UPSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S FACE	TYPE	NOT APPLICABLE			
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	ABUTMENT CONTACTS				

ADDITIONAL COMMENTS:

Dam Evaluation Summary Detail Sheet

1. NID ID:	NA	4. Inspection Date:	November 19, 2018
2. Dam Name:	Unnamed Dam on Clear Bottom Pon	5. Last Insp. Date:	NA
3. Dam Location:	Carver, MA	6. Next Inspection:	November 19, 2023
7. Inspector:	Sage Hardesty, Fuss & O'Neill, Inc.		
8. Consultant:	Fuss & O'Neill, Inc.		
9. Hazard Code:	Non-jurisdic	9a. Is Hazard Code Change Requested?:	No
10. Insp. Frequency:	#N/A	11. Overall Physical Condition of Dam:	SATISFACTORY
12. Spillway Capacity (%SDF)	0-50% of the SDF or Unknown		

E1. Design Methodology:	1	E7. Low-Level Discharge Capacity:	5
E2. Level of Maintenance:	5	E8. Low-Level Outlet Physical Condition:	5
E3. Emergency Action Plan:	1	E9. Spillway Design Flood Capacity:	1
E4. Embankment Seepage:	5	E10. Overall Physical Condition of the Dam:	4
E5. Embankment Condition:	4	E11. Estimated Repair Cost:	N/A
E6. Concrete Condition:	N/A		

Evaluation Description

E1: DESIGN METHODOLOGY
1. Unknown Design – no design records available
2. No design or post-design analyses
3. No analyses, but dam features appear suitable
4. Design or post design analysis show dam meets most criteria
5. State of the art design – design records available & dam meets all crite

E2: LEVEL OF MAINTENANCE
1. Dam in disrepair, no evidence of maintenance, no O&M manual
2. Dam in poor level of upkeep, very little maintenance, no O&M manual
3. Dam in fair level of upkeep, some maintenance and standard procedur
4. Adequate level of maintenance and standard procedures
5. Dam well maintained, detailed maintenance plan that is executed

E3: EMERGENCY ACTION PLAN
1. No plan or idea of what to do in the event of an emergency
2. Some idea but no written plan
3. No formal plan but well thought out
4. Available written plan that needs updating
5. Detailed, updated written plan available and filed with MADCR, annual t

E4: SEEPAGE (Embankments, Foundations, & Abutments)
1. Severe piping and/or seepage with no monitoring
2. Evidence of monitored piping and seepage
3. No piping but uncontrolled seepage
4. Minor seepage or high volumes of seepage with filtered collection
5. No seepage or minor seepage with filtered collection

E5: EMBANKMENT CONDITION (See Note 1)
1. Severe erosion and/or large trees
2. Significant erosion or significant woody vegetation
3. Brush and exposed embankment soils, or moderate erosion
4. Unmaintained grass, rodent activity and maintainable erosion
5. Well maintained healthy uniform grass cover

E6: CONCRETE CONDITION (See Note 2)
1. Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns
2. Cracks with misalignment inclusive of transverse cracks with no misalignment but with potential for significant structural degradation
3. Significant longitudinal cracking and minor transverse cracking
4. Spalling and minor surface cracking
5. No apparent deficiencies

E7: LOW-LEVEL OUTLET DISCHARGE CAPACITY
1. No low level outlet, no provisions (e.g. pumps, siphons) for emptying
2. No operable outlet, plans for emptying pond, but no equipment
3. Outlet with insufficient drawdown capacity, pumping equipment availa
4. Operable gate with sufficient drawdown capacity
5. Operable gate with capacity greater than necessary

E8: LOW-LEVEL OUTLET PHYSICAL CONDITION
1. Outlet inoperative needs replacement, non-existent or inaccessible
2. Outlet inoperative needs repair
3. Outlet operable but needs repair
4. Outlet operable but needs maintenance
5. Outlet and operator operable and well maintained

E9: SPILLWAY DESIGN FLOOD CAPACITY
1. 0 - 50% of the SDF or unknown
2. 50-90% of the SDF
3. 90 - 100% of the SDF
4. >100% of the SDF with actions required by caretaker (e.g. open outle
5. >100% of the SDF with no actions required by caretaker

E10: OVERALL PHYSICAL CONDITION OF DAM
1. UNSAFE – Major structural, operational, and maintenance deficiencies exist under normal operating conditions
2. POOR - Significant structural, operation and maintenance deficiencies are clearly recognized under normal loading conditions
3. FAIR - Significant operational and maintenance deficiencies, no struc deficiencies. Potential deficiencies exist under unusual loading condi that may realistically occur. Can be used when uncertainties exist a critical parameters
4. SATISFACTORY - Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result In deficiencies.
5. GOOD - No existing or potential deficiencies recognized. Safe perforr is expected under all loading including SDF

E11: ESTIMATED REPAIR COST

Estimation of the total cost to address all identified structural, operationa maintenance deficiencies. Cost shall be developed utilizing standard estimating guides and procedures

1.1 Summary Data Table

Required Phase I Report Data	Data Provided by the Inspecting Engineer
National ID #	NA
Dam Name	Unnamed Dam on Clear Bottom Pond
Dam Name (Alternate)	0
River Name	South Meadow Brook (Tributary to the Weweantic R
Impoundment Name	Clear Bottom Pond
Hazard Class	Non-jurisdictional
Size Class	Small
Dam Type	Earth embankment
Dam Purpose	Agriculture
Structural Height of Dam (feet)	5
Hydraulic Height of Dam (feet)	4
Drainage Area (sq. mi.)	Unknown
Reservoir Surface Area (acres)	7.5
Normal Impoundment Volume (acre-feet)	10
Max Impoundment Volume ((top of dam) acre-feet)	18
SDF Impoundment Volume* (acre-feet)	Unknown (No H&H)
Spillway Type	Sharp-crested weir
Spillway Length (feet)	3
Freeboard at Normal Pool (feet)	3
Principal Spillway Capacity* (cfs)	18 ±
Auxiliary Spillway Capacity* (cfs)	NA
Low-Level Outlet Capacity* (cfs)	Unknown (No H&H)
Spillway Design Flood* (flow rate - cfs)	Unknown (No H&H)
Winter Drawdown (feet below normal pool)	NA
Drawdown Impoundment Vol. (acre-feet)	NA
Latitude	41°53'55.32"N
Longitude	70°45'14.27"W
City/Town	Carver
County Name	Plymouth
Public Road on Crest	No
Public Bridge over Spillway	No
EAP Date (if applicable)	NA
Owner Name	Flax Pond Cranberry Co.
Owner Address	Robbins Path
Owner Town	Carver, Massachusetts
Owner Type	Private
Date of Field Inspection	11/19/2018

*In the event a hydraulic and hydrologic analysis has not been completed for the dam, indicate "No H&H" in this table, recommendation section shall include specific recommendation to hire a qualified dam engineering consultant to conduct analysis to determine spillway adequacy in conformance with 302 CMR 10.00.

DAM SAFETY INSPECTION CHECKLIST

NAME OF DAM:	Unnamed Dam on Clear Bottom Pond	STATE ID #:	NA
REGISTERED:	☐ YES ☑ NO	NID ID #:	NA
STATE SIZE CLASSIFICATION:	Small	STATE HAZARD CLASSIFICATION:	Non-jurisdictional
		CHANGE IN HAZARD CLASSIFICATION REQUESTED?:	No

DAM LOCATION INFORMATION

CITY/TOWN:	Carver	COUNTY:	Plymouth
DAM LOCATION: (street address if known)	Robbins Path off of Pond Street	ALTERNATE DAM NAME:	
USGS QUAD.:	Plympton	LAT.: 41°53'55.32"N	LONG.: 70°45'14.27"W
DRAINAGE BASIN:	Buzzards Bay	RIVER:	South Meadow Brook (Tributary to the Weweantic River)
IMPOUNDMENT NAME(S):	Clear Bottom Pond		

GENERAL DAM INFORMATION

TYPE OF DAM:	Earth embankment	OVERALL LENGTH (FT):	200
PURPOSE OF DAM:	Agriculture	NORMAL POOL STORAGE (ACRE-FT):	10
YEAR BUILT:	Unknown	MAXIMUM POOL STORAGE (ACRE-FT):	18
STRUCTURAL HEIGHT (FT):	5	EL. NORMAL POOL (FT):	100.0
HYDRAULIC HEIGHT (FT):	4	EL. MAXIMUM POOL (FT):	107.0

NAME OF DAM: Unnamed Dam on Clear Bottom Pond | STATE ID #: NA

INSPECTION DATE: November 19, 2018 | NID ID #: NA

INSPECTION SUMMARY

DATE OF INSPECTION: November 19, 2018 | DATE OF PREVIOUS INSPECTION: NA

TEMPERATURE/WEATHER: Overcast, 45 F | ARMY CORPS PHASE I: ☐ YES ☑ NO | If YES, date NA

