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Hydrologic & Hydraulic Analyses McTaggart's Pond Dam Removal and Phillips Brook Restoration Project Fitchburg, MA

City of Fitchburg

Fitchburg, Massachusetts

May 7, 2025

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1 Introduction

McTaggart's Pond Dam (ID MA00878) is a Significant hazard, Intermediate sized, run-of-river dam located along Phillips Brook in the City of Fitchburg, Massachusetts. Phillips Brook is a tributary to the North Nashua River, which feeds into the Wachusett Reservoir, providing drinking water to the Boston area. McTaggart's Pond Dam was constructed in the 1930s for industrial purposes and was repaired in the 1950s. The pond purportedly has been used for recreational purposes. In recent years, the pond was not heavily used for this purpose, and the dam is in poor condition with several structural and hydraulic deficiencies. Tighe & Bond developed the McTaggart's Pond Dam Alternatives Analysis Report (Tighe & Bond, 2020) to assess alternatives for rehabilitation, partial removal, or full removal of the dam to maintain ecological resources and improve public safety. The City has elected to undertake the dam removal alternative and contracted Fuss & O'Neill, Inc. to complete design and permitting services to advance the project.

Fuss & O'Neill completed a review of the hydrologic and hydraulic modeling that was developed by Tighe & Bond and described in their 2020 report. Fuss & O'Neill prepared an updated hydraulic model for both pre- and post-dam removal conditions. Dam removal conditions were evaluated for the full range of present-day flood events (i.e., 2-, 5-, 10-, 25-, 50-, 100-, and 500-year events). The updated model was used to size the channel through the former impoundment, assess fish passage conditions, and evaluate project impacts on flood risk and nearby infrastructure. This report describes the model updates and analyses.

2 Hydrologic Analysis

Fuss & O'Neill reviewed a hydrologic analysis previously completed by Tighe & Bond using the U.S. Army Corps Hydrologic Engineering Center Hydraulic Modeling System (HEC-HMS), version 4.2.1 (Tighe & Bond, 2020). Peak flow rates were developed using SCS methodology as specified in TR-55 (United States Department of Agriculture). Tighe & Bond calibrated the HEC-HMS model by comparing the peak flow rates associated with the 2- through 500-year storm events predicted by their HEC-HMS model to peak flows estimated using USGS StreamStats (i.e., regional regression equations). The HEC-HMS model predicted peak flows that were substantially higher than StreamStats. The curve number and time of concentration parameters were adjusted incrementally to obtain peak values that more closely align with the upper 90% confidence interval results from StreamStats. The HEC-HMS modeling efforts and calibration are summarized in detail in the Alternatives Analysis Report (Tighe & Bond, 2020) provided in Appendix A. Fuss & O'Neill sought additional sources of information to determine if the calibrated flow values are reasonable. No peak flow gage data are available for Phillips Brook or other local tributaries to the North Nashua River. Flow data used in the local FEMA Flood Insurance Study were obtained and compared with the StreamStats and HEC-HMS results (Table 1).

Table 1. Peak Flow Comparison

Model	Discharge (cfs)			
	10-year	50-year	100-year	500-year
FEMA (1991)	1,610	2,680	3,220	4,550
HEC-HMS (calibrated)	2,436	4,657	5,727	9,400
StreamStats Upper 90%	2,260	4,050	5,010	7,520
StreamStats Peak Flow Statistics	1,092	1,830	2,190	3,180

The calibrated peak flows from the HEC-HMS model (Tighe and Bond, 2020) provide conservative results for flood modeling and stability calculations and were therefore used in the hydraulic model.

3 Hydraulic Analysis

3.1 Pre-Dam Removal Hydraulic Model (Existing Conditions)

Fuss & O'Neill reviewed a hydraulic analysis previously completed by Tighe & Bond. This hydraulic analysis used the U.S. Army Corps of Engineering Hydraulic Engineering Center River Analysis System (HEC-RAS), version 5.06 (Tighe & Bond, 2020). The channel geometry upstream of the dam was created by combining LiDAR from MassGIS survey of the dam and sediment probe information (Tighe & Bond, 2020).

Fuss & O'Neill has reviewed channel geometry and other input parameters and generated an updated one-dimensional, steady existing conditions model using HEC-RAS version 5.0.7. One-meter resolution LiDAR (2016 USGS CoNED topobathymetric digital elevation model) available from the NOAA Coastal Data viewer was imported to validate the HEC-RAS cross sections and cross reference with the original HEC-RAS cross sections locations[1]. The 2016 LiDAR generally matches the geometry used in the previous model, particularly in overbank areas. It should be noted that LiDAR data captures water surface elevations and therefore does not provide bathymetry. Bathymetry was obtained from a 2018 survey by Sherman & Frydryk, LLC and bathymetric mapping from Tighe & Bond (2020). Cross-sectional geometry was field verified by Fuss & O'Neill on July 15, 2021. Additional input parameters in the hydraulic model that were checked and verified in the field (where applicable) and how they were adopted and/or modified are described below.

- Channel roughness coefficients (i.e., Manning's n) generally remain unchanged between the original and updated HEC-RAS existing conditions model. A main channel roughness coefficient ranging from 0.035 to 0.04 was used.

- Overbank roughness coefficients generally remain unchanged between the original and updated existing conditions model. An overbank roughness coefficient of 0.1 was used.

- Bridge geometries for Westminster and Sanborn Streets were field verified by Fuss & O'Neill and were not changed.

[1] The original terrain file used by Tighe & Bond was no longer available.

- Expansion and contraction coefficients were not changed.

- General spillway geometry was compared with the topographic survey of the dam and field observations by Fuss & O'Neill. The spillway geometry was not changed.

The existing conditions model results represent the system prior to the dam being breached and drawn down in 2018. Table 2 summarizes predicted water surface elevations (WSEL) and velocities under existing, pre-dam removal conditions. HEC-RAS model results and a map of HEC-RAS cross sections are included in Appendix B.

Table 2. Existing Conditions Model Results

Cross Section	10-year		50-year		100-year	
	Velocity (fps)	WSEL	Velocity (fps)	WSEL	Velocity (fps)	WSEL
1583	10.99	619.54	13.48	621.61	14.35	622.47
Sanborn Bridge (US)	13.51	622.40	9.26	628.33	11.33	628.35
Sanborn Bridge (DS)	13.50	620.66	16.77	623.73	10.59	628.09
1636	4.70	625.69	5.33	629.32	6.12	629.93
1681	3.01	625.98	3.70	629.60	4.25	630.28
1737	4.01	633.22	3.72	637.07	4.23	637.61
1783	1.79	633.47	1.93	637.24	2.22	637.82
1927	1.72	633.51	1.82	637.26	2.09	637.86
2113	1.90	633.56	1.89	637.29	2.16	637.89
2376	3.43	633.70	2.60	637.32	2.90	637.93

Notes:

1. All water surface elevations (WSEL) reference the North American Datum of 1988 (NAVD88).
2. Velocity is average channel velocity in units of feet per second.

3.2 Post-Dam Removal Model (Proposed Conditions)

A post-removal stable channel geometry was estimated using three different approaches: HEC-RAS stable channel design functions, the reference reach approach, and regional hydraulic geometry curves.

Table 9–14	Laursen (Copeland 1994) transport function	
Parameter	**River data**	**Flume data**
Median particle size range (mm)	0.08–0.70	0.011–29
Multiple size classes	Yes	Yes
Velocity (ft/s)	0.068–7.8	0.70–9.4
Depth (ft)	0.67–54	0.03–3.6
Slope (ft/ft)	0.0000021–0.0018	0.00025–0.025
Width (ft)	63–3640	0.25–6.6
Water temperature (˚F)	32–93	46–83

Figure 1. Laursen Copeland Sediment Transport Parameters [from USDA (2007)]

The first approach utilizes the built-in functions of HEC-RAS (version 5.0.7). The Copeland Method provides an estimate of the stable channel width and depth for a given discharge and sediment transport regime. The Copeland Method is applicable for a median particle size between 0.08 and 0.7 mm (Figure 1). The fine sediment impounded behind McTaggart's Pond Dam has a median particle size of 0.2 mm, which is within the range of acceptable values for this method.

The method requires input of sediment size gradation. The sediment D84, D50, and D16 were determined from the sediment analysis performed by Tighe & Bond (2020). Two samples were obtained in the impoundment (S-3 and S-4) and the grain size distributions are provided in Appendix D of their report. Fuss & O'Neill used the average of samples S-3 and S-4 to produce a grain size distribution curve for impounded sediment (Figure 2). From this curve, values for D84, D50, and D16 were calculated as 1 mm, 0.2 mm, and 0.015 mm, respectively. The channel side slopes were set at 3H:1V and the Manning's n value of the side slopes was set at 0.1 (assuming banks are vegetated). The inflow sediment concentration was assumed to be 50 ppm, and the bankfull or channel-forming discharge was assumed to be the 2-year peak flow. The results of the analysis provided a width for the stable channel design at approximately 80 to 90 feet.

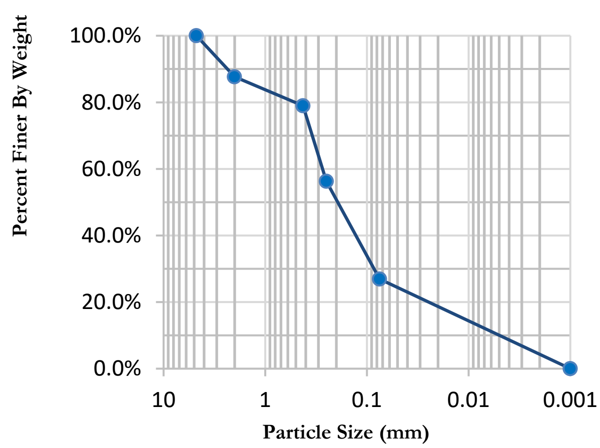

Figure 2. Sediment Grain Size Distribution

The second approach used to calculate the stable channel design was the reference reach approach. Channel measurements were taken by Fuss & O'Neill along the channel upstream of the impoundment to quantify the natural channel form of the system. The average bankfull width outside the hydraulic influence of the dam was estimated to be approximately 40 feet.

The third method involved the use of regional hydraulic geometry curves developed by the U.S. Geological Survey (USGS, 2013). An estimate of bankfull width was obtained from the following equation:

$$\text{Bankfull Width} = 15.0418*(\text{Drainage Area})^{0.4038}$$

McTaggart's Pond Dam has a drainage area of approximately 15.5 square miles, resulting in an estimated bankfull width of 45 feet with lower and upper 90% confidence intervals giving a range of between 30 and 60 feet.

These methods provided starting points for determining the design width and depth of the restored channel through the former impoundment. Fuss & O'Neill tested the capacity of a channel with bankfull widths of 45, 60, and 80 feet to contain the peak runoff rate during a 2-year storm event. The results of the analysis indicate that at a 60-foot bankfull width would have a suitable flow capacity.

As shown on the accompanying plan set, the channel will be excavated within the former impoundment and will extend approximately 500 feet upstream of the former dam location. Channel side slopes will vary depending on the location along the profile. The Dam Removal Plan Set is included in Appendix C.

3.3 Flood Risk Impacts

Post-dam removal conditions were simulated by removing the in-line structure representing McTaggart's Pond Dam from the model geometry and adjusting the upstream cross sections and channel bed elevations to reflect the channel design depicted on the plans. Table 3 provides a summary of predicted water surface elevations and velocities after the dam removal is complete.

The data in Tables 2 and 3 indicate that velocities and flood elevations downstream of the former dam will remain unchanged following dam removal. Upstream, removing the dam will substantially reduce the water surface elevations of Phillips Brook through the former pond (Figure 3). Predicted flow velocities within the newly excavated channel are higher than for the existing impounded conditions, which is expected when returning the system to free-flowing conditions. Bank stabilization and grade control measures are shown on the design plans to minimize the risk of headcutting and rapid lateral migration immediately following dam removal. Over time, the growth of vegetation will moderate channel evolution and erosional and depositional processes.

Table 3. Post Dam Removal Model Results

Cross Section	10-year		50-year		100-year	
	Velocity	WSEL	Velocity	WSEL	Velocity	WSEL
1583.47	10.99	619.54	13.48	621.61	14.35	622.47
Sanborn Bridge (US)	13.51	622.40	9.26	628.33	11.33	628.35
Sanborn Bridge (DS)	13.50	620.66	16.77	623.73	10.59	628.09
1636.923	4.70	625.69	5.33	629.32	6.12	629.93
1681.53	3.01	625.98	3.70	629.60	4.25	630.28
1737.38	5.47	625.85	5.70	629.51	6.43	630.18
1783.649	7.26	625.76	7.16	629.42	7.96	630.08
1927.178	10.17	626.19	9.37	629.46	10.03	630.16
2113.273	8.32	628.43	10.53	630.26	11.23	630.95
2376	10.01	630.31	10.97	632.65	11.69	633.23

Notes:
1. All water surface elevations (WSEL) reference the North American Datum of 1988 (NAVD88).
2. Velocity is average channel velocity in units of feet per second.

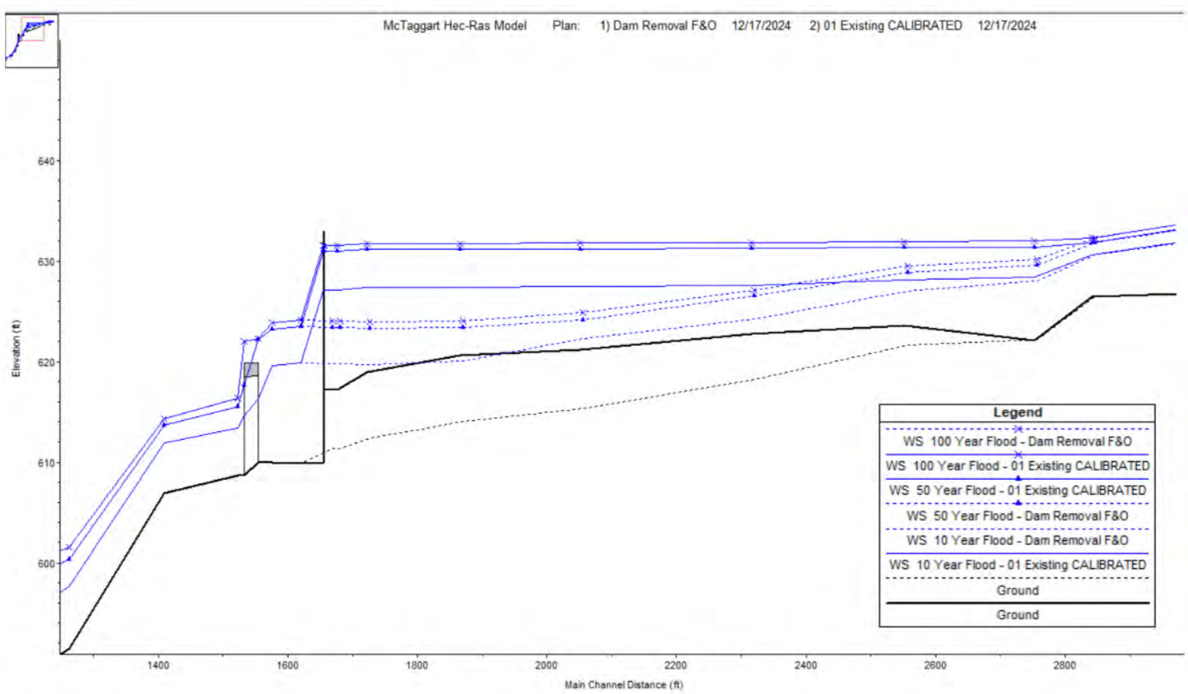

Figure 3. Modeled WSEL Reductions During the 10-year, 50-year, and 100-year

3.4 Fish Passage

To design for fish passage, the August 50% duration statistic flow rate of 2.57cfs was obtained from USGS StreamStats. The August 50% duration flow was modeled in the HEC-RAS model to determine appropriate low-flow channel dimensions. The results of the model indicate that a 1-foot deep, 3-foot wide channel is the optimal configuration to provide sufficient depth for cover under low-flow conditions. The channel invert was set to match the pre-dam channel bottom as determined from the sediment depth probe survey from the Alternatives Analysis Report (Tighe & Bond, 2020).

3.5 Grade Control and Stabilization

Two grade control rock riffles will be constructed. The first rock riffle will be at the downstream limit of grading. The second rock rifle will be constructed at the start of the stable channel (approximately 500 feet upstream of the dam). The rock rifles are intended to provide grade control, regulate sediment transport, and diversify flow regimes using natural materials. Each riffle is backed with a step pool structure that will dissipate energy and store water during low-flow periods to improve aquatic habitat. They are shown on the Dam Removal Plan Set.

Bioengineered bank stabilization measures are proposed to protect exposed vulnerable channel sediment along the left riverbank upstream of the dam. At this location, the high velocities and meandering river channel make the riverbank susceptible to erosion or scour. Live stakes and rootwads are proposed to stabilize the bank slope.