CONSULTANT: Fuss & O'Neill, Inc. | PREVIOUS DCR PHASE I: ☐ YES ☑ NO | If YES, date NA

BENCHMARK/DATUM: NAD83, NAVD88

OVERALL PHYSICAL CONDITION OF DAM: SATISFACTORY | DATE OF LAST REHABILITATION: Unknown

SPILLWAY CAPACITY: 0-50% of the SDF or Unknown

EL. POOL DURING INSP. 102 ± feet | EL. TAILWATER DURING INSP.: 99 ± feet

PERSONS PRESENT AT INSPECTION

NAME	TITLE/POSITION	REPRESENTING
Shawn King, EIT	Project Engineer	Fuss & O'Neill, Inc.
Sage Hardesty	Project Engineer	Fuss & O'Neill, Inc.
Brian Wick	Executive Director	Cape Cod Cranberry Growers' Association

EVALUATION INFORMATION

		Click on box to select E-code
E1)	TYPE OF DESIGN	1
E2)	LEVEL OF MAINTENANCE	5
E3)	EMERGENCY ACTION PLAN	1
E4)	EMBANKMENT SEEPAGE	5
E5)	EMBANKMENT CONDITION	4
E6)	CONCRETE CONDITION	N/A
E7)	LOW-LEVEL OUTLET CAPACITY	5

		Click on box to select E-code
E8)	LOW-LEVEL OUTLET CONDITION	5
E9)	SPILLWAY DESIGN FLOOD CAPACIT	1
E10)	OVERALL PHYSICAL CONDITION	4
E11)	ESTIMATED REPAIR COST	N/A
	ROADWAY OVER CREST	NO
	BRIDGE NEAR DAM	NO

NAME OF DAM: Unnamed Dam on Clear Bottom Pond | STATE ID #: NA

INSPECTION DATE: November 19, 2018 | NID ID #: NA

OWNER:		CARETAKER:	
ORGANIZATION	Flax Pond Cranberry Co.	ORGANIZATION	Flax Pond Cranberry Co.
NAME/TITLE		NAME/TITLE	
STREET	Robbins Path	STREET	Robbins Path
TOWN, STATE, ZIP	Carver, Massachusetts	TOWN, STATE, ZIP	Carver, Massachusetts
PHONE		PHONE	
EMERGENCY PH. #		EMERGENCY PH. #	
FAX		FAX	
EMAIL		EMAIL	
OWNER TYPE	Private		

PRIMARY SPILLWAY TYPE: Sharp-crested weir

SPILLWAY LENGTH (FT): 3 | SPILLWAY CAPACITY (CFS): 18 ±

AUXILIARY SPILLWAY TYPE: NA | AUX. SPILLWAY CAPACITY (CFS): NA

NUMBER OF OUTLETS: 1 | OUTLET(S) CAPACITY (CFS): Unknown (No H&H)

TYPE OF OUTLETS: Agricultural Pump System | TOTAL DISCHARGE CAPACITY (CFS): Unknown (No H&H)

DRAINAGE AREA (SQ MI): Unknown | SPILLWAY DESIGN FLOOD (PERIOD/CFS): Unknown (No H&H)

HAS DAM BEEN BREACHED OR OVERTOPPED ☐ YES ☐ NO | IF YES, PROVIDE DATE(S): Unknown

FISH LADDER (LIST TYPE IF PRESENT): No

DOES CREST SUPPORT PUBLIC ROAD? ☐ YES ☑ NO | IF YES, ROAD NAME: NA

PUBLIC BRIDGE WITHIN 50' OF DAM? ☐ YES ☑ NO | IF YES, ROAD/BRIDGE NAME: NA

MHD BRIDGE NO. (IF APPLICABLE): NA

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	1. SURFACE TYPE	Earth embankment		X*	
	2. SURFACE CRACKING	No issues observed.	X		
	3. SINKHOLES, ANIMAL BURROWS	No issues observed.		X	
	4. VERTICAL ALIGNMENT (DEPRESSIONS)	Some rutting due to frequent vehicular use. Maintained as necessary.		X	
	5. HORIZONTAL ALIGNMENT	Good.	X		
	6. RUTS AND/OR PUDDLES	Some rutting due to frequent vehicular use. Maintained as necessary.		X	
	7. VEGETATION (PRESENCE/CONDITION)	Grass on crest edges. Bare in vehicle tire paths**			X
	8. ABUTMENT CONTACT	Good.	X		

ADDITIONAL COMMENTS: *The crest of the dam also serves as a primary access and haul road within the agricultural bog.

**Due to the frequency of vehicular traffic on the dam crest, it is unlikely healthy grass can be maintained in the bare areas.

** Fill ruts as necessary to prevent significant ponding of water.

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (D/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S SLOPE	1. WET AREAS (NO FLOW)	No wet areas (NO FLOW) observed. Agricultural channels present along dam toe.		X*	
	2. SEEPAGE	No issues observed.	X		
	3. SLIDE, SLOUGH, SCARP	Minor vertical scarp observed at dam toe along the the agricultural channels.		X*	
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. SINKHOLE/ANIMAL BURROWS	No issues observed.		X	
	6. EROSION	No issues observed on d/s face of dam.	X		
	7. UNUSUAL MOVEMENT	No issues observed.	X		
	8. VEGETATION (PRESENCE/CONDITION)	Grass-covered. Well maintained.	X		

ADDITIONAL COMMENTS: *While the wet areas along the dam toe are intentional for agricultural purposes, the condition of the dam embankment should be monitored for erosion or undermining caused by the varying flows and tailwater elevations along the dam toe.

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (U/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	No issues observed on observable surface.	X		
	2. SLOPE PROTECTION TYPE AND COND.	No slope protection observed.	X		
	3. SINKHOLE/ANIMAL BURROWS	No issues observed on observable surface.	X		
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. EROSION	No issues observed on observable surface.	X		
	6. UNUSUAL MOVEMENT	No issues observed on observable surface.	X		
	7. VEGETATION (PRESENCE/CONDITION)	Satisfactory. Minor areas of low-cut woody vegetation.		X	

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	None observed.	X		
	2. OBSERVATION WELLS	None observed.	X		
	3. STAFF GAGE AND RECORDER	None observed.	X		
	4. WEIRS	None observed.	X		
	5. INCLINOMETERS	None observed.	X		
	6. SURVEY MONUMENTS	None observed.	X		
	7. DRAINS	None observed.	X		
	8. FREQUENCY OF READINGS	None observed.	X		
	9. LOCATION OF READINGS	None observed.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S WALLS	1. WALL TYPE				
	2. WALL ALIGNMENT				
	3. WALL CONDITION				
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: max: avg:			
	5. SEEPAGE OR LEAKAGE				
	6. ABUTMENT CONTACT				
	7. EROSION/SINKHOLES BEHIND WALL	NOT APPLICABLE			
	8. ANIMAL BURROWS				
	9. UNUSUAL MOVEMENT				
	10. WET AREAS AT TOE OF WALL				

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

UPSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S WALLS	1. WALL TYPE				
	2. WALL ALIGNMENT				
	3. WALL CONDITION				
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: max: avg:			
	5. ABUTMENT CONTACT				
	6. EROSION/SINKHOLES BEHIND WALL				
	7. ANIMAL BURROWS				
	8. UNUSUAL MOVEMENT				
		NOT APPLICABLE			

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM AREA

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S AREA	1. ABUTMENT LEAKAGE	No issues observed on observable portions of embankment.	X		
	2. FOUNDATION SEEPAGE	Unobservable.	X		
	3. SLIDE, SLOUGH, SCARP	See Downstream Slope		X	
	4. WEIRS	NA	X		
	5. DRAINAGE SYSTEM	See Outlet Works	X		
	6. INSTRUMENTATION	None observed.	X		
	7. VEGETATION	Agricultural. Well maintained.	X		
	8. ACCESSIBILITY	Good.	X		
	9. DOWNSTREAM HAZARD DESCRIPTION	Primarily low-lying agricultural and forested wetland areas.			
	10. DATE OF LAST EAP UPDATE	No formal EAP developed for the dam. The water supply impounded by the dam is used for agricultural purposes as part of the grower's farm plan.			

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

MISCELLANEOUS

AREA INSPECTED	CONDITION	OBSERVATIONS
MISC.	1. RESERVOIR DEPTH (AVG)	5 feet (reported by Owner)
	2. RESERVOIR SHORELINE	See Upstream Slope.
	3. RESERVOIR SLOPES	Shallow.
	4. ACCESS ROADS	Dam crest is used as access road and haul road for farm.
	5. SECURITY DEVICES	None at dam. Private property.
	6. VANDALISM OR TRESPASS	☐ YES ☑ NO WHAT:
	7. AVAILABILITY OF PLANS	☐ YES ☑ NO DATE:
	8. AVAILABILITY OF DESIGN CALCS	☐ YES ☑ NO DATE:
	9. AVAILABILITY OF EAP/LAST UPDATE	☐ YES ☑ NO DATE:
	10. AVAILABILITY OF O&M MANUAL	☐ YES ☑ NO DATE:
	11. CARETAKER/OWNER AVAILABLE	☐ YES ☑ NO DATE:
	12. CONFINED SPACE ENTRY REQUIRED	☐ YES ☑ NO PURPOSE:

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

PRIMARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	Sharp-crested weir	X		
	WEIR TYPE	Flume board drop inlets to corrugated metal discharge pipes.	X		
	SPILLWAY CONDITION	Good.	X		
	TRAINING WALLS	Good.	X		
	SPILLWAY CONTROLS AND CONDITION	Flume boards in good condition.	X		
	UNUSUAL MOVEMENT	None observed.	X		
	APPROACH AREA	Shallow impoundment susceptible to aquatic vegetation growth, sediment, & debris		X	
	DISCHARGE AREA	Well-maintained agricultural farm.	X		
	DEBRIS	None observed.	X		
	WATER LEVEL AT TIME OF INSPECTION	Approximately 1 foot of freeboard.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

AUXILIARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE				
	WEIR TYPE				
	SPILLWAY CONDITION				
	TRAINING WALLS				
	SPILLWAY CONTROLS AND CONDITION				
	UNUSUAL MOVEMENT				
	APPROACH AREA				
	DISCHARGE AREA				
	DEBRIS				
	WATER LEVEL AT TIME OF INSPECTION				

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

OUTLET WORKS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
OUTLET WORKS	TYPE	Pump intake structure*	X		
	INTAKE STRUCTURE	Primary intake appears to be approximately 24" diameter pipe.	X		
	TRASHRACK	Trash rack present at outlet structure/headwall.	X		
	PRIMARY CLOSURE	Unknown			
	SECONDARY CLOSURE	Unknown			
	CONDUIT	Subsurface conduit unobservable.			
	OUTLET STRUCTURE/HEADWALL	Concrete headwall in fair condition. Flume logs present to control discharge.		X	
	EROSION ALONG TOE OF DAM	NA			
	SEEPAGE/LEAKAGE	No issues observed.	X		
	DEBRIS/BLOCKAGE	No issues observed.	X		
	UNUSUAL MOVEMENT	No issues observed.	X		
	DOWNSTREAM AREA	Earthen open-channel used for agricultural purposes.		X**	
	MISCELLANEOUS				

ADDITIONAL COMMENTS: *The main components of the pump intake structure contained within the pump house were not observed.

**Monitor for and maintain accumulated sediments or debris observed in the channel.

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
GENERAL	TYPE				
	AVAILABILITY OF PLANS				
	AVAILABILITY OF DESIGN CALCS				
	PIEZOMETERS				
	OBSERVATION WELLS	NOT APPLICABLE			
	INCLINOMETERS				
	SEEPAGE GALLERY				
	UNUSUAL MOVEMENT				

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	HORIZONTAL ALIGNMENT				
	VERTICAL ALIGNMENT	NOT APPLICABLE			

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (DOWNSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S FACE	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	ABUTMENT CONTACT				
	LEAKAGE				
		NOT APPLICABLE			

ADDITIONAL COMMENTS:

NAME OF DAM: Unnamed Dam on Clear Bottom Pond STATE ID #: NA

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (UPSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S FACE	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	ABUTMENT CONTACTS				
		NOT APPLICABLE			

ADDITIONAL COMMENTS:

Dam Evaluation Summary Detail Sheet

1. NID ID:	NA	4. Inspection Date:	November 19, 2018
2. Dam Name:	Old Center Street Dam	5. Last Insp. Date:	NA
3. Dam Location:	Carver, MA	6. Next Inspection:	NA
7. Inspector:	Sage Hardesty, Fuss & O'Neill, Inc.		
8. Consultant:	Fuss & O'Neill, Inc.		
9. Hazard Code:	Non-Juris.	9a. Is Hazard Code Change Requested?:	No
10. Insp. Frequency:	NA	11. Overall Physical Condition of Dam:	SATISFACTORY
12. Spillway Capacity (%SDF)	0-50% of the SDF or Unknown		

E1. Design Methodology:	1	E7. Low-Level Discharge Capacity:	5
E2. Level of Maintenance:	5	E8. Low-Level Outlet Physical Condition:	5
E3. Emergency Action Plan:	1	E9. Spillway Design Flood Capacity:	1
E4. Embankment Seepage:	5	E10. Overall Physical Condition of the Dam:	4
E5. Embankment Condition:	4	E11. Estimated Repair Cost:	
E6. Concrete Condition:	4		

Evaluation Description

E1: DESIGN METHODOLOGY
1. Unknown Design – no design records available
2. No design or post-design analyses
3. No analyses, but dam features appear suitable
4. Design or post design analysis show dam meets most criteria
5. State of the art design – design records available & dam meets all crite

E2: LEVEL OF MAINTENANCE
1. Dam in disrepair, no evidence of maintenance, no O&M manual
2. Dam in poor level of upkeep, very little maintenance, no O&M manual
3. Dam in fair level of upkeep, some maintenance and standard procedur
4. Adequate level of maintenance and standard procedures
5. Dam well maintained, detailed maintenance plan that is executed

E3: EMERGENCY ACTION PLAN
1. No plan or idea of what to do in the event of an emergency
2. Some idea but no written plan
3. No formal plan but well thought out
4. Available written plan that needs updating
5. Detailed, updated written plan available and filed with MADCR, annual t

E4: SEEPAGE (Embankments, Foundations, & Abutments)
1. Severe piping and/or seepage with no monitoring
2. Evidence of monitored piping and seepage
3. No piping but uncontrolled seepage
4. Minor seepage or high volumes of seepage with filtered collection
5. No seepage or minor seepage with filtered collection

E5: EMBANKMENT CONDITION (See Note 1)
1. Severe erosion and/or large trees
2. Significant erosion or significant woody vegetation
3. Brush and exposed embankment soils, or moderate erosion
4. Unmaintained grass, rodent activity and maintainable erosion
5. Well maintained healthy uniform grass cover

E6: CONCRETE CONDITION (See Note 2)
1. Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns
2. Cracks with misalignment inclusive of transverse cracks with no misalignment but with potential for significant structural degradation
3. Significant longitudinal cracking and minor transverse cracking
4. Spalling and minor surface cracking
5. No apparent deficiencies

E7: LOW-LEVEL OUTLET DISCHARGE CAPACITY
1. No low level outlet, no provisions (e.g. pumps, siphons) for emptying
2. No operable outlet, plans for emptying pond, but no equipment
3. Outlet with insufficient drawdown capacity, pumping equipment availa
4. Operable gate with sufficient drawdown capacity
5. Operable gate with capacity greater than necessary

E8: LOW-LEVEL OUTLET PHYSICAL CONDITION
1. Outlet inoperative needs replacement, non-existent or inaccessible
2. Outlet inoperative needs repair
3. Outlet operable but needs repair
4. Outlet operable but needs maintenance
5. Outlet and operator operable and well maintained

E9: SPILLWAY DESIGN FLOOD CAPACITY
1. 0 - 50% of the SDF or unknown
2. 50-90% of the SDF
3. 90 - 100% of the SDF
4. >100% of the SDF with actions required by caretaker (e.g. open outle
5. >100% of the SDF with no actions required by caretaker

E10: OVERALL PHYSICAL CONDITION OF DAM
1. UNSAFE – Major structural, operational, and maintenance deficiencies exist under normal operating conditions
2. POOR - Significant structural, operation and maintenance deficiencies are clearly recognized under normal loading conditions
3. FAIR - Significant operational and maintenance deficiencies, no struc deficiencies. Potential deficiencies exist under unusual loading condi that may realistically occur. Can be used when uncertainties exist a critical parameters
4. SATISFACTORY - Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result In deficiencies.
5. GOOD - No existing or potential deficiencies recognized. Safe perforr is expected under all loading including SDF

E11: ESTIMATED REPAIR COST

Estimation of the total cost to address all identified structural, operationa maintenance deficiencies. Cost shall be developed utilizing standard estimating guides and procedures

Changes/Deviations to Database Information since Last Inspection

1.1 Summary Data Table

Required Phase I Report Data	Data Provided by the Inspecting Engineer
National ID #	NA
Dam Name	Old Center Street Dam
Dam Name (Alternate)	NA
River Name	South Meadow Brook (Tributary to the Weweantic R
Impoundment Name	Unnamed Agricultural Water Supply
Hazard Class	Non-jurisdictional
Size Class	Small
Dam Type	Earth embankment
Dam Purpose	Agricultural Water Supply
Structural Height of Dam (feet)	7 ±
Hydraulic Height of Dam (feet)	4 ±
Drainage Area (sq. mi.)	< 1
Reservoir Surface Area (acres)	7.2
Normal Impoundment Volume (acre-feet)	9.6
Max Impoundment Volume ((top of dam) acre-feet)	16.8
SDF Impoundment Volume* (acre-feet)	Unknown (No H&H)
Spillway Type	Sharp-crested weir
Spillway Length (feet)	3 ±
Freeboard at Normal Pool (feet)	5
Principal Spillway Capacity* (cfs)	10 ±
Low-Level Outlet Capacity* (cfs)	Unknown (No H&H)
Spillway Design Flood* (flow rate - cfs)	Unknown (No H&H)
Winter Drawdown (feet below normal pool)	NA
Drawdown Impoundment Vol. (acre-feet)	NA
Latitude	41.898334°
Longitude	-70.771828°
City/Town	Carver
County Name	Plymouth
Public Road on Crest	No
Public Bridge over Spillway	No
EAP Date (if applicable)	No formal EAP developed for the dam. The water s
Owner Name	Weston Cranberry Corp.
Owner Address	Center Street
Owner Town	Carver, Massachusetts
Owner Type	Private
Caretaker Emergency Phone	0
Date of Field Inspection	11/19/2018

*In the event a hydraulic and hydrologic analysis has not been completed for the dam, indicate "No H&H" in this table, recommendation section shall include specific recommendation to hire a qualified dam engineering consultant to conduct analysis to determine spillway adequacy in conformance with 302 CMR 10.00.