3.6 Infrastructure Impacts

A scour analysis was performed for the Sanborn Street bridge to determine if the design of the removal of McTaggart's dam will have adverse impacts on the bridge. A visual inspection was completed in the field by Fuss & O'Neill staff on July 15, 2021. The bridge appeared to be in fair condition. Rebar was exposed in some areas in the concrete barriers on the edge of the bridge deck. The pavement was cracked throughout the entire length. The bridge abutments and central pier are comprised of grouted stone. The central pier stands on a concrete block.

The channel materials in the vicinity of the bridge were observed to be a combination of bedrock, concrete, and grouted stone. No large-scale erosion or voids were observed at the time of the inspection. One small area on the concrete footing on the downstream side of the pier appears to have experienced some minor erosion. Water is channeled directly into the central pier on the downstream side of the left culvert (looking downstream) due to the location of the bedrock in the channel.

Existing and post-dam removal velocities were analyzed in HEC-RAS model. Velocity increases downstream of the dam following dam removal is not expected. The 10-, 50- and 100-year storms velocities for existing and proposed conditions are presented in Table 3. There is a negligible difference between existing and proposed velocities for all analyzed design storms (0.02 ft/s or less). Based on these results, it is not anticipated that there will be an increase in scour at the bridge due to the removal of McTaggart's dam.

4 References

Tighe & Bond. (2020). *McTaggart's Pond Dam Alternatives Analysis Report.* Tighe & Bond.

U.S. Department of Agriculture. (2007). *USDA NRCS national engineering handbook: Part 654, stream restoration design*. Natural Resources Conservation Service.

U.S. Geological Survey. (2013). *Equations for estimating bankfull channel geometry and discharge for streams in Massachusetts*. U.S. Department of the Interior.

Appendix A

McTaggart's Pond Dam Alternatives Analysis, Tighe & Bond, January 2020

McTaggarts Pond Dam
Fitchburg, MA

Alternatives Analysis

City of Fitchburg

January 2020

Tighe&Bond
Engineers | Environmental Specialists

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Executive Summary

The City of Fitchburg has retained Tighe & Bond to perform an alternatives analysis to evaluate approaches to address dam safety deficiencies of McTaggarts Pond Dam in Fitchburg, Massachusetts.

In April 2018, McTaggarts Pond Dam was determined to be in Unsafe condition as defined by current DCR rating guidelines. Under present conditions, the dam is a liability to the City of Fitchburg due to the current rapid changes in water level in the upstream pond, the increased risk of fall hazards at the dam site, and the danger to downstream residents in the event of a potential dam failure. For this reason, the "no action" approach towards addressing the dam's deficiencies is an unacceptable alternative.

The purpose of this alternatives analysis is to help weigh the costs and benefits of rehabilitating the dam to maintain the resources that it currently provides while improving public safety, removing the dam to favor ecological benefits, or partially removing the dam in an effort to maintain some of the public benefits the dam provides while reducing the City's compliance obligations.

Preparation of the report included the following tasks:

- Review of Existing Information
- Sediment Assessment and Management Recommendations
- Subsurface Investigation
- Stability Evaluations and Structural Conditions Assessment
- Updated Hydrologic and Hydraulic Study

Conceptual design descriptions, opinions of probable cost for design, permitting, and construction, and a discussion of benefits and drawbacks were developed for each alternative. The three alternatives analyzed in this report are summarized below.

- **Alternative 1 – Dam Rehabilitation** would consist of rehabilitating McTaggarts Pond Dam to address its dam safety deficiencies with a goal of bringing its condition to Good in accordance with Department of Conservation and Recreation's (DCR) current dam safety rating guidelines.

- **Alternative 2 – Dam Crest Height Reduction** would include a partial removal of the dam to yield a structure that would be considered non-jurisdictional by the Office of Dam Safety (ODS), but which would still impound some water. This alternative would involve demolishing the upper portion of the spillway and forming a concrete cap over the remainder of the spillway.

- **Alternative 3 – Dam Removal** includes of the removal of McTaggarts Pond Dam to restore the free-flowing state of Phillips Brook through the location of the dam. Tighe & Bond reviewed two options for removal, including a partial removal where a portion of the spillway is removed and the remainder of the dam is left in place, and a complete removal alternative where the majority of the dam was demolished.

The analysis demonstrates that both removal and rehabilitation would address the City's need to reduce public safety risks and comply with the DCR dam safety order. Reduction of the spillway crest elevation (Alternative 2) would be unlikely to meet the goals of the City or residents.

Although rehabilitation of the dam is feasible, costs would likely be significantly greater than removal, both in terms of construction cost and long-term maintenance cost. Rehabilitation of the dam also provides fewer benefits than removal since the hazard that would occur in the event of a dam failure would remain and since the dam would continue to serve as a barrier within the river system.

In contrast, either dam removal option reduces the City's liability at lower cost than rehabilitation while offering significantly greater ecological benefits. Complete removal is more costly than partial removal; however, while it may provide only marginally improved ecological benefit, complete removal would further improve the safety of the site and improve the site aesthetics.

Executive Summary

Section 1 Background

Section 2 Data Collection and Analysis

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Section 1
Background

1.1 Purpose

The City of Fitchburg has retained Tighe & Bond to perform an alternatives analysis for use in evaluating approaches to address dam safety of McTaggarts Pond Dam in Fitchburg, Massachusetts.

The purpose of this alternatives analysis is to help weigh the costs and benefits of rehabilitating the dam to maintain the resources that it currently provides while improving public safety, removing the dam to favor ecological benefits, or partially removing the dam in an effort to maintain some of the public benefits the dam provides while reducing the City's compliance obligations.

In April 2018, McTaggarts Pond Dam was determined to be in Unsafe condition as defined by current DCR rating guidelines. Under present conditions, the dam is a liability to the City of Fitchburg due to the current rapid changes in water level in the upstream pond, the increased risk of fall hazards at the dam site, and the danger to downstream residents in the event of a potential dam failure. For this reason, no action on addressing the dam's deficiencies is an unacceptable alternative.

1.2 Scope of Work

Tighe & Bond has carried out the following engineering tasks:

1. *Review of Existing Information*

Previous inspection reports and available data from MassGIS were reviewed as part of this study and used to inform the work presented in this report.

2. *Sediment Assessment and Management Recommendations*

An evaluation of sediment was performed in the impoundment, upstream reach, and downstream reach to evaluate sediment management alternatives in the event of dam removal.

3. *Subsurface Investigation*

A subsurface exploration program was conducted to evaluate the materials present in the dam embankment and foundation. The explorations provide important information relative to the construction of the embankments that can be used for future final design and will be useful in performing a seepage and stability analysis of the embankment.

4. *Stability Evaluations*

A seepage analysis using the computer modeling software SLIDE version 8.0 for western earth embankment was conducted based on information available and the conditions observed in the borings. This information is used to evaluate the extent to which the existing embankment could potentially be improved or whether complete replacement would be necessary in a dam rehabilitation scenario. A preliminary spillway evaluation was also conducted to determine if the spillway can be repaired without modification or if significant repairs or replacement is required. A preliminary spillway stability analysis for the spillway was also conducted.

5. Updated Hydrologic and Hydraulic Study

A Spillway Capacity Analysis and Hydraulic Alternatives Evaluation were performed concurrently with this limited Phase II report, with the results summarized in the McTaggarts Pond Dam Hydrologic & Hydraulic Analysis Report dated August 2019. The Spillway Capacity Analysis was prepared using the HEC-HMS computer model and the U.S. Army Corps of Engineers HEC-RAS riverine hydraulics computer model.

6. Alternatives Analysis

Based on the findings of inspections and the analyses discussed herein, alternatives for improvements were prepared for the dam and its appurtenances. Conceptual design descriptions were prepared for the alternatives. Opinions of probable cost for design, permitting, and construction were prepared for each alternative.

7. Final Report

Upon completion of the evaluations of the dam, we prepared this alternative evaluation report outlining and summarizing the results of the studies and investigations. Additionally, recommendations to address observed deficiencies are presented with opinions of probable costs.

The work began in September of 2018, around the time that the pond refilled from a drained state as a result of rainfall and the blockage of the penstock and low-level outlet intakes. Certain scope items, including survey in the area of the spillway and the hands-on structural evaluation, depended on low water levels, so the project

1.3 Definitions

To provide the reader with a better understanding of the report, definitions of commonly used terms associated with dams are provided in Appendix C. Many of these terms may be included in this report. The terms are presented under common categories associated with dams including: 1) orientation; 2) dam components; 3) size classification; 4) hazard classification; and 5) miscellaneous. Reference to left and right directions assume an orientation looking in the downstream direction.

1.4 Dam Description

1.4.1 Location

McTaggarts Pond Dam is located on Phillips Brook in Fitchburg, MA in Worcester County. The structure and impoundment are shown on the Fitchburg USGS quadrangle map at coordinates 42.57953188°, -71.8417107°. The dam is located along Sanborn Street approximately 75 feet west of the Sanborn Street bridge. Access to the dam and spillway is from Sanborn Street. See Figures 1 and 2 in the Figures section of this report for the USGS site locus map and the aerial photograph, respectively.

1.4.2 Owner/Caretaker

The dam is owned and operated by the City of Fitchburg. Current owner/caretaker data (contact information) is provided here:

Caretaker Name: Nicholas H. Bosonetto, PE
Dept. of Public Works Commissioner
Caretaker Address: 301 Broad Street
Caretaker Town: Fitchburg, MA 01420
Caretaker Phone: (978) 829-1912

Owner Address: 166 Boulder Drive, Suite 108
Owner Town: Fitchburg, MA 01420
Owner Phone: (978) 829-1801

1.4.3 Purpose of the Dam

McTaggarts Pond Dam currently impounds McTaggarts Pond for recreational purposes. Previous reports have indicated that the dam was historically used as an ice pond and to impound water for industrial purposes. According to the City of Fitchburg, recreational use in recent years has been very limited.

1.4.4 Description of the Dam and Appurtenances

McTaggarts Pond Dam is an approximately 430-foot long and 24-foot tall earthen embankment and concrete dam. The left side of the dam is an approximately 60-foot long earthen embankment surrounded with a concrete retaining wall that extends from the left of spillway to natural grade. The right side of the dam is an approximately 210-foot long earth embankment that extends from the right of spillway to residential properties. The dam was first built to impound McTaggarts Pond for industrial application, but currently used for recreational purposes.

A concrete gatehouse structure is located on the right of the primary spillway, containing a low-level outlet and penstock. Trash racks are present at the intake side of both structures, although the trash racks are deteriorated. A manual gate operator within the gatehouse was reportedly used to control the abandoned penstock that is 42-inches at the intake. The City removed an extension that reduced the penstock diameter to 12 inches, such that the penstock outlet diameter is also approximately 42 inches, and opened the operators to draw down the pond. The low-level outlet consists of a 2-foot by 2-foot stone box conduit, opening to 2.8 feet high by 2 feet wide, and is controlled by a wooden slide gate but can only be operated by an external mechanical equipment such as a backhoe. This outlet has also been opened in an effort to draw down the pond. A mud gate was present near the center of the spillway in drawings from 1956 with a note calling for it to be closed, although it is unclear whether the closure was to be permanent.

The primary spillway is an approximately 160-foot long concrete broad-crested weir with concrete training walls. The originally spillway was reportedly constructed of stone masonry but was later encapsulated in concrete forming the currently spillway geometry. Both the primary spillway and low-level outlet discharge into the downstream Phillips Brook. The impounded is currently drained for dam safety purposes.

1.4.5 Operations and Maintenance

The City of Fitchburg is responsible for the operation and maintenance of McTaggarts Pond Dam. A formal Operations and Maintenance Plan was reportedly drafted in 2010. Vegetation on the right embankment is cut back on a yearly basis. The penstock gate was reportedly left slightly open, and had repairs reportedly scheduled for July/August 2017. The low-level outlet of the dam was opened since the condition of the dam was declared Unsafe in April 2018. The outlet has remained open since that time.

1.4.6 DCR Size Classification

Previous inspection reports indicate that McTaggarts Pond Dam has a maximum structural height of approximately 22.3 feet and a maximum storage capacity of approximately 72 acre-feet. Therefore, in accordance with Department of Conservation and Recreation classification procedures, under Commonwealth of Massachusetts 302 CMR 10.00 Dam Safety, revised February 10, 2017, McTaggarts Pond Dam is an Intermediate size structure based on storage. Refer to Appendix D for definitions of height of dam and storage.

1.4.7 DCR Hazard Classification

McTaggarts Pond Dam is located upstream of residential properties on Sanborn Street, Westminster Hill Road, and Westminster Street. A failure of the dam at maximum pool may cause loss of life and damage to homes and roadways.

Therefore, in accordance with Department of Conservation and Recreation classification procedures, under the Commonwealth of Massachusetts Regulations 302 CMR 10.00 Dam Safety, as revised February 10, 2017, McTaggarts Pond Dam is currently classified as a Significant (Class II) hazard dam.

1.5 Engineering Data

Data presented in this report were taken from field survey and analysis developed via this study. Elevations are based on the North American Vertical Datum of 1988 (NAVD88).

1.5.1 Drainage Area

The total drainage area contributing to the watershed is approximately 15.4 square miles, based on a watershed delineated using USGS StreamStats. The drainage area is comprised mainly of forest, low to very-low density residential, cropland, and pasture lands. Figure 3, included in the Figures section of this report, outlines the drainage area boundary.

1.5.2 Impoundment

The impoundment has the following features:

Impoundment Level	Elevation (feet)	Estimated Surface Area (acres)	Estimated Storage Volume (acre-feet)
Normal Pool	633.2	6.3	19.6
Maximum Pool	638.8	8.9	61.3
100-year Pool	637.6	8.2	51.0

The dam’s penstock gate and low-level outlet were opened in the Spring of 2018 in response to dam safety deficiencies observed. The pond drained and remained in a drained state for the spring and summer of 2018. During that period, a low-flow channel cut through the sediments in the river bottom and the surrounding sediment stabilized significantly. Later, in the fall, increased inflows resulting from precipitation caused the pond level to rise again, and debris obstructed the low-level outlet, so the impoundment remained filled throughout the winter and into 2019. The moderation in velocity caused by the refilling of the pond when the outlet capacity is exceeded limits the evolution of the channel through the sediments.

The impoundment limits are identifiable in the field by a knickpoint which was observed in the upstream river channel where the river bottom transitioned from sediment to embedded stones.

1.5.3 Discharges at the Dam Site

No recorded discharges from the dam were available at the time of the inspection. However, the caretaker reported that the water surface level of the impoundment was generally consistent prior to the opening of the low-level outlet, varying little even after large storms. The 2012 Phase I Report lists discharges from three storms summarized below.

Storm Event	Rainfall, inches	Flood Elevation (NGVD29)	Flow over spillway, feet
March 1936	13	639.4 +/-	3.4 +/-
September 1938	11.5	638 +/-	2.0 +/-
August 1955	>4	639.5 +/-	3.5 +/-

Note that these elevations reference a different datum than the current study, and that the right embankment crest was lower and overtopped in 1955. The subsequent change in the geometry of the dam means that these elevations are not directly applicable to existing conditions.

1.5.4 General Elevations

Elevations presented are in units of feet and are based on a survey conducted by Sherman & Frydryk, LLC dated August 7, 2019. The datum used to develop the plan is the North American Vertical Datum of 1988 (NAVD88).

A.	Top of Dam	639.0
B.	Spillway Design Flood Pool	637.6
C.	Normal Pool	633.2
D.	Streambed at Toe of the Dam	618.0
E.	Low Point along Toe of the Dam	616.0

1.5.5 Primary Spillway

A.	Type	Uncontrolled concrete broad crested weir
B.	Length of Weir	160’
C.	Crest Elevation of Weir	633.2’
D.	Upstream Channel	McTaggarts Pond
E.	Downstream Channel	Phillips Brook
F.	Downstream Water Elevation	618.5’ ±

1.5.6 Penstocks

A.	Type	Penstock
B.	Size	42-inch at discharge
C.	Closure Type	Stoplogs and slide gate

D.	Inlet Invert Elevation	624.3'*
E.	Outlet Invert Elevation	624.3'

1.5.7 Low-Level Outlet

F.	Type	Stone box culvert
G.	Size	2'x2' box to 2.8'hx2'w box at outlet
H.	Closure Type	Slide gate
I.	Inlet Invert Elevation	622.8'*
J.	Outlet Invert Elevation	622.1'

**value was not measured as part of this study but estimated based on information provided in the 2012 Phase I Inspection Report*

1.6 Records

1.6.1 Design and Construction Records

A design drawing for McTaggarts Pond Dam was made available to Tighe & Bond by the City of Fitchburg. The drawing, titled "Reconstruction of McTaggart Dam" was prepared by Howard M. Turner Consulting Engineer of Boston, MA for Crocker Burbank & Co. and is dated March 1956. The drawing provides plan, section, and elevation views of the embankment, spillway, gatehouse, and low-level outlet. The drawing appears to show the dam in approximately its current configuration. The 2012 Phase I Inspection Report prepared by City of Fitchburg engineering staff provides additional information on the history of the dam.

1.6.2 Operating Records

No formal operating reports are available for McTaggarts Pond Dam.

1.6.3 Emergency Warning System

An Emergency Action Plan (EAP) was prepared in 2007 by GZA GeoEnvironmental, Inc., for McTaggarts Pond Dam. At that time, McTaggarts Pond Dam was registered as a High-hazard dam. The hazard classification was reduced to Significant in 2012 or 2013. In an effort to implement February 2017 changes to state dam safety regulations, preparation of EAPs for Significant hazard dams were ordered in December 2018 by the Office of Dam Safety.

Section 2 Data Collection and Analysis

2.1 Existing Conditions Assessment

McTaggarts Pond Dam receives regular inspections by City personnel and by the City's consultants. Tighe & Bond is in agreement with the results reported in these inspections. McTaggarts Pond Dam is generally considered in **Unsafe** condition as defined by current DCR rating guidelines. The Unsafe condition rating was made in April 2018 during a follow-up inspection when an area of uncontrolled seepage at the toe and a sinkhole on the crest were identified in approximate alignment with each other. The following deficiencies were reported in an April 28, 2017 Phase I Inspection/Evaluation Report and a July 27, 2018 Follow-Up Inspection Report, both prepared by Weston & Sampson.

1. The right embankment upstream slope is overgrown with brush. Riprap protection is missing or displaced. Slope cracking was observed, along with numerous animal burrows, voids, scarps, and erosion exposing embankment soils.
2. The dam crest elevation is approximately 21 inches lower in areas behind the right upstream concrete training walls.
3. The concrete training walls are eroded and undermined by the normal water line.
4. Wetness, uncontrolled seepage, and iron staining was observed along the toe of the right downstream wall and in the downstream area.
5. Concrete spalling, exposed aggregate, delamination, exposed rebar, efflorescence, and horizontal cracking and voids were observed on the right downstream wall and gatehouse structure. The gatehouse structure downstream headwall facing is separated approximately 16 inches at the top of the wall from the remaining wall (this facing has since fallen away).
6. Concrete spalling, exposed aggregate, and exposed rebar were observed at the primary spillway discharge walls and weir.
7. The trash rack at the penstock intake chamber is corroded and partially missing.
8. Pond debris and logs were observed on the weir and discharge area of the primary spillway.
9. There are trees growing on the left upstream slope near the left abutment.
10. Piping was observed in the seepage area approximately 25 feet to the right of the penstock. Flows were estimated as high was 60 gpm and transported fine to coarse sands as well as a couple crayfish through the area.
11. Flow at a rate of approximately 8 to 9 gpm was observed discharging from the existing discharge collection pipe reportedly connected to the wall foundation drain. The seepage was free of mineral sediment.
12. A sinkhole (approximately 33 inches diameter and 7 inches deep) was observed on the crest of the dam in the general vicinity of the downstream piping location during the April 13, 2018 Follow-Up Inspection. This condition worsened as observed during the July 27, 2018 Follow-Up Inspection to a sinkhole approximately 40 inches in diameter and 7 inches deep.

13. A wet area was observed to the right of the sandbag dike near existing boulders and tree stumps.
14. The right upstream concrete wall is deteriorated approximately 6 feet from the top of the wall to approximately 2 feet of the mudline. Several voids penetrate through the concrete wall and expose the original embankment material. Portions of the voids are non-structurally patched with bricks and concrete.
15. The impoundment floor has debris (tires, glass, corroded metal, car battery, metal bike frame, and large logs and branches) in front of the low-level outlet and penstock.
16. Voids exist at the downstream side of the primary spillway base with water seepage; voids were up to 10 inches in depth.
17. The left upstream concrete wall is deteriorated. An approximately 25 inches high and 7 inches deep section at the corner of the wall is eroded.
18. The primary spillway weir has several voids, extending laterally up to 21 inches and vertically up to 7 inches.

The structural evaluation presented in Section 2.4 provides more information regarding the dam's structural deficiencies. Photographs documenting conditions are presented in Appendix B.

2.2 Sediment Characterization

Appropriate sediment management is an important component of dam repair and removal since sediment that would normally migrate downstream during long periods tends to accumulate in the more slowly flowing water upstream from a dam, and since chemical contaminants tend to adsorb readily to small sediment particles. During a dam repair project, sediment may need to be relocated to allow access for construction equipment and personnel and to expose dam elements that have become buried. Following a dam removal project, a portion of the accumulated sediment will eventually re-mobilize if not otherwise addressed. In many cases this may be considered acceptable, but in some instances significant sediment movement can cause adverse impacts.

In an effort to understand the characteristics of sediment within McTaggart's Pond, Tighe & Bond has performed the following tasks:

- Environmental due-diligence review to identify current or past releases of hazardous substances or petroleum that have the potential to impact the on-site sediments that will be managed as part of this project.
- Developed a sediment sampling plan and subsequently collected samples for analysis.
- Compiled the results and compared to sediment management criteria.
- Developed management options.

The results of these analysis are provided in the attached Sediment Management Plan and are summarized in the following sections.

2.2.1 Due Diligence Review

Tighe & Bond commissioned the services of Environmental Data Resources, Inc. (EDR) of Shelton, Connecticut to search state and federal databases for records related to the site and vicinity. In addition, EDR was commissioned to provide available historical aerial photographs, historical topographic maps, city directories and Sanborn Fire Insurance maps (Sanborns) for the site. Tighe & Bond reviewed resulting records to identify current or past releases of oil or other hazardous materials (OHM) that have the potential to impact the sediments within McTaggarts Pond.

Tighe & Bond did not identify nearby sites or documented releases of OHM that have the potential to impact the sediment within McTaggarts Pond. However, historical woolen manufacturing that occurred immediately adjacent to the dam, on the east side, involved the use of heavy metals. In addition, our research indicates that coal and wood were used as fuel, and kerosene was used for lighting fuel, in the woolen mill that was previously located adjacent to the dam. Heavy metals and extractable petroleum hydrocarbons (EPH) with polycyclic aromatic hydrocarbons (PAHs) are analytical parameters that would detect potential metals, PAHs associated with ash or petroleum in sediment samples submitted for analysis.

2.2.2 Sediment Analytical Testing

Five sediment samples were collected from the project area for analysis to screen the impoundment for potential contaminants and to evaluate whether the sediment within the pond is more or less contaminated than sediment located upstream and downstream. The sediment sample locations are shown in Figure 4, and included:

- One sample from the stream upgradient of McTaggarts Pond,
- Two samples collected from within McTaggarts Pond, and;
- Two samples collected in depositional areas downstream of McTaggarts Pond dam.

The two samples from within the pond (samples S-3 and S-4) were composite sediment samples composed of three aliquots each, collected within a ten-foot radius. Each aliquot was be collected using a manual/hand-held stainless-steel bucket auger. The bucket auger and each bowl were decontaminated with water and biodegradable detergent before and after each sample/aliquot was collected. The location of each sample was collected in the field using GPS technology with sub-meter accuracy. The three aliquots were combined in one bowl and composited prior to being placed into laboratory-supplied containers. Samples analyzed for volatile organic compounds (VOCs) were collected directly from an individual aliquot, prior to being composited, to minimize volatilization. The samples were transported to TestAmerica Analytical Laboratory of Westfield, Massachusetts (TestAmerica) for analysis under proper chain of custody.

2.2.3 Sediment Characterization Results

Physical sample results indicate mostly gravel-sized particles upstream of the pond, consistent with a moving streambed and fine to sandy sized particles within the pond, with finer sediment located closer to the dam. Greater than 10% of the material in the two in-pond samples passed the number 200 sieve, which distinguishes fine particles from sand-sized particles. MassDEP is generally less concerned about the potential for sediment contamination if less than 10% of the material is finer than sand.

In general, the two sediment samples collected downgradient of the dam (S-1 and S-2) contained the highest concentrations of contaminants and samples collected from the impoundment (S-3 and S-4) and the upgradient sample (S-5) contained much lower concentrations. Within the table, the analytical results are compared to the following criteria:

- 401 Water Quality Criteria Reporting Limits - These are the necessary reporting limits the lab needs to meet; not standards.

- S-1 and S-2 Reportable Concentrations (RCs) from the Massachusetts Contingency Plan (MCP, 310 CMR 40.0000) – These standards are applicable to soil, not sediment. However, we've included them in the table as a common reference standard. Note that if the sediment were excavated/removed from the impoundment, the material would be considered soil and must then be managed as soil (some MCP standards would apply).

- Stage I Freshwater Sediment Screening Criteria for performing environmental risk characterizations under the MCP.

Concentrations of metals, volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), extractable petroleum hydrocarbons (EPH) and polycyclic aromatic hydrocarbons (PAHs) were detected in the downgradient (S-1 and S-2) samples. Elevated concentrations of metals and PAHs, above the reference values included in the table, were detected in the S-1 and S-2 samples.

In general, low to residual contaminant concentrations were detected in the two samples collected within the pond (S-3 and S-4) and the upgradient sample (S-5) with concentrations generally decreasing between S-3 and S-5. The PAH dibenzo(a,h)anthracene was the only analyte detected in S-3, S-4 and S-5 above reference values included in the table. In summary, we did not identify contaminant concentrations within the pond sediment that would indicate significant contamination or that the sediment requires special handling.

2.2.4 Sediment Volume Estimate

Separate from the sediment sample collection, a series of sediment probes were performed in McTaggart's Pond. The probes were performed to gauge thickness and calculate the estimated volume of sediment within the pond. The probes included six transects across the pond with the top and bottom of sediment elevations being measured at each probe location. Probe locations and results are shown in Figure 5. The average sediment thickness measurement in the pond was 2.9 feet. The estimated volume of sediment is estimated to be between 35,000 and 40,000 cubic yards.

2.3 Geotechnical Evaluation

Tighe & Bond performed a subsurface exploration program and seepage and stability analyses on a section of McTaggart's Pond Dam in Fitchburg, Massachusetts. A memorandum describing the work performed and the results obtained are presented in Appendix E. A summary of the work is described in the following sections.

Field Data Collection - Three geotechnical test borings (B-1 through B-3) were drilled by Seaboard Drilling, Inc. of Chicopee, Massachusetts on November 7 and 8, 2018. An additional boring (B-3A) was drilled by Seaboard Drilling, Inc. on March 18, 2019. The borings were drilled along a cross-section through the dam embankment near the maximum section, right of the spillway. Test borings were advanced to between 7.5 and 17.5 feet below the existing ground surface. Split-spoon sampling and Standard Penetration Tests (SPTs) were conducted continuously through the dam embankment and existing fill soils at the toe of the dam. Test borings were terminated upon casing refusal, except for boring B-1, which was terminated within the embankment fill at a depth of 15 feet. A 5-foot rock core was obtained in test boring B-3A. Groundwater monitoring wells were installed in test borings B-1 and B-2 upon completion of drilling. A borehole permeability test was attempted in boring B-2, but the embankment fill was too permeable to provide reliable results. Test borings B-3 and B-3A were grouted via tremie methods upon completion of drilling.

Laboratory Testing – Laboratory tests were performed to aid in soil classifications and estimation of strength and permeability properties. Three mechanical Particle Size Analysis tests (ASTM D6913) were performed on samples taken during the explorations. Laboratory test results are included in Appendix C.

Summary of Subsurface Conditions – In general, subsurface conditions observed in the explorations performed within the dam embankment consisted of approximately 6 inches of topsoil, overlying approximately 18 feet of existing embankment fill, overlying bedrock. Subsurface conditions observed in the explorations performed at the downstream toe of the dam generally consisted of approximately 6 inches of topsoil, overlying approximately 5 to 7 feet of existing fill, overlying gneissic bedrock. Organic material (fibrous peat) was observed to be intermixed near the bottom of the existing fill stratum.

Groundwater was encountered approximately 4.5 to 6.5 feet below the existing ground surface within the dam embankment, corresponding to elevations 631.5 to 633.5 feet. Groundwater was encountered approximately 2.5 feet below the existing ground surface at the downstream toe of the dam, corresponding to elevation 622.5 feet. Water levels can fluctuate with season, precipitation, and nearby construction or other below grade activities, such as excavation, dewatering, wells, infiltration basins, etc.

Seepage Analysis – A seepage analysis was performed near the maximum embankment section using the finite element groundwater capabilities of Slide 8.018 by Rocscience, Inc. The analysis was performed under two impoundment water surface conditions: normal storage pool elevation (635.3 feet) and maximum pool at the top dam elevation (638.9 feet). Soil permeability values were adjusted to generate a phreatic surface through the embankment that was in general agreement with the water surface observed in the groundwater monitoring wells.

Under the normal pool condition, the predicted phreatic surface generally flows horizontally through the dam embankment and drops steeply through the downstream retaining wall. This generally agrees with the groundwater measurements taken during the subsurface explorations. Under the maximum pool condition, the predicted phreatic surface is similar to the normal pool condition, although higher in the embankment due to the increased impoundment level.

Seepage cutoff appears to be adequate based on the results of the seepage analysis. However, areas of active seepage have been identified in past dam inspections, which may indicate specific defects that allow more seepage than is predicted. The above-referenced historical drawings indicate below-grade drainpipes penetrating through the downstream retaining wall, which may be a contributing factor. Additionally, bedrock fractures may provide preferential seepage paths. Therefore, it is recommended that a toe drain be installed to safely filter, collect, and discharge seepage flows.

Stability Analysis – A stability analysis was performed according to the requirements presented in Commonwealth of Massachusetts 302 CMR 10.00 Dam Safety, revised February 10, 2017. The guidelines provide minimum factors of safety for stability under specific loading conditions. The stability analyses were performed for the following conditions:

- Steady State – Assumes that the impoundment elevation (normal pool and maximum pool) remains constant for a sufficient period of time for seepage to reach equilibrium.

- Rapid Drawdown – Evaluates the stability of the dam if there is a rapid loss of water in the impoundment (normal pool and maximum pool) while leaving the upstream slope saturated. The rapid drawdown condition is a relative term that assumes that the impoundment will recede much quicker than the embankment soils can drain.

- Earthquake – Examines the stability of the dam during a seismic event. Maximum pool is not considered during this analysis as it is recognized that the probability of a flood and seismic event occurring at the same time is extremely low.

Slope stability software, Slide version 8.018, using the Spencer method, was used to analyze the conditions and determine the factor of safety against a global slope failure. The Spencer method is used to analyze slopes of varying geometries and is considered a rigorous method, as it satisfies both force and moment equilibrium. Results are presented in Appendix F.

2.4 Structural Evaluation

To consider rehabilitation, an important decision-making point is whether the spillway can be repaired without modification or whether significant repairs or replacement is required. A Tighe & Bond structural engineer visited the site to review existing conditions, performing a visual evaluation of the structure and spot hammer soundings of the surface concrete in visible and accessible areas. A preliminary stability analysis was also performed for the spillway using the available record drawing cross section combined with field observations.

2.4.1 Condition

In general, deterioration is present in many areas on the dam's various concrete structures. If the dam is to be retained, significant repairs to some structural elements and replacement of others are recommended as discussed below. Any original concrete that remains exposed should be coated to protect it from freeze/thaw deterioration, which will extend its life.

Crest and Upstream - The spillway crest and upstream face consists of a welded wire fabric (WWF)-reinforced shotcrete coating up to 6 feet wide (in the direction of flow) the full length of the spillway. The coating is worn, exposing the WWF, and with areas where the coating has debonded from the underlying concrete. Near the center of the spillway, a large area of the shotcrete overcoat is spalled, exposing an area (estimated to be approximately 20 square feet) of severely deteriorated underlying concrete. The mortar paste of the underlying concrete is falling apart, likely from freeze thaw. A deep repair would likely be needed in this area. At each end of the spillway crest near the training walls, spalling and very heavy wear was observed.

Visible lower portions of spillway, upstream of the section repaired with shotcrete, are in satisfactory condition, although wear and exposed coarse aggregate were observed. The remainder of the lower portions of the spillway were covered by sediment and debris at the time of the site visit and were thus not visible. No evaluation was performed

Recommendations:

- Remove shotcrete coating and install new cementitious overlay to previously shotcreted areas and extending down the downstream face.
- Repair large isolated spall and worn areas at each end of the spillway.
- Further investigate of the lower portions of the spillway may be warranted, to verify the scope/extents of repairs. Note that these areas are likely to be somewhat protected by debris and sediment.

Downstream – Weepholes are present along the downstream face of the spillway. Discharge was noted form one was weephole. The impoundment was drained at the time of the site visit, except within the eroded channel, so it is unknown whether the other weeps remain functional. Bedrock is clearly visible at base of the majority of the spillway, except in areas that are covered in riprap.

Severe deterioration was noted at area immediately below the shotcrete crest overlay for nearly the full extents of the spillway. The shotcrete overly has been performing as a drip edge, and water has scoured the original spillway concrete below.