DAM SAFETY INSPECTION CHECKLIST

NAME OF DAM: Old Center Street Dam
STATE ID #: MA02073

REGISTERED: ☐ YES ☑ NO
NID ID #: NA

STATE SIZE CLASSIFICATION: Small
STATE HAZARD CLASSIFICATION: Non-Jurisdictional
CHANGE IN HAZARD CLASSIFICATION REQUESTED?: No

DAM LOCATION INFORMATION

CITY/TOWN: Carver
COUNTY: Plymouth

DAM LOCATION: Center Street
(street address if known)
ALTERNATE DAM NAME: NA

USGS QUAD.: Plympton
LAT.: 41.898334°
LONG.: -70.771828°

DRAINAGE BASIN: Buzzards Bay
RIVER: South Meadow Brook (Tributary to the Weweantic River)

IMPOUNDMENT NAME(S): Unnamed Agricultural Water Supply

GENERAL DAM INFORMATION

TYPE OF DAM: Earth embankment
OVERALL LENGTH (FT): 750

PURPOSE OF DAM: Agricultural Water Supply
NORMAL POOL STORAGE (ACRE-FT): 9.6

YEAR BUILT: Unknown
MAXIMUM POOL STORAGE (ACRE-FT): 16.8

STRUCTURAL HEIGHT (FT): 7 ±
EL. NORMAL POOL (FT): 99.0

HYDRAULIC HEIGHT (FT): 4 ±
EL. MAXIMUM POOL (FT): 101.5

NAME OF DAM Old Center Street Dam | STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 | NID ID #: NA

INSPECTION SUMMARY

DATE OF INSPECTION: November 19, 2018 | DATE OF PREVIOUS INSPECTION: Unknown

TEMPERATURE/WEATHER: Overcast, 45 F | ARMY CORPS PHASE I: ☐ YES ☑ NO | If YES, date NA

CONSULTANT: Fuss & O'Neill, Inc. | PREVIOUS DCR PHASE I: ☐ YES ☑ NO | If YES, date NA

BENCHMARK/DATUM: NAD83, NAVD88

OVERALL PHYSICAL CONDITION OF DAM: SATISFACTORY | DATE OF LAST REHABILITATION: Unknown

SPILLWAY CAPACITY: 0-50% of the SDF or Unknown

EL. POOL DURING INSP. | EL. TAILWATER DURING INSP.: 94.5 ±

PERSONS PRESENT AT INSPECTION

NAME	TITLE/POSITION	REPRESENTING
Shawn King, EIT	Project Engineer	Fuss & O'Neill, Inc.
Sage Hardesty	Project Engineer	Fuss & O'Neill, Inc.
Craig Weston	Fire Chief	Town of Carver - Fire Department

EVALUATION INFORMATION

		Click on box to select E-code
E1)	TYPE OF DESIGN	1
E2)	LEVEL OF MAINTENANCE	5
E3)	EMERGENCY ACTION PLAN	1
E4)	EMBANKMENT SEEPAGE	5
E5)	EMBANKMENT CONDITION	4
E6)	CONCRETE CONDITION	4
E7)	LOW-LEVEL OUTLET CAPACITY	5

		Click on box to select E-code
E8)	LOW-LEVEL OUTLET CONDITION	5
E9)	SPILLWAY DESIGN FLOOD CAPACIT	1
E10)	OVERALL PHYSICAL CONDITION	4
E11)	ESTIMATED REPAIR COST	
	ROADWAY OVER CREST	NO
	BRIDGE NEAR DAM	NO

NAME OF DAM: Old Center Street Dam | STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 | NID ID #: NA

OWNER:	ORGANIZATION	Weston Cranberry Corp.	CARETAKER:	ORGANIZATION	Weston Cranberry Corp.
	NAME/TITLE	Craig Weston		NAME/TITLE	Craig Weston
	STREET	Center Street		STREET	
	TOWN, STATE, ZIP	Carver, Massachusetts		TOWN, STATE, ZIP	Carver, Massachusetts
	PHONE			PHONE	
	EMERGENCY PH. #			EMERGENCY PH. #	
	FAX			FAX	
	EMAIL	craig.weston@carverfire.org		EMAIL	craig.weston@carverfire.org
	OWNER TYPE	Private			

PRIMARY SPILLWAY TYPE: Sharp-crested weir

SPILLWAY LENGTH (FT): 3 ± | SPILLWAY CAPACITY (CFS): 10 ±

NUMBER OF OUTLETS: 3 (see type of outlets below) | OUTLET(S) CAPACITY (CFS): Unknown (No H&H)

TYPE OF OUTLETS: Agricultural Pump (2), Diversion Channel (1) | TOTAL DISCHARGE CAPACITY (CFS): Unknown (No H&H)

DRAINAGE AREA (SQ MI): < 1 | SPILLWAY DESIGN FLOOD (PERIOD/CFS): Unknown (No H&H)

HAS DAM BEEN BREACHED OR OVERTOPPED ☐ YES ☐ NO | IF YES, PROVIDE DATE(S): Unknown

FISH LADDER (LIST TYPE IF PRESENT): NA

DOES CREST SUPPORT PUBLIC ROAD? ☐ YES ☑ NO | IF YES, ROAD NAME: NA

PUBLIC BRIDGE WITHIN 50' OF DAM? ☐ YES ☑ NO | IF YES, ROAD/BRIDGE NAME: NA

MHD BRIDGE NO. (IF APPLICABLE): NA

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	1. SURFACE TYPE	Earth embankment		X*	
	2. SURFACE CRACKING	No issues observed.	X		
	3. SINKHOLES, ANIMAL BURROWS	No issues observed.	X		
	4. VERTICAL ALIGNMENT (DEPRESSIONS)	Minor rutting due to frequent vehicular use. Maintained as necessary.		X	
	5. HORIZONTAL ALIGNMENT	Good. Crest width fairly uniform in width, alignment good.	X		
	6. RUTS AND/OR PUDDLES	Minor rutting due to frequent vehicular use. Maintained as necessary.		X	
	7. VEGETATION (PRESENCE/CONDITION)	Vegetation presence is fair. Grass-covered crest. Bare areas in tire ruts.**			X
	8. ABUTMENT CONTACT	Good.	X		

ADDITIONAL COMMENTS: *The crest of the dam also serves as a primary access and haul road within the agricultural bog.

**Due to the frequency of vehicular traffic on the dam crest, maintaining a healthy grass-covered surface may be difficult.

**Fill tire ruts as necessary to prevent significant ponding.

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (D/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S SLOPE	1. WET AREAS (NO FLOW)	No wet areas (NO FLOW) observed. Agricultural channels present along dam toe.		X*	
	2. SEEPAGE	No issues observed in observerable portion of dam embankment.	X		
	3. SLIDE, SLOUGH, SCARP	Embankment material loss in vicinity of primary spillway structure.			X
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. SINKHOLE/ANIMAL BURROWS	No issues observed.		X	
	6. EROSION	Some bare areas present on d/s face. Erosion noted along primary spillway structure.			X
	7. UNUSUAL MOVEMENT	No issues observed.	X		
	8. VEGETATION (PRESENCE/CONDITION)	Grass-covered. Mowed regularly. Some bare areas present on d/s face.	X		

ADDITIONAL COMMENTS: *While the wet areas along the dam toe are intentional for agricultural purposes, the condition of the dam embankment should be monitored for erosion or undermining caused by the varying flows and tailwater elevations along the dam toe.