At each end of the spillway there are deep areas of deterioration on the vertical face of the spillway that extend from the deteriorated areas noted above on the crest.

The vertical face is typically in satisfactory condition with heavy moss and algae growth, although wear exposing the coarse aggregate due to water flow was noted. The vertical face also has random shallow spalls and hollow-sounding areas.

There was water visible at the base of the spillway on the left end. It was unclear whether the water was seeping at bedrock joint or coming from left abutment/embankment.

Recommendations

- The deteriorated concrete below the spillway crest and the deep spalls on the ends of the downstream face should be chipped away and new concrete poured integrally with the new crest overlay.
- An overlay of the downstream face of the spillway can be considered, although water ingress into the spillway from the left abutment or spillway base could seep out through joints and cause an overlay to deteriorate over time.
- Considering the heavy deterioration at the end of the spillway, and the need to construct a new right training wall, casting of a new, complete section of the

spillway at the training wall interface would address the deterioration and limit abutment seepage ingress.

Left Embankment Walls – The walls appear to have been constructed during two separate periods, with an inner original section and later outer section. Some wear is present along the top of the upstream wall, and heavy wear is present along waterline. Along the spillway training wall, on the south side of the left abutment, heavy wear was observed along the normal pool water line and a large spall was present at the downstream end. Rebar was observed exposed within the wear area, and cracking and efflorescence was present above the wear area. Along the downstream wall, the outer layer of concrete is very poor condition with spalling, cracking and efflorescence. No railing present along the top of the walls.

Recommendations

- Demolish and repour outer section of the downstream wall.
- Repair the concrete of the upstream wall and training wall at the wear line and above.
- Add a suitable personnel guardrail along the top of the walls.

Structures at right side - The gate structure has areas of very heavy deterioration on upstream and downstream faces, and the trash rack is in failed condition. The right training wall and upstream face of the wall between the training wall and the outlet structure exhibits a heavy wear band along the normal water line and cracking with efflorescence above the wear band. The downstream wall adjacent to the training wall has a very large spall along vertical face adjacent to the spillway, along with cracking and spalling in other areas.

The downstream retaining wall to the south of the outlet structure has an isolated large spall with exposed rebar adjacent to the outlet structure and has random cracking w/ efflorescence throughout.

The upstream retaining wall south of the outlet structure has a large irregular spall partially infilled by bricks. Immediately above this area is some cracking and efflorescence, although the concrete appeared sound overall.

Recommendations

- The gate structure and segments of walls between the spillway and the gate structure should be demolished and rebuilt. Since industrial power is no longer the dam’s purpose, a simpler low-level outlet through the embankment could be more cost-effective than construction of an outlet structure.
- Although repair of the training wall and downstream wall could be considered, reconfiguration of the downstream wall into a corewall and replacement of the training wall may be more cost-effective. However, reuse of the existing corewall carries pricing risk. The masonry underlying the concrete wall has the potential to contain voids that would be costly to grout, and the contact of the wall with underlying materials is not well known.

2.4.2 Spillway Stability

Tighe & Bond completed a preliminary stability analysis of the spillway section at the McTaggart's Dam. The section properties of the spillway were developed from an existing drawing dated 1928. The spillway was analyzed as a gravity element for its stability in terms of sliding and overturning in only the normal pool condition. The factors of safety used for these conditions are based on recommendations from U.S. Army Corps of Engineers, USACE.

The section has sufficient resistance to overturning. The factor of safety for sliding was calculated at 1.80; a value of 2.0 for the normal pool condition is required per the USACE. In the analysis, we assumed that the ground surface below the dam is sloped downward in the downstream direction. This assumption is based on the ground profile presented in the available drawing. If the ground surface were assumed to be roughly flat, then the section would have a sufficient factor of safety for both sliding and overturning.

Overall, the spillway section as analyzed has a moderate deficit in its capacity to resist sliding in the normal pool condition. A complete analysis including the relevant load combinations for the design flood and seismic conditions should be completed if the spillway is to be rehabilitated. In Tighe & Bond's opinion, it is likely that the section will not have sufficient sliding stability under these conditions. Further testing to more precisely determine the dimensions of the spillway cross section and the slope of the grade at the base of the spillway would likely be recommended as part of a refined analysis, since refined information and assumptions could lead to improved demonstrated performance.

2.5 Hydrologic and Hydraulic Evaluation

2.5.1 Methods and Existing Conditions

Tighe & Bond completed a Hydrologic and Hydraulic (H&H) Evaluation for McTaggarts Pond Dam. A report is presented in Appendix D.

In summary, Tighe & Bond performed a hydrologic analysis to estimate inflows into the pond. No nearby stream gauge or measured spillway flow data were available for comparison at the time of the hydrologic model development. As such, the hydrologic analysis for McTaggarts Pond Dam was performed using HEC-HMS (v. 4.2.1), a tool developed by the United States Army Corps of Engineers (USACE) for rainfall-runoff modeling. The United States Department of Agriculture's (USDA) Technical Release 55 (TR 55) methods (e.g., the curve number methodology) were used within HEC-HMS to develop the storm flow hydrographs for the 2-, 5-, 10-, 25-, 50-, 100- and 500-year frequency storm events.

The 24-hour precipitation for the storm events were estimated using the National Oceanic and Atmospheric Administrations (NOAA) Atlas 14 Volume 10 data. A Northeast Regional Climate Center (NRCC) Type C rainfall distribution was used based on guidance from the NRCC. Table 2-1 provides the precipitation amounts used for the range of storms analyzed.

Table 2-1
24-hour Precipitation Values used in H&H Analysis

Storm Return Frequency	Precipitation Values (inches)
2-Year	3.08
5-Year	3.95
10-Year	4.67
25-Year	5.66
50-Year	6.42
100-Year	7.19
500-Year	9.70

USGS StreamStats-reported peak flows calculated with a regression analysis using the Zarriello, P.J., 2017 method was used to validate initial HEC-HMS modeled peak flows of the various frequency storms. Incremental adjustments to Tc and CN values were performed to better match the overall watershed response with the USGS regression analysis predicted peak flows. The adjusted values are still significantly higher than the regression analysis predictions but are more in-line with the regression equation upper confidence interval estimates.

The hydraulic analysis for this project was performed using HEC-RAS (v 5.0.6), a U.S. Army Corps of Engineers (USACE) riverine hydraulics computer model. Attenuated flows developed in HEC HMS were used in the HEC RAS steady flow module. The hydraulic model results suggest the existing spillway structure can provide a freeboard of 1.2 feet, during a 100-year storm, which is the McTaggarts Pond Dam Spillway Design Flood (SDF). Table 2-2 presents the results. Attachment C provides a summary of HEC-RAS results.

Generally accepted dam safety design practice dictates that at least 1 foot of freeboard be available during peak SDF storm conditions unless wave run-up is thought to be a concern, in which case a wave run-up analysis should be performed. In the case of McTaggarts Pond Dam, the impoundment is small and the potential for large wind-induced waves is low. Therefore, McTaggarts Pond Dam has adequate spillway capacity in its current configuration.

Table 2-2
Hydraulic Analysis Results for McTaggarts Pond Dam – Existing Conditions

Storm Return Frequency	Peak Water Surface Elevation of McTaggarts Pond (feet, NAVD88)	Available Freeboard (feet)*
25-Year	636.5	2.3
50-Year	637.1	1.7
100-Year	637.6	1.2
500-Year	639.1	-0.3

* The Top of dam is at 638.8 feet North American Vertical Datum of 1988 (NAVD88), a negative value represents overtopping of dam.

2.5.2 Hydraulic Alternatives

Two alternatives were evaluated for proposed changes for McTaggarts Pond Dam in an effort to reduce downstream risk and ecological benefits. A third hydraulic alternative for rehabilitating the dam was not needed since the spillway capacity is adequate.

Hydraulic Alternative 1 – Partial Dam Removal – This alternative consists of partial spillway removal by lowering the existing spillway elevation to meet the Massachusetts ODS 302 CMR, 10.06.2 Size and Hazard Potential Classification for a non-jurisdictional dam. The criterion a dam must satisfy to become a non-jurisdictional dam is having either a maximum storage of 15 acre-feet during a 100-year storm event or a maximum dam height of 6 feet. A non-jurisdictional status would mean lower downstream risk and lower compliance costs for the City.

This alternative assumes that the existing top of dam elevation and spillway width would the same as existing conditions, while the existing spillway elevation would need to be reduced from an average of 633.2 feet to a level determined by modelling to achieve the peak storage of 15 ace-feet or less during a 100-year storm. By trial and error, the updated spillway elevation was determined to be 627.2 feet, corresponding to a reduction in normal pool elevation of 5.6 feet. Table 2-3 shows the anticipated inflows, outflows, water surface elevations, storage, and anticipated storage for the partial dam removal scenario. The lowering of the spillway crest would not significantly change downstream flood discharge rates or elevations.

Table 2-3
Hydrologic and Hydraulic Model Results for McTaggarts Pond Dam – Alternative 1: Partial Dam Removal

Storm Return Frequency	Peak Inflow to Pond (cfs*)	Peak Discharge from Pond (cfs*)	Increase in Peak Discharge Compared to Existing Conditions	Peak Pond Storage (acre-feet)	Peak Water Elevation of Pond (feet, NAVD88)	Available Freeboard (feet)†
25-Year	3650.1	3650.1	5.9	4.1	630.1	8.9
50-Year	4657.2	4652.6	2.3	5.4	630.6	8.4
100-Year	5726.7	5724.7	6.4	13.5	632.3	6.8
500-Year	9399.6	9398	2.6	21.3	633.5	5.5

* cfs = cubic feet per second
†The Top of dam is at 638.8 feet North American Vertical Datum of 1988 (NAVD88), a negative value represents overtopping of dam.

Hydraulic Alternative 2 – Dam Removal - Alternative 2 involves removing the dam by constructing a breach starting at elevation 619 with a width of 70 feet, that extends up to the existing spillway elevation with a 1 unit horizontal to 1 unit vertical (1H:1V) side slopes.

Table 2-4 shows the hydraulic and hydrologic results for the dam removal assuming that the channel bottom through the dam breach erodes or is constructed to the elevation of refusal encountered during the sediment probing. It is unknown whether this refusal elevation relates to bedrock, stones and cobbles, or a firmer soil layer. As such, Table 2-5 shows results if the channel were graded through refusal to create a more consistent slope through the breach.

With either approach, there would be almost no attenuation in peak flows at the dam, although downstream flows would not significantly increase since there is little attenuation under existing conditions. This alternative would also result in 100-year speak storage volumes of less than 15-acre feet, which would result in non-jurisdictional hazard classification for McTaggarts Pond Dam. This alternative would remove the impoundment capacity of the dam allowing the Philips Brook to begin to revert back to natural riverine conditions.

Table 2-4
Hydrologic and Hydraulic Model Results for McTaggarts Pond Dam – Alternative 2: Dam Removal with Existing Sediment Conditions within McTaggarts Pond

Storm Return Frequency	Peak Inflow to Pond (cfs*)	Peak Discharge from Pond (cfs*)	Increase in Peak Discharge Compared to Existing Conditions	Peak Pond Storage (acre-feet)	Peak Water Elevation of Pond (feet, NAVD88)
25-Year	3650.1	3650.1	28.5	1.8	629.0
50-Year	4657.2	4656.3	6	3.7	630.0
100-Year	5726.7	5726.7	12.3	6.8	631.0
500-Year	9399.6	9399.6	5	21.6	633.5

Table 2-5
Hydrologic and Hydraulic Model Results for McTaggarts Pond Dam – Alternative 3: Dam Removal Assuming the Channel Sediment in McTaggarts Pond Extends to Refusal

Storm Return Frequency	Peak Inflow to Pond (cfs*)	Peak Discharge from Pond (cfs*)	Increase in Peak Discharge Compared to Existing Conditions	Peak Pond Storage (acre-feet)	Peak Water Elevation of Pond (feet, NAVD88)
25-Year	3650.1	3650.1	28.5	1.2	628.6
50-Year	4657.2	4656.3	6	2.1	629.3
100-Year	5726.7	5726.7	12.3	3.4	629.9
500-Year	9399.6	9399.6	5	11.1	631.9

2.6 Ecological Resource Information

Tighe & Bond performed a wetland resource area delineation in the area surrounding McTaggarts Pond Dam on November 18, 2018. The wetland delineation was conducted in conformance with state and Federal guidelines, including the Wetlands Protection Act (MAWPA, M.G.L. c. 131 sec. 40) and its implementing regulations (310 CMR 10.00); Delineating Bordering Vegetated Wetlands under the MA Wetlands Protection Act (1995), the 1987 Corps of Engineers Wetlands Delineation Manual; the Regional Supplement to the Corps of Engineers Wetlands Delineation Manual: Northcentral and Northeast Region (2012); and Field Indicators for Identifying Hydric Soils in New England (Version 4, 2017).

The following wetland resource areas identified within the subject parcels are subject to jurisdiction under the MAWPA (M.G.L. Chapter 131 § 40), and its implementing regulations (310 CMR 10.00):

- Inland Bank (associated with the Phillips Brook)
- Bordering Vegetated Wetlands (BVW)
- Land Under Water and Water Bodies (LUW)
- Bordering Land Subject to Flooding (BLSF)
- Riverfront Area, the riverward limit of which is Mean Annual High Water (MAHW)

Other resource areas present within the project area include:

- Ordinary High Water (Federal Clean Water Act jurisdiction) OHW, which was generally found to concur with MAHW

Jurisdictional wetland resource areas and Buffer Zones are shown on the Project Plans provided in Appendix F. Figure 6 in Appendix A presents resources located in the project area. Table 2-6 presents wetlands identified in the area of McTaggarts Pond.

Table 2-6
Wetland Resource Areas Identified in the Vicinity of McTaggarts Pond

Resource Area ID	Flag Numbers	Wetland Type*
1A	1A-1 → 1A-11 1A-12 → 1A-26	Inland Bank (south) / OHW of McTaggarts Pond Inland Bank (south)/ MAHW/ OHW Phillips Brook
1B	1B-14 → 1B-24 1B-1 → 1B-15	Inland Bank (north) / OHW of McTaggarts Pond Inland Bank (north)/ MAHW/ OHW Phillips Brook
1C	1C-1 → 1C-3	BVW
1D	1D-1 → 1D-7	BVW

Inland Bank / Mean Annual High Water / Ordinary High Water

As defined at 310 CMR 10.54(2a), inland Bank is the portion of the land surface which normal abuts and confines a water body. Inland Bank is present in association with McTaggarts Pond, an inland impoundment of Phillips Brook caused by the dam, and Phillips Brook. Within the limits of the delineation Bank of McTaggarts Pond is coincident with OHW and Bank of Phillips Brook is generally coincident with MAHW/OHW.

Inland Bank of McTaggarts Pond is characterized by a steep slope with boulders and vegetation including silky dogwood (*Conus amomum*), highbush blueberry (*Vaccinium corymbosum)*, Japanese barberry (*Berberis thunbrgii*), and multiflora rose (*Rosa multiflora*). The Banks also consist of concrete retaining walls of the dam between flags 1A-4 to 1A-13, and 1B-15 to 1B-16.

Inland Bank of Phillips Brook is characterized by stones, boulders, and bedrock in areas, and is vegetated with sugar maple (*Acer saccharum*), grey birch (*Betula populifolia*), maleberry (*Lyonia ligustrina*), silky dogwood, multiflora rose, steeple bush (*Spiraea tomentosa*), and goldenrods (*Solidago spp*).

Bordering Vegetated Wetlands

As defined at 310 CMR 10.55(2a), Bordering Vegetated Wetlands (BVW) are freshwater wetlands that border on creeks, rivers, streams, ponds and lakes. BVWs include wet meadows, marshes, swamps, and bogs. The soils of BVWs are saturated and/or inundated such that they support a predominance of wetland indicator plants.

Two (2) small areas of BVW were identified within the limits of the delineation. Wetland 1C is best characterized as a Palustrine Emergent Wetland (PEM) bordering the northern Bank of McTaggarts Pond. Vegetation within Wetland 1C consists of sweet woodreed (*Cinna arundinacea*), and goldenrods, maleberry, and silky dogwood. Standing water, oxidized rhizospheres, and saturation to the soil surface were observed within the Wetland 1C.

Downstream of the dam, an additional BVW (i.e. Wetland 1D) was observed within a ditch where a former penstock is located. The penstock has been disconnected so the primary hydrologic source associated with this wetland may no longer be present, although it does border Phillips Brook. Vegetation included sensitive fern (*Onoclea sensibilis*), multiflora rose, and silky dogwood. Oxidized rhizospheres were observed within the soil matrix and the hydric soil indicator, redox dark surface, was observed.

Land Under Water Bodies and Waterways

As defined at 310 CMR 10.56(2), Land Under Water Bodies and Waterways (LUW) is the land beneath any creek, river, stream, pond or lake. Said land may be composed of organic muck or peat, fine sediments, rocks or bedrock.