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (U/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	Majority of slope submerged at the time of the inspection. Shallow but varying slope	X		
	2. SLOPE PROTECTION TYPE AND COND.	No slope protection observed.	X		
	3. SINKHOLE/ANIMAL BURROWS	No issues observed in the exposed portions of the embankment.	X		
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. EROSION	Varying shallow slopes may indicate past erosion. Vegetation indicates no recent notable erosion.		X	
	6. UNUSUAL MOVEMENT	No issues observed.	X		
	7. VEGETATION (PRESENCE/CONDITION)	Grass-covered slope. Mowed regularly.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	None observed.	X		
	2. OBSERVATION WELLS	None observed.	X		
	3. STAFF GAGE AND RECORDER	None observed.	X		
	4. WEIRS	None observed.	X		
	5. INCLINOMETERS	None observed.	X		
	6. SURVEY MONUMENTS	None observed.	X		
	7. DRAINS	None observed.	X		
	8. FREQUENCY OF READINGS	None observed.	X		
	9. LOCATION OF READINGS	None observed.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S WALLS	1. WALL TYPE				
	2. WALL ALIGNMENT				
	3. WALL CONDITION				
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: max: avg:			
	5. SEEPAGE OR LEAKAGE				
	6. ABUTMENT CONTACT				
	7. EROSION/SINKHOLES BEHIND WALL				
	8. ANIMAL BURROWS				
	9. UNUSUAL MOVEMENT				
	10. WET AREAS AT TOE OF WALL				

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

UPSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS			NO ACTION	MONITOR	REPAIR
U/S WALLS	1. WALL TYPE						
	2. WALL ALIGNMENT						
	3. WALL CONDITION						
	4. HEIGHT: TOP OF WALL TO MUDLINE	min:	max:	avg:			
	5. ABUTMENT CONTACT						
	6. EROSION/SINKHOLES BEHIND WALL						
	7. ANIMAL BURROWS						
	8. UNUSUAL MOVEMENT						

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM AREA

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S AREA	1. ABUTMENT LEAKAGE	No issues observed on observable portions of embankment.	X		
	2. FOUNDATION SEEPAGE	No issues observed on observable portions of embankment.	X		
	3. SLIDE, SLOUGH, SCARP	No issues observed on observable portions of embankment.	X		
	4. WEIRS	None observed.	X		
	5. DRAINAGE SYSTEM	None observed.	X		
	6. INSTRUMENTATION	None observed.	X		
	7. VEGETATION	Agricultural. Well maintained.	X		
	8. ACCESSIBILITY	Good.	X		
	9. DOWNSTREAM HAZARD DESCRIPTION	Low-lying agricultural areas, forested wetlands, some residential properties, and two public roadways.			
	10. DATE OF LAST EAP UPDATE	No formal EAP developed for the dam. The water supply impounded by the dam is used for agricultural purposes as part of the grower's farm plan.			

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

MISCELLANEOUS

AREA INSPECTED	CONDITION	OBSERVATIONS
MISC.	1. RESERVOIR DEPTH (AVG)	
	2. RESERVOIR SHORELINE	See Upstream Slope.
	3. RESERVOIR SLOPES	Varying shallow slopes.
	4. ACCESS ROADS	Dam crest is used as access road and haul road for farm.
	5. SECURITY DEVICES	Surveillance
	6. VANDALISM OR TRESPASS	☐ YES ☑ NO WHAT:
	7. AVAILABILITY OF PLANS	☐ YES ☑ NO DATE:
	8. AVAILABILITY OF DESIGN CALCS	☐ YES ☑ NO DATE:
	9. AVAILABILITY OF EAP/LAST UPDATE	☐ YES ☑ NO DATE:
	10. AVAILABILITY OF O&M MANUAL	☐ YES ☑ NO DATE:
	11. CARETAKER/OWNER AVAILABLE	☑ YES ☐ NO DATE: November 19, 2018
	12. CONFINED SPACE ENTRY REQUIRED	☐ YES ☑ NO PURPOSE:

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

PRIMARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	Sharp-crested weir	X		
	WEIR TYPE	Flume boards		X*	
	SPILLWAY CONDITION	Satisfactory. Minor leakage of flume boards. Embankment deficiencies.			X**
	TRAINING WALLS	Satisfactory.	X		
	SPILLWAY CONTROLS AND CONDITION	See Spillway Condition			
	UNUSUAL MOVEMENT	No issues observed.	X		
	APPROACH AREA	Shallow impoundment susceptible to aquatic vegetation growth, sediment, & debris		X	
	DISCHARGE AREA	Well-maintained agricultural farm.	X		
	DEBRIS	None observed.	X		
	WATER LEVEL AT TIME OF INSPECTION	Approximately 1 foot of freeboard.	X		

ADDITIONAL COMMENTS: *Monitor leakage and replace flume boards as required to reduce flow through or around boards.
**See Downstream Slope

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

AUXILIARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE				
	WEIR TYPE				
	SPILLWAY CONDITION				
	TRAINING WALLS	NOT APPLICABLE			
	SPILLWAY CONTROLS AND CONDITION				
	UNUSUAL MOVEMENT				
	APPROACH AREA				
	DISCHARGE AREA				
	DEBRIS				
	WATER LEVEL AT TIME OF INSPECTION				

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

OUTLET WORKS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
OUTLET WORKS	TYPE	Pump intake structures (2)*, Agricultural diversion channel (1)	X		
	INTAKE STRUCTURE	Primary intakes appear to be approximately 12" diameter pipe.	X		
	TRASHRACK	No trash racks observed.	X		
	PRIMARY CLOSURE	Unknown			
	SECONDARY CLOSURE	Unknown			
	CONDUIT	Diversion channel is earthen open channel and maintained. Susceptible to sediment		X	
	OUTLET STRUCTURE/HEADWALL	See Primary Spillway			
	EROSION ALONG TOE OF DAM	No erosion issues associated with outlet works were observed.	X		
	SEEPAGE/LEAKAGE	No issues observed.	X		
	DEBRIS/BLOCKAGE	No issues observed.	X		
	UNUSUAL MOVEMENT	No issues observed.	X		
	DOWNSTREAM AREA	Earthen open-channels used for agricultural purposes.		X**	
	MISCELLANEOUS				

ADDITIONAL COMMENTS: *The main components of the pump intake structure contained within the pump house were not observed.

**Monitor for and maintain accumulated sediments or debris observed in the channel.

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
GENERAL	TYPE				
	AVAILABILITY OF PLANS				
	AVAILABILITY OF DESIGN CALCS				
	PIEZOMETERS	NOT APPLICABLE			
	OBSERVATION WELLS				
	INCLINOMETERS				
	SEEPAGE GALLERY				
	UNUSUAL MOVEMENT				

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	TYPE	NOT APPLICABLE			
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	HORIZONTAL ALIGNMENT				
	VERTICAL ALIGNMENT				

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (DOWNSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S FACE	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT	NOT APPLICABLE			
	ABUTMENT CONTACT				
	LEAKAGE				

ADDITIONAL COMMENTS:

NAME OF DAM: Old Center Street Dam STATE ID #: MA02073

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (UPSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S FACE	TYPE	NOT APPLICABLE			
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	ABUTMENT CONTACTS				

ADDITIONAL COMMENTS:

Dam Evaluation Summary Detail Sheet

1. NID ID:	NA	4. Inspection Date:	November 19, 2018
2. Dam Name:	Shaw Bog Reservoir Dam	5. Last Insp. Date:	NA
3. Dam Location:	Carver, MA	6. Next Inspection:	NA
7. Inspector:	Sage Hardesty, Fuss & O'Neill, Inc.		
8. Consultant:	Fuss & O'Neill, Inc.		
9. Hazard Code:	Non-Juris.	9a. Is Hazard Code Change Requested?:	No
10. Insp. Frequency:	NA	11. Overall Physical Condition of Dam:	SATISFACTORY
12. Spillway Capacity (%SDF)	0-50% of the SDF or Unknown		(No H&H)

E1. Design Methodology:	1	E7. Low-Level Discharge Capacity:	5
E2. Level of Maintenance:	5	E8. Low-Level Outlet Physical Condition:	5
E3. Emergency Action Plan:	1	E9. Spillway Design Flood Capacity:	1
E4. Embankment Seepage:	5	E10. Overall Physical Condition of the Dam:	4
E5. Embankment Condition:	4	E11. Estimated Repair Cost:	N/A
E6. Concrete Condition:	N/A		

Evaluation Description

E1: DESIGN METHODOLOGY
1. Unknown Design – no design records available
2. No design or post-design analyses
3. No analyses, but dam features appear suitable
4. Design or post design analysis show dam meets most criteria
5. State of the art design – design records available & dam meets all crite

E2: LEVEL OF MAINTENANCE
1. Dam in disrepair, no evidence of maintenance, no O&M manual
2. Dam in poor level of upkeep, very little maintenance, no O&M manual
3. Dam in fair level of upkeep, some maintenance and standard procedur
4. Adequate level of maintenance and standard procedures
5. Dam well maintained, detailed maintenance plan that is executed

E3: EMERGENCY ACTION PLAN
1. No plan or idea of what to do in the event of an emergency
2. Some idea but no written plan
3. No formal plan but well thought out
4. Available written plan that needs updating
5. Detailed, updated written plan available and filed with MADCR, annual t