LUW within the site is confined to McTaggarts Pond and Phillips Brook. No significant aquatic vegetation was noted. The water surface level of McTaggarts Pond has varied significantly since the low-level outlet was opened, limiting the ability of the formation of aquatic vegetation in the pond. Rooted upland and wetland vegetation established in the pond over the preceding summer, although this vegetation was submerged at the time of the delineation. LUW of the McTaggarts Pond consists of sandy sediment with some gravel. LUW of Phillips Brook consists of sandy sediment, gravel, and bedrock.

The bankfull width of Phillips Brook upstream and downstream from the impoundment is approximately 34 feet. The width of the channel cut through sediments when the pond level is drawn down is limited by the capacity of the outlet structure; when flow increases, instead of the flow velocity increasing and carrying more sediment away to widen the channel, the limited outlet capacity causes the impoundment to refill, reducing velocity such that sediment that may otherwise be mobile remains in-place.

Bordering Land Subject to Flooding

As defined at 310 CMR 10.57(2), Bordering Land Subject to Flooding (BLSF) is an area with low, flat topography adjacent to and inundated by flood waters rising from creeks, rivers, streams, ponds or lakes. It extends from the banks of these waterways and water bodies; where a bordering vegetated wetland occurs, it extends from said wetland.

According to the FEMA Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRM), portions of the project area are situated within the limits of BLSF associated with the McTaggarts Pond and Phillips Brook. According to the FIRM (Community Number 250304, Maps 007B, effective May 16, 1983), the 100-year base flood elevation ranges from 637 to 638 feet (NGVD 1929) within McTaggarts Pond and from elevation 627 and 622 downstream from the dam to Sanborn Street. The H&H model prepared for the project provides a refinement of these results but is generally consistent. Floodplain within the vicinity of the Dam consists of wetland and upland areas.

Riverfront Area

Per 310 CMR 10.58(2), a Riverfront Area is the area of land between a river's mean annual high water line measured horizontally outward from the river (or perennial stream) and a parallel line located 200 feet away. The Riverfront Area does not have a buffer zone, but may overlap with other resource areas or their buffer zones.

Phillips Brook is considered perennial under the MAWPA. Riverfront Area of Phillips Brook extends 200 feet horizontally from the delineated MAHW which is coincident with OHW. Within the project area, Riverfront Area primarily includes upland areas with one vegetated wetland area (i.e. Series 1D). The upland areas include the forested riparian buffer along Phillips Brook adjacent to the brook and developed residential properties in the outer portions of the Riverfront Area.

Rare Species Information

Tighe & Bond reviewed the Massachusetts Natural Heritage and Endangered Species Program (NHESP) Atlas, dated August 2017, and MassGIS online mapping. According to these sources, no portion of the project site is within the limits of mapped Priority Habitat of Rare Species or Estimated Habitat of Rare Wildlife. In addition, no areas of Estimated or Priority Habitats were identified downstream of the dam along Phillips Brook until the North Branch Nashua River enters Lancaster, more than 8.5 miles downstream from the dam.

In addition, the NHESP online mapping related to Northern Long-Eared Bat was reviewed. The nearest winter hibernaculum is located approximately 12.5 miles from the site in Townsend and would thus not be a concern for a project at McTaggarts Pond Dam unless a hibernacula or maternal roost tree is found near the project site.

Cold Water Fishery Resources

Phillips Brook is listed as a Cold Water Fishery resource. Cold water fisheries (CWFs) are designated streams and rivers that provide habitat for fish that prefer colder water, including a number of rare and recreationally-important species. CWFs are designated by the Massachusetts Division of Fisheries and Wildlife (MassWildlife) based on species and sizes of fish found there and other biological data.

Section 3
Alternatives Evaluation

Tighe & Bond evaluated three alternatives for addressing dam safety deficiencies associated with McTaggarts Pond Dam. Two alternatives, dam rehabilitation and dam removal, were considered feasible and evaluated in detail, while a third, partial removal, was found to provide no benefit to the City and stakeholders, so it was evaluated in less detail. Each of the three alternatives was evaluated in terms of:

- Environmental and ecological benefit
- Aesthetics
- Recreational opportunities
- The relationship of the alternative to the historical context of the site
- Public safety considerations
- Permitting feasibility

Costs for the feasible alternatives were also developed. Drawings showing the two conceptual alternatives are presented in Appendix F.

3.1 Alternative 1 - Dam Rehabilitation

This alternative would consist of rehabilitating McTaggarts Pond Dam to address its dam safety deficiencies with a goal of bringing its condition to Good in accordance with DCR's current dam safety rating guidelines. Drawing 2 in Appendix G presents the conceptual drawing of Alternative 1. In general, the work would include:

- Clearing trees and brush on and within 20 feet of the dam, including grubbing stumps and rootballs.
- Left Abutment
  - Demolish and repair the outer layer of the downstream wall.
  - Repair deteriorated concrete at and above the waterline on the training wall and upstream wall.
  - Coat exposed walls for protection from freeze/thaw cycles.
  - Install a personnel guard along the top of the wall
- Spillway
  - Further investigate the lower portions of the spillway to verify the scope/extents of repair.
  - Investigate the elevation and slope of underlying bedrock to determine depth and slope and update the stability analysis using the information.
  - Remove shotcrete coating from spillway crest and install new cementitious overlay.

  - Repair large isolated spall and worn areas at each end of the spillway. Consider a complete replacement of a short segment at each end to limit water ingress from the abutments.
  - Further investigate of the lower portions of the upstream slope and face of the spillway to verify the scope/extents of repairs.
  - Chip away the concrete below the spillway crest and the deep spalls on the ends of the downstream face. Pour new concrete integrally with the new crest overlay. Complete section replacement at both ends would address the deep spalls on the downstream face.
  - An overlay of the downstream face of the spillway could be considered, although water ingress into the spillway from the left abutment or spillway base could seep out through joints and cause an overlay to deteriorate over time.
- Structures at Right Side
  - Investigate the contact of the right downstream embankment wall with underlying bedrock or soil. Obtaining a definitive determination in advance of construction may be difficult, however.
  - Demolish right training wall, outlet structure, upstream embankment wall, and associated appurtenances.
  - Construct a new right spillway training wall and low-level outlet structure. The outlet could consist of an upstream wall facing parallel to the spillway with a face-mounted slide gate and a trash rack. The conduit could consist of either ductile iron pipe or a cast-in-place concrete box discharging through the right downstream training wall.
  - If the downstream embankment wall has good contact with underlying bedrock, it could be reused as corewall within the embankment.
    - In this case, extend it from the demolished outlet structure to the replacement right training wall near the upstream edge of the spillway to provide seepage cut-off. Locate and grout weepholes through the wall.
    - If the downstream concrete wall is found to have poor or no contact with underlying bedrock, or if the masonry beneath the concrete is found to have voids, or if the City would prefer to reduce pricing risk, demolish the wall and construct a new embankment corewall.
- Right Embankment
  - Reconfigure the right embankment from an embankment with an upstream slope, crest, and downstream concrete wall to an embankment with slopes on the upstream and downstream side. This configuration would be more economical, more reliable, and easier to maintain than an embankment with a wall on the downstream side, and adequate land area is available for extending the embankment slope outward in the downstream direction.
  - If the downstream embankment wall is to be demolished and replaced, excavation of the majority of the embankment will be required to accommodate the work. This activity will give the opportunity to remove

unsuitable materials and replace them with suitable fill and will also address zones of loose soil and potential voids.

- o If the downstream embankment wall is to be retained, unsuitable fill materials and potential voids upstream of the wall would need to be addressed, either through excavation and replacement of the embankment or through implementation of a subsurface grouting program.
- o Install a toe drain near the downstream end of the replacement slope to collect and discharge seepage.

3.1.1 Environmental and Ecological Benefit

Rehabilitating the dam would allow restoration of the ecologic and hydrologic regime that existed prior to the drawdown of the pond, consisting of a segmented river system with a small impoundment providing habitat for fish and other organisms. The natural setting of the area, consisting of open water starkly transitioning to a high-canopy forest on the north side and to residential property on the south side, will also stay the same. Both of these characteristics are common in the region. Given that Phillips Brook is a cold water resource and the impoundment is relatively small, cold water fish are more likely to be present, but may avoid the impoundment due to heating.

3.1.1 Aesthetics

People are attracted to open water areas and, relative to the pond, rehabilitation of the dam will maintain the current aesthetic of open water and adjacent forest that is available to abutting residents and public visitors to the pond. The appearance of the dam itself when viewed from Sanborn Street would change significantly, from a crumbling concrete structure into a gentle grass slope with new concrete walls. A concrete formliner could be applied to the concrete walls as well to give the appearance of stone masonry or other materials. Aesthetics are subjective, so, although some people may find the appearance of industrial decay appealing, the openness, more uniform, and safe appearance of a properly-maintained dam is likely to be appealing to more residents.

3.1.2 Recreational Opportunities

McTaggarts Pond Dam provides limited recreational fishing use. Reportedly, the pond was once used for swimming, with a beach located on the northern shoreline for corporate employees of the dam owner. The City currently owns a park area with parking and a soccer field north of the impoundment, providing parking and access to the pond via a gravel access road. Residents along the pond also shoreline also benefit from the pond, and at least one resident has constructed stairs down to the shoreline. Rehabilitation of the dam would allow these continued uses of the pond to continue.

The pond does not appear to receive significant usage pressure, likely since the open space area is small and access to the pond is not convenient. Providing increased usage of the pond following dam rehabilitation would likely require significant investment. During a site visit with Tighe & Bond, a resident mentioned interest in reestablishment of a swimming area at the pond along the north shore, in the area once used for this purpose. Restoration of a swimming area could increase the value of the pond to residents, but the investment required would be significant in terms of facilities, personnel needs (e.g., lifeguards, management, etc.), and accessibility. Additionally, restoration of a swimming area at the pond creates a major liability for the City due to the inherent risks associated with the pond, including turbid water, uncontrolled water quality, a low contrast bottom surface, lack of adequate supervision, etc. The City has closed two swimming ponds in recent history for exactly these reasons.

3.1.3 Historical Context of the Site

In terms of historical context, the rehabilitation alternative proposed would result in a significant visual difference from existing conditions, since what is currently constructed of deteriorated concrete and overgrown vegetation on the right side of the dam would be remade with more easily maintainable vegetation and less concrete. However, the spillway would remain essentially the same, and the continued presence of the impoundment would maintain the familiarity of the location with residents.

To remake the dam in a way that was more visually consistent with the current site characteristics would be costly since the outlet structure portion of the dam needs to be completely replaced. There are less costly ways to accomplish that goal since much of the complexity associated with the old structure was to serve industrial uses that no longer exist. The absence of those uses from the site allow for the expansion of the dam since historical mapping obtained through the due-diligence review suggest that the dam’s downstream wall served a dual purpose as the building foundation.

It would be possible to memorialize the dam as it now exists by recovering the portion of downstream concrete wall with the date stamp and parts of the gate operators and creating a pocket park around them in the downstream area, perhaps with interpretive signage.

3.1.4 Public Safety Considerations

Dam rehabilitation will significantly improve public safety by addressing the immediate danger posed to downstream areas by a dam in Unsafe condition. In addition, proposed site improvements, including a slope instead of tall walls, and handrails will make the site safer for the public accessing the site. The dam will likely remain Significant in hazard classification following implementation of this alternative, so an Emergency Action Plan will be required.

In terms of the benefits of the dam itself, the H&H analysis has shown that the dam provides no flood protection for downstream areas. The flood flow attenuation resulting from the dam is less than 1% lower than the inflow for all storms analyzed. This finding is intuitive since the pond volume is small and the spillway is wide.

3.1.5 Permitting Feasibility

Permitting a dam rehabilitation project is complex but commonly performed and not insurmountable. The following permits are generally required for a dam rehabilitation project and would likely be required for McTaggarts Pond Dam as well given our understanding of what the project would entail.

Permit	Description of Applicability	Anticipated Review Time
401 Water Quality Certificate through the Massachusetts Department of Environmental Protection (MassDEP)	Required for projects with alteration of 5,000 square feet cumulatively of bordering or isolated vegetated wetlands and land under water, or proposed dredging greater than 100 cubic yards, or meeting any other thresholds listed in 314 CMR 9.04*.	8 to 13 months

Permit	Description of Applicability	Anticipated Review Time
Chapter 91 Waterways License	Required for structures located in non-tidal rivers and streams, except for portions not navigable during any season by any vessel, with construction, excavation, improvements, maintenance or removal of structures.	8 to 13 months
Environmental Notification Form (ENF) pursuant to the Massachusetts Environmental Policy Act (MEPA)	Required for state actions, including receiving a state permit (such as a 401 Water Quality Certification) or funds, that exceed given thresholds. MEPA review is usually, but not always, required for dam rehabilitation projects.	2 months, or longer if an EIR is found to be required
Chapter 253 Dam Safety Permit submitted to the Department of Conservation and Recreation (DCR) Office of Dam Safety (ODS)	Required before any significant repairs, reconstruction, breach or removal of a dam can be conducted.	2 to 4 months
Section 404 of the Clean Water Act Authorization General Permits Pre-Construction Notification to the U.S. Army Corps of Engineers	Required for projects in navigable and non-navigable water in the United States.	4 to 6 months
Project Notification Form (PNF)	Required to satisfy historical notification requirements of MEPA and MA GPs.	2 to 4 months
Wetlands Protection Act Notice of Intent (NOI) for Ecological Restoration Projects submitted to the Fitchburg Conservation Commissions	Required for projects in or near wetland resources. It is anticipated that the application will be for an Ecological Restoration Order of Conditions, providing an expedited permitting process when certain conditions are met.	1 to 3 months

It is important to note that, in recent years, the regulatory community has favored robust analysis and dialogue regarding the decision to rehabilitate a dam over the alternative of removing a dam. Dams are increasingly regarded as causing an overall negative impact on the landscape and ecosystems and the intent is to ensure that the costs of rehabilitation are considered in relation to the benefits of removal. This analysis should be useful in facilitating that review.

3.1.6 Maintenance

Once a dam is rehabilitated, the cost of maintenance is relatively low compared to the cost of making repairs, but those costs add up over time. Maintenance requirements generally consist of the following:

- Daily or weekly walk-overs by the owner looking for unusual or unexpected conditions.
- Monthly documented inspections by the owner to log current conditions.
- Twice annual (minimum) vegetation maintenance, including cutting grass and removing weed growth from riprap and concrete joints
- Removal of debris from the spillway.

- Updating the Emergency Action Plan, which is now required for Significant-hazard dams
- Testing the Emergency Action Plan, including performing training workshops and exercises.
- Inspecting the dam every five years as is required for a Significant-hazard dam.

The following table presents a general schedule of maintenance requirements.

Task	Frequency	By Who	Cost/Time per Instance
Owner Walk-Overs	Weekly	City	1 hour
Owner Inspections	Monthly	City	2 hours
Vegetation Management	Twice/year	City or contractor	8 hour / $1,000
Debris Removal	As-Needed	City	4 hours
EAP Updates (one plan is developed)	Annual	City or consultant	6-12 hours/$3,000
EAP Training Workshop	Workshops	City or consultant	2 hours per employee plus 8 hours for leader
EAP Tests	Tabletop – 3-4 year Functional – 5 year	Consultant	4 hours per employee, plus 20 to 40 hours per lead employee, plus $6,000 to $12,000 for consultant
Dam Safety Inspections	5 year	Consultant	$5,000
Total (annual basis)			36-46 hours / $6,200 - $7,400

Performing future maintenance and inspections would require improved access to the left abutment area, to which access is now limited to private property.

3.1.7 Opinion of Probable Cost

Tighe & Bond developed an Opinion of Probable Cost (OPC) for dam rehabilitation for the purpose of comparison with removal as an alternative. The OPC is an approximation based on limited investigations and our experience on other similar sized projects. Once further detailed investigations are performed, the scope of work may change, affecting the actual construction costs. The estimates include engineering, permits and contingencies where applicable.

Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing. The estimates of probable construction costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the Probable Construction Cost.

Item No.	Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
1	Erosion Controls	1	LS	$10,000	$10,000
2	Water Controls	1	LS	$200,000	$200,000
3	Temporary access	1	LS	$30,000	$30,000
4	Clearing and grubbing	0.21	AC	$40,000	$8,000
5	Site preparation	1,200	SY	$20	$24,000
6	Excavation	1500	CY	$30	$45,000
7	Demolition	1	LS	$80,000	$80,000
8	Right Walls (replacement, incl. core wall)	1	LS	$626,000	$626,000
9	Spillway Rehabilitation	1	LS	$433,000	$433,000
10	Left Wall Repairs	1	LS	$35,000	$35,000
11	Embankment Reconstruction	2,500	CY	$35	$88,000
12	Riprap Slope Protection (some reused)	270	TONS	$70	$19,000
13	Toe Drain	125	LF	$70	$9,000
14	Sluice Gate	1	EA	$30,000	$30,000
15	Trash Rack	1	EA	$20,000	$20,000
16	Outlet Conduit	1	LS	$10,000	$10,000
17	Outlet Concrete Cradle	13	13	$2,000	$26,000
18	Loam & Seed	1,500	SY	$9	$14,000
				Subtotal	$1,707,000
	Mobilization/Demobilization			5%	$86,000
	General Conditions			15%	$257,000
	Project Contingency			20%	$342,000
				Subtotal	$2,392,000
	Engineering			10%	$240,000
	Construction Engineering			12%	$288,000
	Material and Bidding Contingency			20%	$479,000
	Total				**$3,399,000**

3.2 Alternative 2 – Dam Crest Height Reduction

Alternative 2 would include a partial removal of the dam to yield a structure that would be considered non-jurisdictional by the Office of Dam Safety, but which would still impound some water. Non jurisdictional dams generally meet two criteria:

- They pose low hazard potential to downstream areas, meaning that minimal property damage and no loss of life would be expected if the dam were to fail.