E4: SEEPAGE (Embankments, Foundations, & Abutments)
1. Severe piping and/or seepage with no monitoring
2. Evidence of monitored piping and seepage
3. No piping but uncontrolled seepage
4. Minor seepage or high volumes of seepage with filtered collection
5. No seepage or minor seepage with filtered collection

E5: EMBANKMENT CONDITION (See Note 1)
1. Severe erosion and/or large trees
2. Significant erosion or significant woody vegetation
3. Brush and exposed embankment soils, or moderate erosion
4. Unmaintained grass, rodent activity and maintainable erosion
5. Well maintained healthy uniform grass cover

E6: CONCRETE CONDITION (See Note 2)
1. Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns
2. Cracks with misalignment inclusive of transverse cracks with no misalignment but with potential for significant structural degradation
3. Significant longitudinal cracking and minor transverse cracking
4. Spalling and minor surface cracking
5. No apparent deficiencies

E7: LOW-LEVEL OUTLET DISCHARGE CAPACITY
1. No low level outlet, no provisions (e.g. pumps, siphons) for emptying
2. No operable outlet, plans for emptying pond, but no equipment
3. Outlet with insufficient drawdown capacity, pumping equipment availa
4. Operable gate with sufficient drawdown capacity
5. Operable gate with capacity greater than necessary

E8: LOW-LEVEL OUTLET PHYSICAL CONDITION
1. Outlet inoperative needs replacement, non-existent or inaccessible
2. Outlet inoperative needs repair
3. Outlet operable but needs repair
4. Outlet operable but needs maintenance
5. Outlet and operator operable and well maintained

E9: SPILLWAY DESIGN FLOOD CAPACITY
1. 0 - 50% of the SDF or unknown
2. 50-90% of the SDF
3. 90 - 100% of the SDF
4. >100% of the SDF with actions required by caretaker (e.g. open outle
5. >100% of the SDF with no actions required by caretaker

E10: OVERALL PHYSICAL CONDITION OF DAM
1. UNSAFE – Major structural, operational, and maintenance deficiencies exist under normal operating conditions
2. POOR - Significant structural, operation and maintenance deficiencies are clearly recognized under normal loading conditions
3. FAIR - Significant operational and maintenance deficiencies, no struc deficiencies. Potential deficiencies exist under unusual loading condi that may realistically occur. Can be used when uncertainties exist a critical parameters
4. SATISFACTORY - Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result In deficiencies.
5. GOOD - No existing or potential deficiencies recognized. Safe perforr is expected under all loading including SDF

E11: ESTIMATED REPAIR COST

Estimation of the total cost to address all identified structural, operationa maintenance deficiencies. Cost shall be developed utilizing standard estimating guides and procedures

1.1 Summary Data Table

Required Phase I Report Data	Data Provided by the Inspecting Engineer
National ID #	NA
Dam Name	Shaw Bog Reservoir Dam
Dam Name (Alternate)	0
River Name	N/A
Impoundment Name	Shaw Bog Reservoir
Hazard Class	Non-juridictional
Size Class	Small
Dam Type	Earth Embankment
Dam Purpose	Agricultural Water Supply
Structural Height of Dam (feet)	5.5 ±
Hydraulic Height of Dam (feet)	4 ±
Drainage Area (sq. mi.)	Unknown
Reservoir Surface Area (acres)	14
Normal Impoundment Volume (acre-feet)	19 ±
Max Impoundment Volume ((top of dam) acre-feet)	Unknown (Extensive Wetland)
SDF Impoundment Volume* (acre-feet)	Unknown SDF or SDF Impoundment Volume
Spillway Type	Sharp-crested weir
Spillway Length (feet)	15 ± (5 weirs @ 3 ft each)
Freeboard at Normal Pool (feet)	2
Principal Spillway Capacity* (cfs)	No H&H
Auxiliary Spillway Capacity* (cfs)	No H&H
Low-Level Outlet Capacity* (cfs)	No H&H
Spillway Design Flood* (flow rate - cfs)	No H&H
Winter Drawdown (feet below normal pool)	NA
Drawdown Impoundment Vol. (acre-feet)	NA
Latitude	41.877466
Longitude	-70.75898
City/Town	Carver
County Name	Plymouth
Public Road on Crest	No
Public Bridge over Spillway	No
EAP Date (if applicable)	NA
Owner Name	Oiva Hannula & Sons, Inc.
Owner Address	8 Rochester Road
Owner Town	Carver
Owner Type	Private
Date of Field Inspection	11/19/2018

*In the event a hydraulic and hydrologic analysis has not been completed for the dam, indicate "No H&H" in this table, recommendation section shall include specific recommendation to hire a qualified dam engineering consultant to conduct analysis to determine spillway adequacy in conformance with 302 CMR 10.00.

DAM SAFETY INSPECTION CHECKLIST

NAME OF DAM:	Shaw Bog Reservoir Dam	STATE ID #:	MA00089
REGISTERED:	☐ YES ☑ NO	NID ID #:	NA
STATE SIZE CLASSIFICATION:	Small	STATE HAZARD CLASSIFICATION:	Non-jurisdictional
		CHANGE IN HAZARD CLASSIFICATION REQUESTED?:	No

DAM LOCATION INFORMATION

CITY/TOWN:	Carver	COUNTY:	Plymouth
DAM LOCATION: (street address if known)	East of Mainstreet, Shaw Bog	ALTERNATE DAM NAME:	
USGS QUAD.:	Plympton	LAT.: 41.877466	LONG.: -70.75898
DRAINAGE BASIN:	Buzzards Bay	RIVER:	N/A
IMPOUNDMENT NAME(S):	Shaw Bog Reservoir		

GENERAL DAM INFORMATION

TYPE OF DAM:	Earth Embankment	OVERALL LENGTH (FT):	560 ±
PURPOSE OF DAM:	Agricultural Water Supply	NORMAL POOL STORAGE (ACRE-FT):	19 ±
YEAR BUILT:	Unknown	MAXIMUM POOL STORAGE (ACRE-FT):	Unknown (Extensive Wetland)
STRUCTURAL HEIGHT (FT):	5.5 ±	EL. NORMAL POOL (FT):	92.0
HYDRAULIC HEIGHT (FT):	4 ±	EL. MAXIMUM POOL (FT):	94.0

NAME OF DAM: Shaw Bog Reservoir Dam | STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 | NID ID #: NA

INSPECTION SUMMARY

DATE OF INSPECTION: November 19, 2018 | DATE OF PREVIOUS INSPECTION: NA

TEMPERATURE/WEATHER: Overcast, 45 F | ARMY CORPS PHASE I: ☐ YES ☑ NO | If YES, date

CONSULTANT: Fuss & O'Neill, Inc. | PREVIOUS DCR PHASE I: ☐ YES ☑ NO | If YES, date

BENCHMARK/DATUM: NAD83, NAVD88

OVERALL PHYSICAL CONDITION OF DAM: SATISFACTORY | DATE OF LAST REHABILITATION: Unknown

SPILLWAY CAPACITY: 0-50% of the SDF or Unknown

EL. POOL DURING INSP. | EL. TAILWATER DURING INSP.: 91 ±

PERSONS PRESENT AT INSPECTION

NAME	TITLE/POSITION	REPRESENTING
Shawn King, EIT	Project Engineer	Fuss & O'Neill, Inc.
Sage Hardesty	Project Engineer	Fuss & O'Neill, Inc.
Brian Wick	Executive Director	Cape Cod Cranberry Growers' Association

EVALUATION INFORMATION

		Click on box to select E-code
E1)	TYPE OF DESIGN	1
E2)	LEVEL OF MAINTENANCE	5
E3)	EMERGENCY ACTION PLAN	1
E4)	EMBANKMENT SEEPAGE	5
E5)	EMBANKMENT CONDITION	4
E6)	CONCRETE CONDITION	N/A
E7)	LOW-LEVEL OUTLET CAPACITY	5

		Click on box to select E-code
E8)	LOW-LEVEL OUTLET CONDITION	5
E9)	SPILLWAY DESIGN FLOOD CAPACIT	1
E10)	OVERALL PHYSICAL CONDITION	4
E11)	ESTIMATED REPAIR COST	N/A
	ROADWAY OVER CREST	NO
	BRIDGE NEAR DAM	NO

NAME OF DAM: Shaw Bog Reservoir Dam | STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 | NID ID #: NA

OWNER:		CARETAKER:	
ORGANIZATION	Oiva Hannula & Sons, Inc.	ORGANIZATION	Oiva Hannula & Sons, Inc.
NAME/TITLE		NAME/TITLE	
STREET	8 Rochester Road	STREET	8 Rochester Road
TOWN, STATE, ZIP	Carver	TOWN, STATE, ZIP	Carver
PHONE		PHONE	
EMERGENCY PH. #		EMERGENCY PH. #	
FAX		FAX	
EMAIL		EMAIL	
OWNER TYPE	Private		