- They impound water to a volume less than 15 acre-feet in volume, typically interpreted by Office of Dam Safety to apply during a 100-year storm, OR they are less than 6 feet in structural height.

Tighe & Bond focused on the second of these criteria when performing the H&H analysis included in Appendix D of this report, finding that a reduction in spillway elevation to 627.2 feet, a reduction in normal pool elevation of 5.6 feet, would increase the 100-year flood storage to less than 15 acre-feet. The spillway would remain approximately 8 to 9 feet high compared to a downstream elevation in the range of 618 to 619 feet. Decreasing the structural height to less than 6 feet would not be feasible.

This alternative would involve demolishing the upper portion of the spillway and forming a concrete cap over the remainder of the spillway. The repairs to the left abutment described in Alternative 1 would still be needed, as would much of the work to the right embankment and outlet structures, although the replacement embankment and structures could be rebuilt to a lower height (approximately 632.0’) which would result in significant cost savings.

While these findings may point to a feasible alternative, it is important to note that significant sediment is present within the impoundment, and the normal pool volume would be very small under existing conditions; the majority of the volume present during storm conditions would be the storm flows themselves. Dredging of the pond to increase its normal pool storage, and thus the usability of the pond, would increase the pond storage volume and thus require further decreasing the spillway crest elevation to meet the maximum storage volume criterion of 15 acre-feet.

Lastly, it is not currently clear whether the dam, reconstructed to these parameters, could be reduced in hazard classification to Low and thus qualify for non-jurisdictional status. This consideration is discussed in Public Safety, below.

Since it has severe limitations, an Opinion of Probable Cost and sketch have not been completed for this alternative, although its benefits and drawbacks are presented below. Collection of water level data in the pond in conjunction with precipitation data could result in better refinement of the flow results presented in the H&H study and be marginally more favorable to this alternative.

3.2.1 Environmental and Ecological Benefits

This alternative would provide few of the environmental and ecological benefits associated with either dam rehabilitation or removal. The river system would still be segmented with a dam, while any limited open water benefits provided by the pond would be lost since the remaining normal impoundment volume would be small.

3.2.2 Aesthetics

The City could have more aesthetic options with this alternative since the remaining components of the dam would not be so large. The height of the right embankment could be as low as seven feet above the ground level on the downstream side of the embankment (relating to a structural height of approximately 14 feet for the dam compared to the elevation of the channel below the spillway), may provide more options for aesthetics for the right embankment area, such as reusing the existing wall and keeping it visible (facilitated by excavating behind it and backfilling with more suitable soil, plus adding a drain with an appropriate filter), or transitioning to a slope, or moving toward a stone masonry wall. Otherwise, aesthetics of the rehabilitated dam would be similar to the dam rehabilitation alternative, while the aesthetics of the pond would be usual under normal conditions, consisting of a stream flowing into a small pond at a large dam.

3.2.3 Recreational Opportunities

This dam crest height reduction alternative would provide no recreational opportunity advantage compared to removal or rehabilitation. The impoundment would not be useful for swimming or small boats and fishing would be similar to the removal scenario, except that the river would remain segmented, isolating fish by limiting migration.

3.2.4 Historical Context of the Site

In terms of historical context, the spillway crest height reduction alternative proposed would result in a significant visual difference from existing conditions, since the remaining structure and impoundment would be quite a bit smaller. However, as with aesthetics, it may be possible to reuse more of the existing dam in a visible way since the wall heights will be reduced.

It would be possible to memorialize the dam as it now exists by recovering the portion of downstream concrete wall with the date stamp and parts of the gate operators and creating a pocket park around them in the downstream area, perhaps with interpretive signage.

3.2.5 Public Safety Considerations

There would be increased significantly improved public safety benefits under this alternative by addressing the immediate danger posed to downstream areas by a dam in Unsafe condition. In addition, proposed site improvements, including handrails on the tops of tall structures will make the site safer for the public accessing the site.

It is not yet determinate whether the dam would remain Significant-hazard or be reduced to Low-hazard and thus non-jurisdictional under this alternative, since Sanborn Street is located close to and downstream of the dam and the peak 100-year water surface elevation at the dam would be approximately 5 feet above the crest elevation of the road. A dam breach analysis would need to be performed to determine whether a dam breach could adversely affect the road under these conditions.

In terms of the benefits of the dam itself, the H&H analysis has shown that the dam provides no flood protection for downstream areas. The flood flow attenuation resulting from the dam is less than 1% lower than the inflow for all storms analyzed. This finding is intuitive since the pond volume is small and the spillway is wide.

3.2.6 Permitting Feasibility

Permitting this alternative would be similar to permitting the dam rehabilitation alternative in terms of the permits required. However, permitting complexity may be significantly increased since many of the benefits provided by the pond to the Public would significantly decrease or be lost without other gains in ecological benefit. These considerations would result in increased review complexity through MEPA. The following permits would likely be required for a rehabilitation that included a reduction in the crest elevation of the McTaggarts Pond Dam spillway.

Permit	Description of Applicability	Anticipated Review Time
401 Water Quality Certificate through the Massachusetts Department of Environmental Protection (MassDEP)	Required for projects with alteration of 5,000 square feet cumulatively of bordering or isolated vegetated wetlands and land under water, or proposed dredging greater than 100 cubic yards, or meeting any other thresholds listed in 314 CMR 9.04*.	8 to 13 months
Chapter 91 Waterways License	Required for structures located in non-tidal rivers and streams, except for portions not navigable during any season by any vessel, with construction, excavation, improvements, maintenance or removal of structures.	8 to 13 months
Expanded Environmental Notification Form (EENF) pursuant to the Massachusetts Environmental Policy Act (MEPA) and Environmental Impact Report (EIR) waiver Request	Dam spillway crest height reduction trips the mandatory EIR threshold for 'structural alternation of a dam that causes any decrease in impoundment capacity.' Since it is a partial removal and the impacts and benefits may not be well known, as they would be for a complete dam removal, receipt of an EIR waiver may not be likely.	6 to 8 months
Chapter 253 Dam Safety Permit submitted to the Department of Conservation and Recreation (DCR) Office of Dam Safety (ODS)	Required before any significant repairs, reconstruction, breach or removal of a dam can be conducted.	2 to 4 months
Section 404 of the Clean Water Act Authorization General Permits Pre-Construction Notification to the U.S. Army Corps of Engineers	Required for projects in navigable and non-navigable water in the United States.	4 to 6 months
Project Notification Form (PNF)	Required to satisfy historical notification requirements of MEPA and MA GPs.	2 to 4 months
Wetlands Protection Act Notice of Intent (NOI) for Ecological Restoration Projects submitted to the Fitchburg Conservation Commissions	Required for projects in or near wetland resources. It is anticipated that the application will be for an Ecological Restoration Order of Conditions, providing an expedited permitting process when certain conditions are met.	1 to 3 months

It is important to note that, in recent years, the regulatory community has favored robust analysis and dialogue regarding the decision to rehabilitate a dam over the alternative of removing a dam. Dams are increasingly regarded as causing an overall negative impact on the landscape and ecosystems and the intent is to ensure that the costs of rehabilitation are considered in relation to the benefits of removal. This analysis should be useful in facilitating that review

In addition, following construction completion it is anticipated that the City will need to file a Letter of Map Revision (LOMR) with FEMA to update the flood elevations in the area, since flood elevations through the impoundment will decrease as a result spillway elevation reduction.

3.2.7 Maintenance

Once a dam is rehabilitated, the cost of maintenance is relatively low compared to the cost of making repairs, but those costs add up over time. If the dam were non-jurisdictional, which would depend on a low-hazard rating, maintenance requirements would generally consist of the following:

- Daily or weekly walk-overs by the owner looking for unusual or unexpected conditions.
- Monthly documented inspections by the owner to log current conditions.
- Twice annual (minimum) vegetation maintenance, including cutting grass and removing weed growth from riprap and concrete joints
- Removal of debris from the spillway.

Occasional evaluation by a third party would also be beneficial.

The following table presents a general schedule of maintenance requirements.

Task	Frequency	By Who	Cost/Time per Instance
Owner Walk-Overs	Weekly	City	1 hour
Owner Inspections	Monthly	City	2 hours
Vegetation Management	Twice/year	City or contractor	8 hour / $1,000
Debris Removal	As-Needed	City	4 hours
Total (annual basis)			15 hours / $1,000

Performing future maintenance and inspections would require improved access to the left abutment area, to which access is now limited to private property.

3.2.8 Opinion of Probable Cost

No opinion of probable cost was developed since this alternative is believed to be infeasible.

3.3 Alternative 3

Alternative 3 consists of removal of McTaggarts Pond Dam to restore the free-flowing state of Phillips Brook through the location of the dam. Tighe & Bond reviewed two possibilities for dam removal – a partial removal and a fill removal.

The partial removal option would include demolition of the minimum portion of the spillway that would be needed to accommodate the bankfull flow of Phillips Brook. The estimated bankfull width of 34 feet could be accommodated through removal of a section of the spillway of approximately 70 feet in width, accommodating the flowing river and overbank areas on each side.

It would not be necessary to remove the dam embankment, outlet structure, or the entirety of the spillway (although the City may elect to remove these items for safety reasons since the high structures pose a fall hazard and would continue to deteriorate over time). These structures could be repaired or stabilized to serve as a historical reminder of the site. Repairs could involve removal of corroded and jagged metal, filling openings with low-strength concrete, placement of fencing or railings along the tops of the high structures, and removing loose concrete and grouting voids. Figure 3 in Appendix G shows a partial removal alternative.

The complete removal option, which would include significantly more of the spillway, the outlet structure, and right embankment and associated walls, would further reduce the City's risk and long-term costs by further reducing fall hazard potential. It would also provide opportunities for marginally improved ecological benefits. Some elements of the dam, such as the left abutment area that is located on private property and an abutting section of the spillway could still be retained if necessary. Figure 4 in Appendix G presents a figure showing more complete removal, while leaving the left abutment area in place.

Regardless of whether full or partial removal is selected, removal of the dam would require significant additional sediment management. While opening of the low-level outlet resulted in a channel being cut through the sediments, the sediment has likely cut no deeper than the elevation of the penstock and low-level outlets, the inlet elevations of which are approximately 624.3 feet and 622.8 feet, respectively. This is corroborated by the survey and sediment probing for the project, which found the pond bottom elevation in this area to be approximately 624 feet and sediment thickness remaining to range from approximately 1 to 3 feet.

Further upstream, the existing channel appears to have eroded to the pond's natural hard bottom, below the sediment, but the channel is still narrower than it would be in were Phillips Brook in its free-flowing condition given the hydraulic restriction provided by the outlet. The volume of sediment that would likely require management is estimated to be 9,100 cubic yards.

Since the sediment is believed to be generally uncontaminated, there are two primary feasible options for management of the sediment.

In-Stream Management. This alternative would involve removal of the dam and allowing Phillips Brook to cut through the remaining impoundment sediments, carrying it downstream. Initially, normal flows would provide sufficient tractive effort to move sediment downstream, where it would accumulate in deep areas. Storms would subsequently lead to additional migration and pushing sediment accumulated downstream along. The rate of sediment export from the former impoundment would decrease with time, and the downstream sediment would spread along the rivers length and eventually dissipate. Our review suggests that in-stream management would likely be feasible for McTaggarts Pond Dam since normal contraindications are not present:

- The downstream bridges and culverts on Phillips Brook are sufficiently open to accommodate sediment migration in this manner without clogging.

- The sediments within the pond have little contamination present, so release of the sediment would not increase sediment contamination downstream.

- Absence of mapped Estimated and Priority Habitat downstream suggest there are no state listed mussel beds downstream. Mussels can be smothered by migrating sediment

Deep pools, such as in the gorge downstream from Westminster Hill Road, would fill with sediment in the short term but will eventually clear. In-stream management is preferred when feasible since it results in development of natural river conditions and reduces the risk of loss of investment. Additional sediment data collection would be needed to verify the viability of this alternative.

Active Sediment Management. This alternative would consist of designing a river channel based on hydraulic analysis and site conditions and transporting of the excess sediment away using heavy machinery. In the case of McTaggarts Pond Dam, the sediment is relatively uncontaminated, so it could be relocated to the northerly side of the pond, placed, and seeded for stabilization. Were the sediment more contaminated than the sediment at the targeted placement location, such on-site stabilization would not likely be allowed and disposal at an off-site facility may be needed. This alternative involves higher cost and higher risk of a less successful river restoration but reduces the risk of unanticipated off-site impacts. In the case of active sediment management, care would need to be taken to stabilize the river channel around the sharp bend upstream of the dam. The river's energy would be directed at the northerly bank, upstream of the spillway, so this area may need to be heavily stabilized using a variety of generally-accepted stream restoration techniques, and the City and stakeholders would need to acknowledge that the potential for future evolution through in-stream processes would still be likely in this area.

It is important to note that there is an obstruction downstream of McTaggarts Pond Dam below the Sanborn Street bridge. Below the bridge is a concrete weir that itself serves as an obstruction to fish passage and segments the stream system. Removal of this weir, or construction of a rock ramp up to the weir from downstream, should be investigated for dam removal to have significant benefit. For the purposes of this evaluation, we assume that such an improvement would be included in the project scope since it would enhance the favorability of the work to receive future grants.

3.3.1 Environmental and Ecological Benefits

The removal of McTaggarts Pond Dam provides greater ecological benefit than the Alternatives 1 and 2 through restoration of the natural sediment dynamics of Phillips Brook and elimination of the additional heat source on the brook. Removal of the dam would also restore the riparian corridor to the Nashua River. Addressing the weir below Sanborn Street in conjunction with the dam removal would also restore natural river dynamics and potential for fish passage.

Upgradient areas will also benefit post removal as the area formerly occupied by pond will transition to floodplain meadow and eventually forest, providing a greater upland habitat diversity than currently exists.

3.3.2 Aesthetics

Although residents may prefer the open water look of a pond, the restored stream resulting from dam removal would also be attractive, and, with a large section of the spillway removed, the river will be more visible to more people from Sanborn Street.

In addition, the remnants of the outlet structure and embankment may be considered as an eyesore to some, so removal of these structures would improve the aesthetics of the site. Removal would also provide an excellent opportunity for construction of a low-impact passive recreational amenity. These aesthetic considerations would need to be considered in light of the historical context of this alternative.

3.3.3 Recreational opportunities

Removal of the spillway and restoration of the brook would not preclude fishing as cold-water fish will remain in the river. However, since they will be able to move more easily (provided the weir below Sanborn Street is addressed), they may be less likely to congregate in one location and fishing may not be perceived as being as good.

Removal of the embankment could provide improved recreational opportunity since removal of the current unsafe structure would allow for creation of a new open space amenity in its place.

3.3.4 Historical Context of the Site

Complete removal of the dam would be the ultimate expression of restoration of the site to its historical context, since the dam is a relatively new structure in relation to the history of the area. However, removal of the dam would represent a significant change compared to the site's history in recent memory, during which many residents recollect the presence of the impoundment and some may remember its more active recreational use.

Keeping elements of the dam, including the outlet structure and a portion of the spillway, would serve as a reminder of the site's previous uses. However, doing so would need to be considered in conjunction with the hazards posed by the structure's remnants, in terms of the potential for fall hazards and continued deterioration and destabilization of the structure. Keeping parts of the structure would be best facilitated by repairing elements to remain and providing handrails along the top of potential drops for safety reasons. Such repairs and improvements, which would significantly increase the cost of dam removal.

3.3.5 Public Safety Considerations

Public safety treats resulting from the dam will be eliminated through dam removal, since the risk of dam failure is eliminated. If elements of the dam remain, site hazards should be mitigated through performing repairs and adding safety improvements. In terms of downstream hazards, dam removal provides no appreciable flood flow attenuation, so downstream flood risk would not increase as a result of dam removal.

3.3.6 Permitting Feasibility

Dam removal permitting is generally no less complex than dam repair, but the regulatory generally prefers dam removal to repair since the ecological benefits are significantly greater.

Permit	Description of Applicability	Anticipated Review Time
401 Water Quality Certificate through the Massachusetts Department of Environmental Protection (MassDEP)	Required for projects with alteration of 5,000 square feet cumulatively of bordering or isolated vegetated wetlands and land under water, or proposed dredging greater than 100 cubic yards, or meeting any other thresholds listed in 314 CMR 9.04*.	8 to 13 months
Chapter 91 Waterways Permit	Required for projects located in non-tidal rivers and streams, except for portions not navigable during any season by any vessel, with construction, excavation, improvements,	Concurrent with 401 Application

Permit	Description of Applicability	Anticipated Review Time
	maintenance or removal of structures.	
Expanded Environmental Notification Form (EENF) pursuant to the Massachusetts Environmental Policy Act (MEPA) and Environmental Impact Report (EIR) waiver Request	Dam removal trips the mandatory EIR threshold for 'structural alternation of a dam that causes any decrease in impoundment capacity.' Past dam removal projects in the state have received a waiver from the mandatory EIR requirement through preparation of an Expanded ENF (EENF). It is assumed that the project would require only submission of an EENF and an EIR waiver request.	6 to 8 months
Chapter 253 Dam Safety Permit submitted to the Department of Conservation and Recreation (DCR) Office of Dam Safety (ODS)	Required before any significant repairs, reconstruction, breach or removal of a dam can be conducted.	2 to 4 months
Pre-Construction Notification to the U.S. Army Corps of Engineers (USACE) under the Massachusetts General Permits (MA GP) for authorization as a restoration project (Section 404 of the Clean Water Act Authorization)	Required for projects in navigable and non-navigable water in the United States. It is anticipated that that the project will qualify for the Pre-Construction Notification Category of General Permit 23, Habitat Restoration, Establishment, and Enhancement Activities.	4 to 6 months
Project Notification Form (PNF)	Required to satisfy historical notification requirements of MEPA and MA GPs.	2 to 4 months
Wetlands Protection Act Notice of Intent (NOI) for Ecological Restoration Projects submitted to the Conservation Commission	Required for projects in or near wetland resources. It is anticipated that the application will be for an Ecological Restoration Order of Conditions, providing an expedited permitting process when certain conditions are met.	1 to 3 months

In addition, following construction, it is anticipated that the City will need to file a Letter of Map Revision (LOMR) with FEMA to update the FIRMs since flood elevations will be reduced in the impoundment following removal of the dam.

3.3.7 Maintenance

If the dam is completely removed, no future maintenance would be required unless an open space amenity were to be added to the site. Partial removal, including leaving the right embankment in-place, would require mowing and maintenance to keep the site in good repair. The annual maintenance cost would be nominal until such time that additional repairs would be needed.

3.3.8 Opinion of Probable Cost

Tighe & Bond developed an Opinion of Probable Cost (OPC) for dam removal for the purpose of comparison with rehabilitation as an alternative. The OPC is an approximation based on limited investigations and our experience on other similar sized projects. Once further detailed investigations are performed, the scope of work may change, affecting the actual construction costs. The estimates include engineering, permits and contingencies where applicable.

The OPC is broken down into:

- The partial dam removal option, in which a portion of the spillway would be removed but the remainder of the dam would stay in place. This alternative would leave walls and remnant structures that would require safety improvements and either require occasional future maintenance or would continue to deteriorate.

- An additional incremental OPC for complete dam removal, in which the remainder of the embankment and the abutment areas would be removed, leaving minimal trace of the dam. The cost of safety improvements required for a basic dam removal project are subtracted from this total.

- An additional incremental OPC for active sediment management in the event that it is required.

Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing. The estimates of probable construction costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the Probable Construction Cost.

Item No.	Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
Basic Removal					
1	Erosion Controls	1	LS	$10,000	$10,000
2	Water Controls	1	LS	$50,000	$50,000
3	Spillway Demolition	750	CY	$500	$375,000
4	Concrete Repairs	1	LS	$100,000	$100,000
5	Safety Rails	309	LF	$85	$26,000
6	Outlet structure stabilization	45	CY	$2,000	$90,000
7	Loam & Seed	1200	SY	$9	$11,000
				Subtotal	$662,000
	Mobilization/Demobilization			5%	$34,000
	General Conditions			15%	$100,000
	Project Contingency			20%	$133,000
				Subtotal	$929,000
	Engineering and Permitting				$160,000
	Construction Engineering			12%	$112,000
	Material and Bidding Contingency			20%	$186,000
Basic Removal Total					**$1,387,000**
Additional Cost of Complete Removal					
1	Clearing	0.21	AC	$40,000	$8,000
2	Demolition - Right Side	1	EA	$80,000	$80,000
3	Excavation and removal - Right Side	1500	CY	$35	$53,000
4	Demolition - Left Side	1	EA	$20,000	$20,000

Item No.	Item	Quantity	Unit	Unit Cost	Opinion of Probable Cost
5	Excavation and removal - Left Side	120	CY	$35	$4,000
6	Demolish remainder of spillway	750	CY	$500	$375,000
7	Credit - repair no longer needed	1	LS	-$216,000	-$216,000
8	Loam & Seed	300	SY	$9	$3,000
				Subtotal	$327,000
	Mobilization/Demobilization			5%	$17,000
	General Conditions			15%	$50,000
	Project Contingency			20%	$66,000
				Subtotal	$460,000
	Additional Engineering and Permitting				$0
	Construction Engineering - Additional			12%	$56,000
	Material and Bidding Contingency			20%	$92,000
Additional Cost of Complete Removal					**$608,000**
Complete Removal Total					**$1,995,000**

Active Sediment Management					
1	Excavate, shift, and stabilize sediment	9100	CY	$40	$364,000
2	Channel Stabilization	1	LS	$100,000	$100,000
				Subtotal	$464,000
	Mobilization/Demobilization			5%	$24,000
	General Conditions			15%	$70,000
	Project Contingency			20%	$93,000
				Subtotal	$651,000
	Additional Engineering and Permitting				$0
	Construction Engineering - Additional			12%	$79,000
	Material and Bidding Contingency			20%	$131,000
Active Sediment Management Total					**$861,000**
Complete Removal plus Active Management					**$2,856,000**

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Section 4
Conclusions

As presented in Section 1, No Action is not a viable alternative due to public safety risks imposed by the dam. Both removal and rehabilitation would address the City's need to reduce public safety risks and comply with the DCR dam safety order. Reduction of the spillway crest elevation would be unlikely to meet the goals of the City or residents.

Although rehabilitation of the dam is feasible, costs would likely be significantly greater than removal, both in terms of construction cost and long-term maintenance cost. Rehabilitation of the dam also provides fewer benefits than removal since the hazard that would occur in the event of a dam failure would remain and since the dam would continue to serve as a barrier within the river system.

In contrast, either dam removal option reduces the City's liability at lower cost than rehabilitation while offering significantly greater ecological benefits. Complete removal is more costly than partial removal; however, while it may provide only marginally improved ecological benefit, complete removal would further improve the safety of the site and improve the site aesthetics.

APPENDIX A
Report Figures

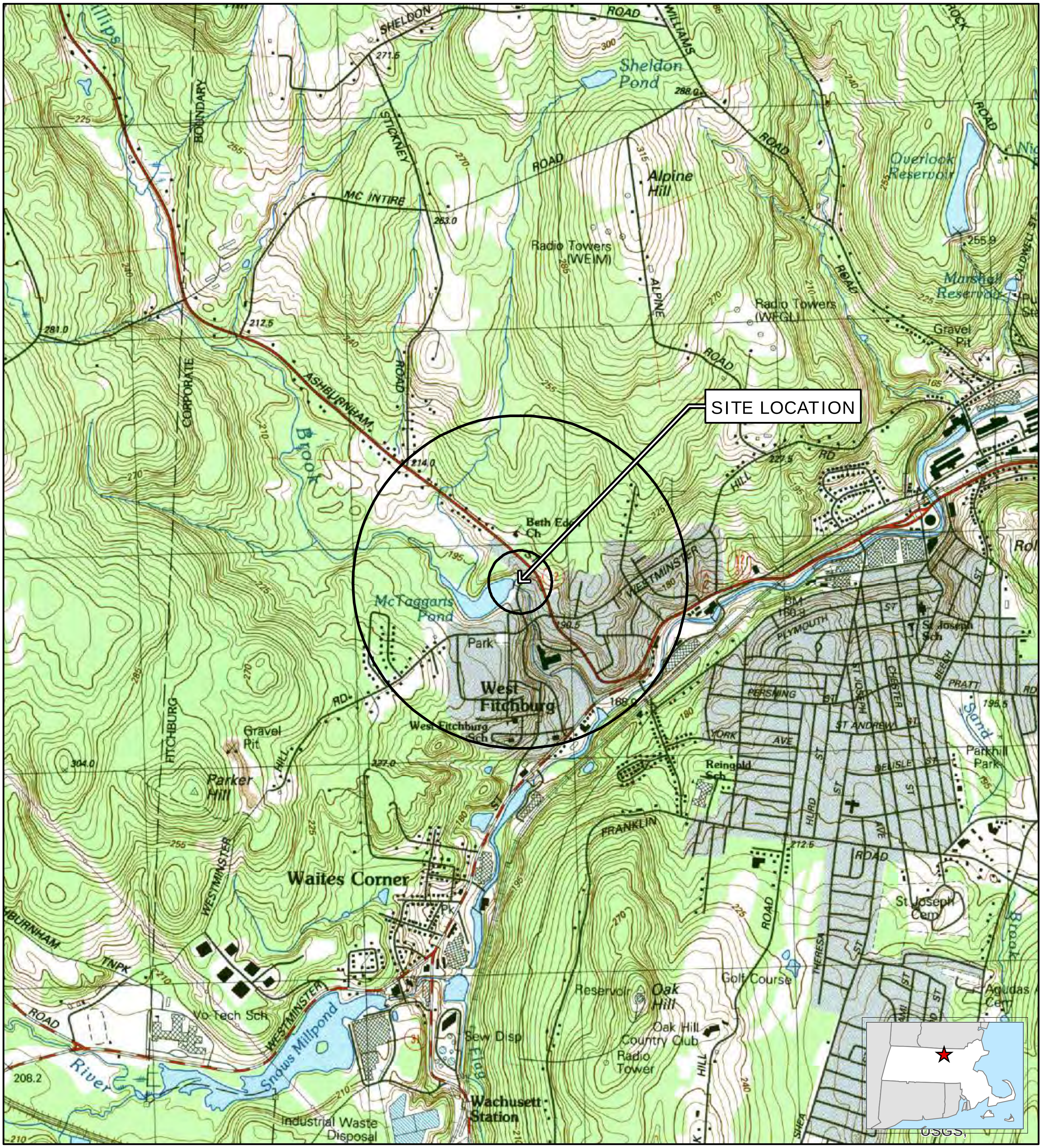

FIGURE 1
SITE LOCATION

MA00879

McTaggart's Pond Dam

Fitchburg, Massachusetts

October 2019

Tighe&Bond
Engineers | Environmental Specialists

Based on USGS Topographic Map for Fitchburg, MA Revised 1988.
Contour Interval Equals 3 meters.
Circles indicate 500-foot and half-mile radii

1:24,000

0 1,000 2,000

Feet

N

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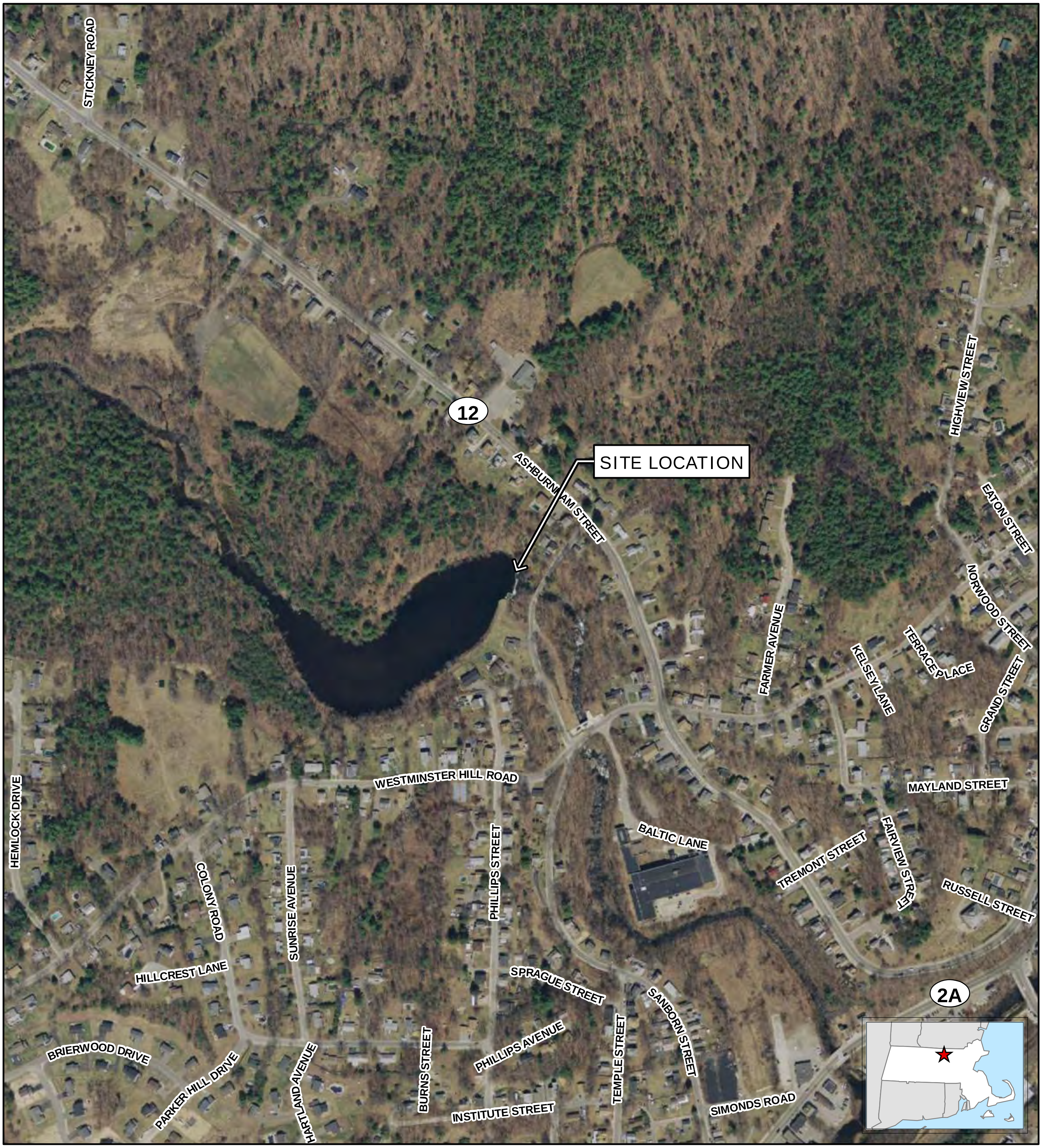


FIGURE 2
ORTHOPHOTOGRAPH
MA00879
McTaggart's Pond Dam
Fitchburg, Massachusetts

Tighe&Bond
Engineers | Environmental Specialists

Based on MassGIS Color Orthophotography (2014)

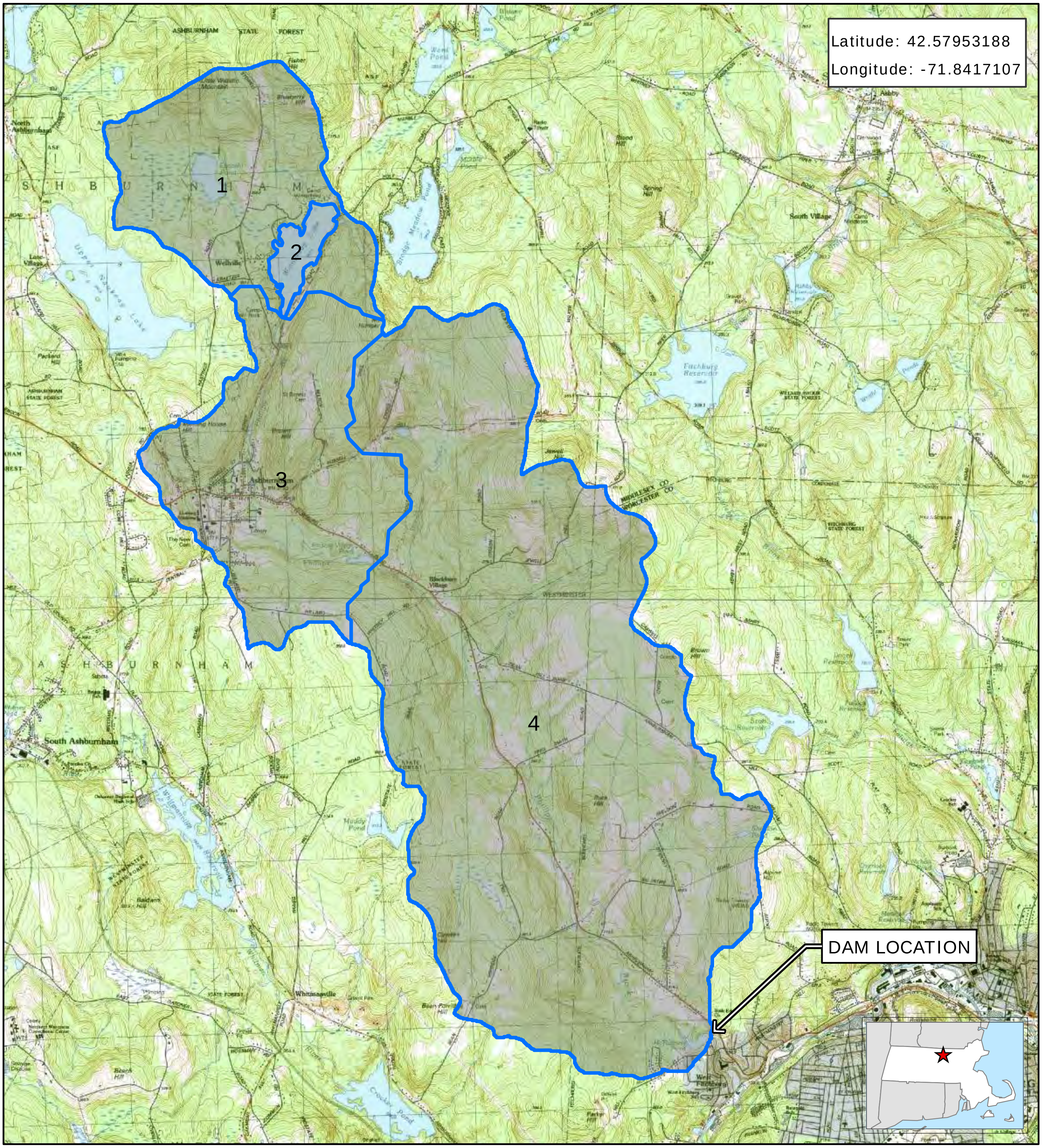
1:6,000

0 250 500

Feet

N

October 2019



Legend

HydroCAD Sub-Drainage Areas (number indicated sub-basin ID)

Tighe&Bond
Engineers | Environmental Specialists

Based on USGS Topographic Map for
Ashburnham, MA Revised 1988.
Ashby, MA Revised 1988.
Gardner, MA Revised 1988.
Fitchburg, MA 1988.