PRIMARY SPILLWAY TYPE: Sharp-crested weirs

SPILLWAY LENGTH (FT): 15 ± (5 weirs @ 3 ft each) | SPILLWAY CAPACITY (CFS): 50 ±

AUXILIARY SPILLWAY TYPE: NA | AUX. SPILLWAY CAPACITY (CFS): NA

NUMBER OF OUTLETS: 5 | OUTLET(S) CAPACITY (CFS): Unknown (No H&H)

TYPE OF OUTLETS: Diversion Channel (5) | TOTAL DISCHARGE CAPACITY (CFS): Unknown (No H&H)

DRAINAGE AREA (SQ MI): Unknown | SPILLWAY DESIGN FLOOD (PERIOD/CFS): Unknown (No H&H)

HAS DAM BEEN BREACHED OR OVERTOPPED ☐ YES ☐ NO | IF YES, PROVIDE DATE(S): Unknown

FISH LADDER (LIST TYPE IF PRESENT): No

DOES CREST SUPPORT PUBLIC ROAD? ☐ YES ☑ NO | IF YES, ROAD NAME: NA

PUBLIC BRIDGE WITHIN 50' OF DAM? ☐ YES ☑ NO | IF YES, ROAD/BRIDGE NAME: NA

MHD BRIDGE NO. (IF APPLICABLE): NA

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	1. SURFACE TYPE	Earth embankment		X*	
	2. SURFACE CRACKING	No issues observed.	X		
	3. SINKHOLES, ANIMAL BURROWS	No issues observed.		X	
	4. VERTICAL ALIGNMENT (DEPRESSIONS)	Some rutting due to frequent vehicular use. Maintained as necessary.		X	
	5. HORIZONTAL ALIGNMENT	Good.	X		
	6. RUTS AND/OR PUDDLES	Some rutting due to frequent vehicular use. Maintained as necessary.		X	
	7. VEGETATION (PRESENCE/CONDITION)	Grass on crest edges. Bare in vehicle tire paths**			X
	8. ABUTMENT CONTACT	Good.	X		

ADDITIONAL COMMENTS: *The crest of the dam also serves as a primary access and haul road within the agricultural bog.

**Due to the frequency of vehicular traffic on the dam crest, it is unlikely healthy grass can be maintained in the bare areas.

**Fill ruts as needed to prevent significant ponding of water.

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (D/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S SLOPE	1. WET AREAS (NO FLOW)	No wet areas (NO FLOW) observed. Agricultural channels present along dam toe.		X*	
	2. SEEPAGE	No issues observed.	X		
	3. SLIDE, SLOUGH, SCARP	Minor vertical scarp observed at dam toe along the the agricultural channels.		X*	
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. SINKHOLE/ANIMAL BURROWS	No issues observed.		X	
	6. EROSION	No issues observed on d/s face of dam.	X		
	7. UNUSUAL MOVEMENT	No issues observed.	X		
	8. VEGETATION (PRESENCE/CONDITION)	Grass-covered. Well maintained.	X		

ADDITIONAL COMMENTS: *While the wet areas along the dam toe are intentional for agricultural purposes, the condition of the dam embankment should be monitored for erosion or undermining caused by the varying flows and tailwater elevations along the dam toe.

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

EMBANKMENT (U/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	No issues observed on observable surface.	X		
	2. SLOPE PROTECTION TYPE AND COND.	No slope protection observed.	X		
	3. SINKHOLE/ANIMAL BURROWS	No issues observed on observable surface.	X		
	4. EMB.-ABUTMENT CONTACT	Good.	X		
	5. EROSION	No issues observed on observable surface.	X		
	6. UNUSUAL MOVEMENT	No issues observed on observable surface.	X		
	7. VEGETATION (PRESENCE/CONDITION)	Satisfactory.		X	

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	None observed.	X		
	2. OBSERVATION WELLS	None observed.	X		
	3. STAFF GAGE AND RECORDER	None observed.	X		
	4. WEIRS	None observed.	X		
	5. INCLINOMETERS	None observed.	X		
	6. SURVEY MONUMENTS	None observed.	X		
	7. DRAINS	None observed.	X		
	8. FREQUENCY OF READINGS	None observed.	X		
	9. LOCATION OF READINGS	None observed.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S WALLS	1. WALL TYPE				
	2. WALL ALIGNMENT				
	3. WALL CONDITION				
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: max: avg:			
	5. SEEPAGE OR LEAKAGE				
	6. ABUTMENT CONTACT				
	7. EROSION/SINKHOLES BEHIND WALL				
	8. ANIMAL BURROWS				
	9. UNUSUAL MOVEMENT				
	10. WET AREAS AT TOE OF WALL				

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

UPSTREAM MASONRY WALLS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S WALLS	1. WALL TYPE				
	2. WALL ALIGNMENT				
	3. WALL CONDITION				
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: max: avg:			
	5. ABUTMENT CONTACT				
	6. EROSION/SINKHOLES BEHIND WALL				
	7. ANIMAL BURROWS				
	8. UNUSUAL MOVEMENT				

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

DOWNSTREAM AREA

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S AREA	1. ABUTMENT LEAKAGE	No issues observed on observable portions of embankment.	X		
	2. FOUNDATION SEEPAGE	Unobservable.	X		
	3. SLIDE, SLOUGH, SCARP	See Downstream Slope		X	
	4. WEIRS	NA	X		
	5. DRAINAGE SYSTEM	See Outlet Works	X		
	6. INSTRUMENTATION	None observed.	X		
	7. VEGETATION	Agricultural. Well maintained.	X		
	8. ACCESSIBILITY	Good.	X		
	9. DOWNSTREAM HAZARD DESCRIPTION	Primarily low-lying agricultural and forested wetland areas.			
	10. DATE OF LAST EAP UPDATE	No formal EAP developed for the dam. The water supply impounded by the dam is used for agricultural purposes as part of the grower's farm plan.			

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

MISCELLANEOUS

AREA INSPECTED	CONDITION	OBSERVATIONS		
MISC.	1. RESERVOIR DEPTH (AVG)	Unknown. Estimated 3 feet.		
	2. RESERVOIR SHORELINE	See Upstream Slope.		
	3. RESERVOIR SLOPES	Shallow.		
	4. ACCESS ROADS	Dam crest is used as access road and haul road for farm.		
	5. SECURITY DEVICES	None at dam. Private property.		
	6. VANDALISM OR TRESPASS	☐ YES	☑ NO	WHAT:
	7. AVAILABILITY OF PLANS	☐ YES	☑ NO	DATE:
	8. AVAILABILITY OF DESIGN CALCS	☐ YES	☑ NO	DATE:
	9. AVAILABILITY OF EAP/LAST UPDATE	☐ YES	☑ NO	DATE:
	10. AVAILABILITY OF O&M MANUAL	☐ YES	☑ NO	DATE:
	11. CARETAKER/OWNER AVAILABLE	☐ YES	☑ NO	DATE:
	12. CONFINED SPACE ENTRY REQUIRED	☐ YES	☑ NO	PURPOSE:

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

PRIMARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	Sharp-crested weir	X		
	WEIR TYPE	Flume board drop inlets to corrugated metal discharge pipes.	X		
	SPILLWAY CONDITION	Good.	X		
	TRAINING WALLS	Good.	X		
	SPILLWAY CONTROLS AND CONDITION	Flume boards in good condition.	X		
	UNUSUAL MOVEMENT	None observed.	X		
	APPROACH AREA	Shallow impoundment susceptible to aquatic vegetation growth, sediment, & debris		X	
	DISCHARGE AREA	Well-maintained agricultural farm.	X		
	DEBRIS	None observed.	X		
	WATER LEVEL AT TIME OF INSPECTION	Approximately 1.5 feet of freeboard.	X		

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

AUXILIARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE				
	WEIR TYPE				
	SPILLWAY CONDITION				
	TRAINING WALLS				
	SPILLWAY CONTROLS AND CONDITION				
	UNUSUAL MOVEMENT				
	APPROACH AREA				
	DISCHARGE AREA				
	DEBRIS				
	WATER LEVEL AT TIME OF INSPECTION				

NOT APPLICABLE

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

OUTLET WORKS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
OUTLET WORKS	TYPE				
	INTAKE STRUCTURE				
	TRASHRACK				
	PRIMARY CLOSURE				
	SECONDARY CLOSURE				
	CONDUIT				
	OUTLET STRUCTURE/HEADWALL	NOT APPLICABLE			
	EROSION ALONG TOE OF DAM				
	SEEPAGE/LEAKAGE				
	DEBRIS/BLOCKAGE				
	UNUSUAL MOVEMENT				
	DOWNSTREAM AREA				
	MISCELLANEOUS				

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
GENERAL	TYPE				
	AVAILABILITY OF PLANS				
	AVAILABILITY OF DESIGN CALCS				
	PIEZOMETERS				
	OBSERVATION WELLS				
	INCLINOMETERS				
	SEEPAGE GALLERY	NOT APPLICABLE			
	UNUSUAL MOVEMENT				

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	HORIZONTAL ALIGNMENT				
	VERTICAL ALIGNMENT				
		NOT APPLICABLE			

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (DOWNSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S FACE	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	ABUTMENT CONTACT				
	LEAKAGE	NOT APPLICABLE			

ADDITIONAL COMMENTS:

NAME OF DAM: Shaw Bog Reservoir Dam STATE ID #: MA00089

INSPECTION DATE: November 19, 2018 NID ID #: NA

CONCRETE/MASONRY DAMS (UPSTREAM FACE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S FACE	TYPE				
	SURFACE CONDITIONS				
	CONDITIONS OF JOINTS				
	UNUSUAL MOVEMENT				
	ABUTMENT CONTACTS	NOT APPLICABLE			

ADDITIONAL COMMENTS:

Appendix C

Cranberry Growers Survey and Results Summary

Carver Municipal Vulnerability Program Action Grant Cranberry Growers Survey

* 1. Name of Farm/Grower

* 2. Location in Carver (address)

* 3. How do you harvest cranberries?