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0 2,500 5,000
Feet

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FIGURE 3
DRAINAGE AREA MAP

MA00879
McTaggart's Pond Dam
Fitchburg, Massachusetts

October 2019

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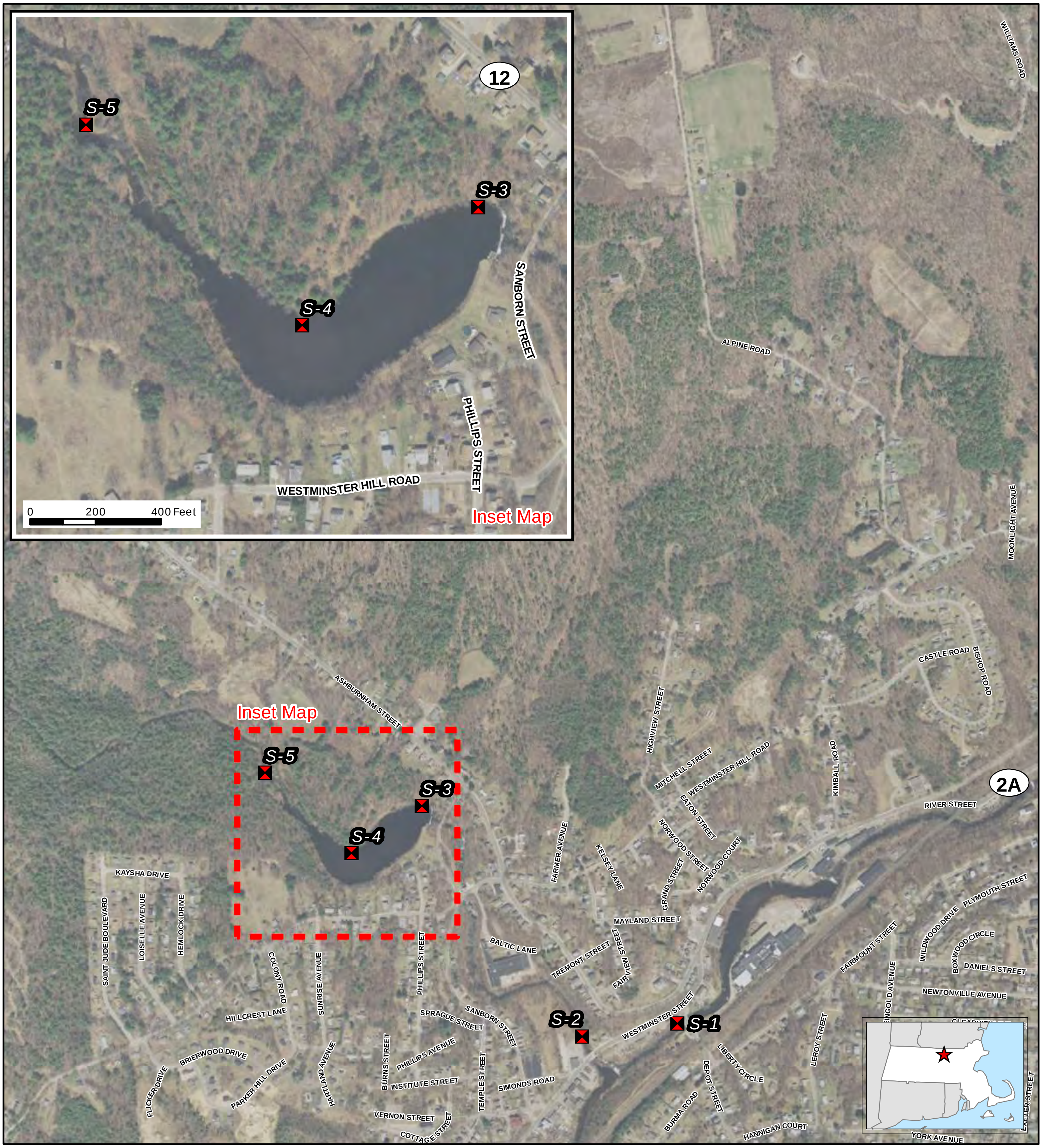

Legend

Composite Sediment Sample Locations

Tighe&Bond
Engineers | Environmental Specialists

Based on MassGIS Color Orthophotography (2014)

1:12,000
0 500 1,000
Feet

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FIGURE 4
SEDIMENT SAMPLE
COLLECTION LOCATIONS

MA00879
McTaggart's Pond Dam
Fitchburg, Massachusetts

October 2019

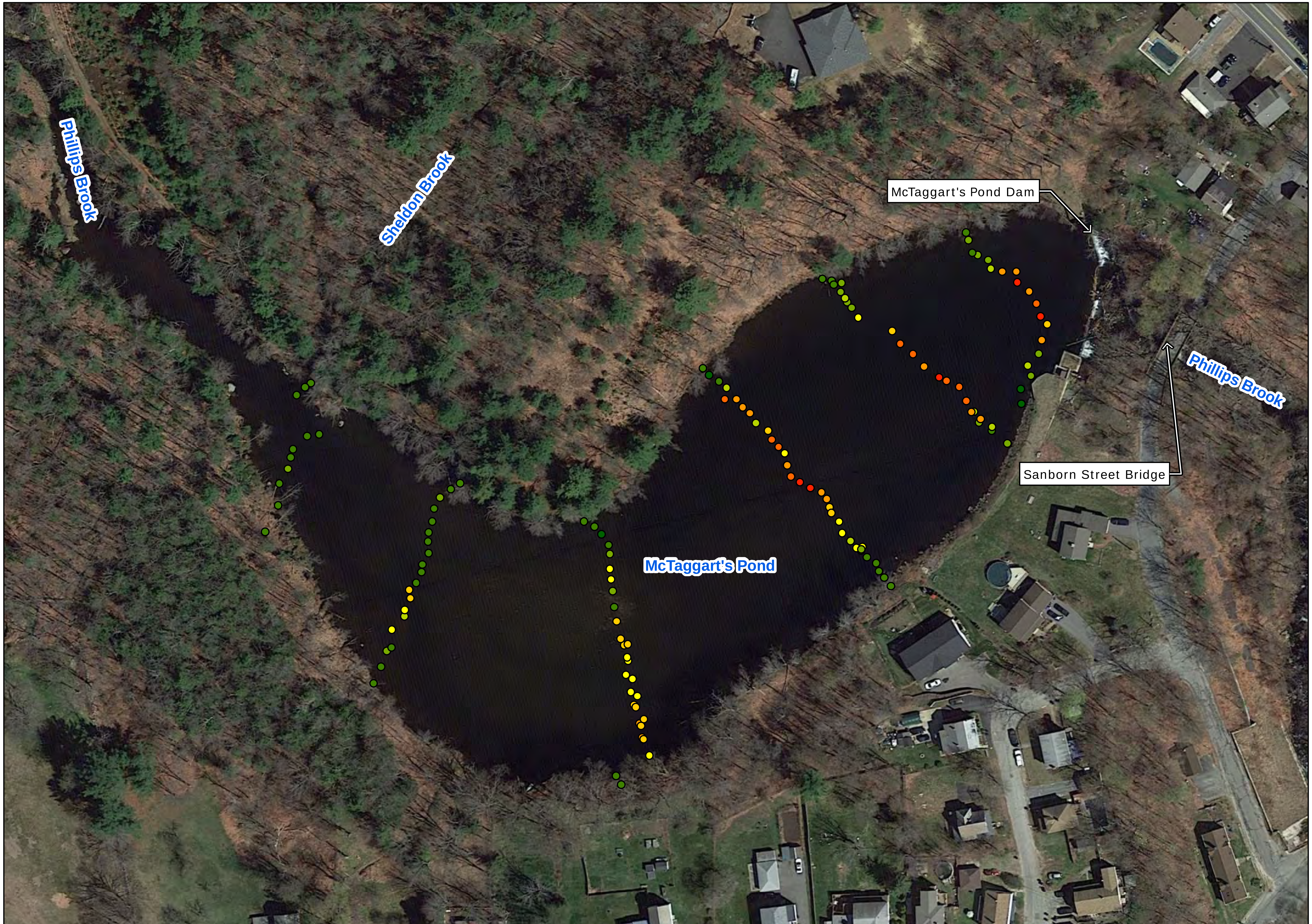


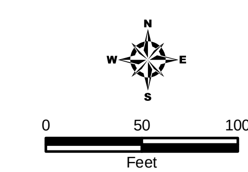
FIGURE 5
SEDIMENT THICKNESS MAPPING RESULTS

LEGEND

Sediment Thickness (ft)

- -1- 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8

LOCUS MAP



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NOTES

1. Based on Google Imagery(2016).

MA00879
McTaggart's Pond Dam
Fitchburg, Massachusetts

October 2019

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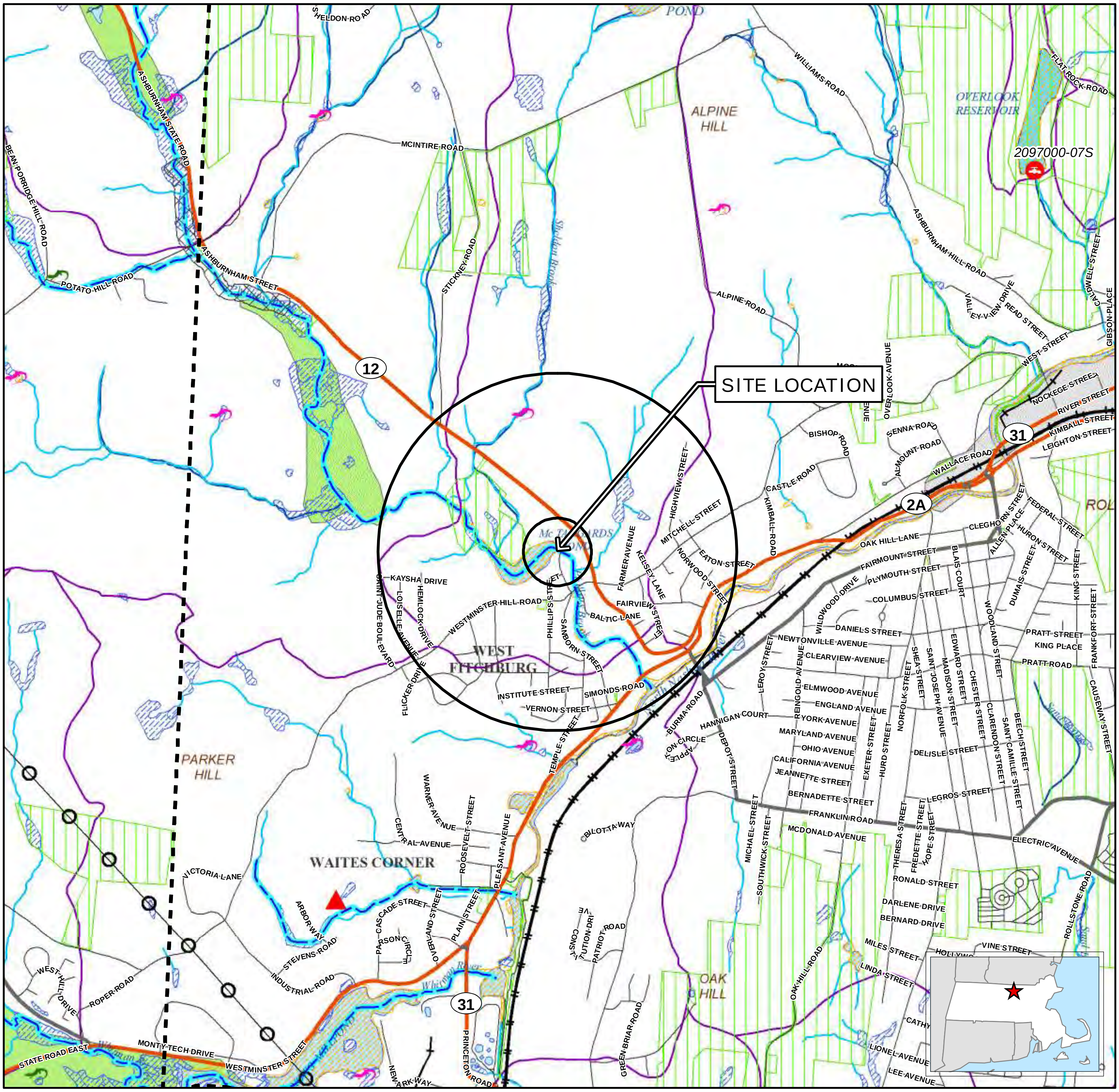

Legend

- NHESP Certified Vernal Pools
- NHESP Potential Vernal Pools
- Non-Landfill Solid Waste Sites
- Proposed Well
- Emergency Surface Water
- Community Public Water Supply - Surface Water
- Community Public Water Supply - Groundwater
- Non-Community Non-Transient Public Water Supply
- Non-Community Transient Public Water Supply
- Limited Access Highway
- Multi-Lane Highway, NOT Limited Access
- Other Numbered Highway
- Major Road - Collector
- Minor Street or Road
- Aquaducts
- Hydrologic Connections
- Stream/Intermittent Stream
- Powerline
- Pipeline
- Track or Trail
- Trains
- Public Surface Water Supply Protection Area (Zone A)
- DEP Approved Wellhead Protection Area (Zone I)
- DEP Approved Wellhead Protection Area (Zone II)
- DEP Interim Wellhead Protection Area (IWPA)
- Protected and Recreational Open Space
- Solid Waste Landfill
- Area of Critical Environmental Concern (ACEC)
- NHESP Priority Habitats for Rare Species
- NHESP Estimated Habitats for Rare Wildlife
- EPA Designated Sole Source Aquifer
- Major Drainage Basin
- Sub Drainage Basin
- MassDEP Open Water
- MassDEP Inland Wetlands
- MassDEP Coastal Wetlands
- MassDEP Not Interpreted Wetlands
- MA DFW Coldwater Fisheries Resources
- Public Surface Water Supply (PSWS)
- Water Bodies
- Non-Potential Drinking Water Source Area - High Yield
- Non-Potential Drinking Water Source Area - Medium Yield
- Potentially Productive Medium Yield Aquifer
- Potentially Productive High Yield Aquifer
- County Boundary
- Town Boundary
- USGS Quadrangle Sheet Boundary

1:24,000

0 1,000 2,000

Feet

N

FIGURE 6
PRIORITY RESOURCES & COLD WATER FISHERIES RESOURCES

MA00879

McTaggart's Pond Dam

Fitchburg, Massachusetts

Data source: Bureau of Geographic Information (MassGIS), Commonwealth of Massachusetts, Executive Office of Technology
Circles indicate 500-foot and half-mile radii.
Data valid as of October 2019.

October 2019

Tighe&Bond
Engineers | Environmental Specialists