- Wet pick
- Dry pick
- Both

4. How many water supplies do you use for cranberry growing?

Carver Municipal Vulnerability Program Action Grant Cranberry Growers Survey

Water Source #1

Please provide information for your first water source. You will be able to provide information for additional water sources on the following pages.

* 5. What is the primary water source you use for cranberry growing and name of water source (if named)?

- ◯ Swamp
- ◯ Pond
- ◯ Stream
- ◯ Reservoir

Please enter the name of the water source here.

* 6. Is your water supply also used by the town for potential emergency fire/safety purposes?

- ◯ Yes
- ◯ No

7. If you have a pond for water supply, what is the approximate depth (in feet)?

Water Source #2

* 8. What is the primary water source you use for cranberry growing and name of water source (if named)?

- ○ Swamp
- ○ Pond
- ○ Stream
- ○ Reservoir
- ○ I only have one water source.

Please enter the name of the water source here.

9. Is your water supply also used by the town for potential emergency fire/safety purposes?

- ○ Yes
- ○ No

10. If you have a pond for water supply, what is the approximate depth (in feet)?

Water Source #3

* 11. What is the primary water source you use for cranberry growing and name of water source (if named)?

- Swamp
- Pond
- Stream
- Reservoir
- I only have two water sources.

Please enter the name of the water source here.

12. Is your water supply also used by the town for potential emergency fire/safety purposes?

- Yes
- No

13. If you have a pond for water supply, what is the approximate depth (in feet)?

Water Source #4

* 14. What is the primary water source you use for cranberry growing and name of water source (if named)?

- ○ Swamp
- ○ Pond
- ○ Stream
- ○ Reservoir
- ○ I only have three water sources.

Please enter the name of the water source here.

15. Is your water supply also used by the town for potential emergency fire/safety purposes?

- ○ Yes
- ○ No

16. If you have a pond for water supply, what is the approximate depth (in feet)?

Water Source #5

* 17. What is the primary water source you use for cranberry growing and name of water source (if named)?

- ○ Swamp
- ○ Pond
- ○ Stream
- ○ Reservoir
- ○ I only have four water sources.

Please enter the name of the water source here.

18. Is your water supply also used by the town for potential emergency fire/safety purposes?

- ○ Yes
- ○ No

19. If you have a pond for water supply, what is the approximate depth (in feet)?

Water Source #6

* 20. What is the primary water source you use for cranberry growing and name of water source (if named)?

- ○ Swamp
- ○ Pond
- ○ Stream
- ○ Reservoir
- ○ I only have five water sources.

Please enter the name of the water source here.

21. Is your water supply also used by the town for potential emergency fire/safety purposes?

- ○ Yes
- ○ No

22. If you have a pond for water supply, what is the approximate depth (in feet)?

* 23. Do you have the ability to move water around the farm (e.g., canals, etc)

- Yes
- No

* 24. Please describe your ability to move water around the farm.

Carver Municipal Vulnerability Program Action Grant Cranberry Growers Survey

* 25. Was your growing operation affected by the 2016 drought?

- Yes
- No

* 26. What level of water decline was observed and how was your operation impacted by the drought?

* 27. Has your growing operation been affected by other droughts?

- Yes
- No

* 28. Please explain when your operation was impacted, what level of water decline was observed, and how your operation was impacted.

Carver Municipal Vulnerability Program Action Grant Cranberry Growers Survey

* 29. Have you had any issues with having enough water for harvesting or frost protection?

* 30. What is the size, in acres, of your bog(s)?

* 31. What is your estimate of the area (in acres) draining to your bog?

- None
- Less than 5 acres
- 5-20 acres
- Greater than 20 acres

* 32. Do you have the ability to share water resources with another farm, in the event of a drought or other water emergency?

- Yes
- No

* 33. Please explain how you were able to share water resources.

Carver Municipal Vulnerability Program Action Grant Cranberry Growers Survey

* 34. What type of water control structures exist on your farm, i.e. flumeboards, etc.?

* 35. Is there an automated irrigation system for the bog?

- Yes
- No

* 36. Is there a backup groundwater supply?

- Yes
- No

* 37. Is there area on the existing bog operation to add additional water supply or water storage?

- Yes
- No

* 38. Do you have the ability to dredge your existing water supply ponds?

- Yes
- No

* 39. Is the water source located within the property of the existing bog operation?

- Yes
- No

* 40. Please explain how the water source is located within the property of the existing bog operation.

* 41. Does the bog share water rights with another property?

- Yes
- No

* 42. If there is currently a water diversion to the bog, is there the opportunity to increase the diversion amount?

- Yes
- No

* 43. Is there water reuse – either on your farm or with another grower?

- Yes
- No

* 44. Please describe the water reuse, including whether it is on your farm or with another grower.

Carver Municipal Vulnerability Program Action Grant Cranberry Growers Survey

* 45. Would you like to be able to manage the water on your property differently?

- Yes
- No

* 46. Please explain how you would like to manage the water on your property.

47. Do you have any other information or concerns related to water management that you'd like to share?

Appendix D

Potential Resiliency Measures Recommendation Worksheet - Example

Cranberry Bog Water Source Resiliency Measure Recommendation Tool

Municipal Vulnerability Preparedness Planning (MVP) Process

Town of Carver, MA

Cranberry Bog Name: Hypothetical Bog		Potential Resiliency Measure															
Potential Resiliency Measure –>		**Dredge accumulated sediments from storage ponds**	**Remove debris from and dredge diversion channels to restore diversion capacity**	**Expand area of existing pond**	**Over excavate pond to a 12 foot overall depth to intercept anticipated drought condition groundwater levels**	**Excavate new storage pond**	**Drill new well**	**Repair earthen berm to reduce leakage and enhance stability and durability**	**Repair flume board structure to reduce leakage and enhance useful life**	**Raise water level with additional flume boards**	**Install pumps and piping systems**	**Restore original well capacity by redeveloping existing well(s) by surging, hydrofracturing, or defouling.**	**Repair leaking pumps and pipes**	**Develop back up provisions for dry harvesting**	**Recycle water for reuse**	**Seek shared water sources**	**Install diversions**
Applicability	**Response**	**Priority Level**															
Has pond lost substantial storage volume due to sediment accumulation?	(•) Yes ( ) No	Priority															
Has capacity of diversion channels diminished over time due to debris and or sediment accumulation?	(•) Yes ( ) No		Priority														
Is there room for existing pond to be expanded in surface area?	( ) Yes (•) No			Not Priority													
Is normal pond depth only 3 feet or did pond go nearly dry in 2016?	(•) Yes ( ) No				Priority												
Is there room to excavate a new storage pond into groundwater?	( ) Yes (•) No					Not Priority											
Are there locations for the drilling of a gravel packed well given proper setbacks from existing on site sanitary waste disposal systems or other wells or surface water sources that could be influenced by well drawdown?	( ) Yes (•) No						Not Priority										
Are earthen berms or dams in poor condition (such as leakage, erosion, covered in trees, etc.) or in need of maintenance?	(•) Yes ( ) No							Priority									
Are flume board structures in poor condition (such as leakage, erosion, corrosion, covered in trees, etc.) or in need of maintenance?	( ) Yes (•) No								Not Priority								
Can water level be raised without causing upstream flooding of infrastructure or bogs?	( ) Yes (•) No									Not Priority							
Are water sources with surplus storage located downstream?	( ) Yes (•) No										Not Priority						
Has capacity of existing well(s) diminished over time?	( ) Yes (•) No											Not Priority					
Are pipes or pumps leaking?	( ) Yes (•) No												Not Priority				
Are wet harvesting methods currently employed?	(•) Yes ( ) No													Priority			
Is water not currently recycled for reuse?	(•) Yes ( ) No														Priority		
Are there water sources with known surplus as evidenced by 2016 drought in reasonably close proximity?	( ) Yes (•) No															Not Priority	
Are water sources with surplus storage located upstream?	( ) Yes (•) No																Not Priority

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