ALTERNATIVES REPORT

FACTORY POND DAM

MA02952 / 4-9-136-7

HOLLISTON, MASSACHUSETTS

PREPARED FOR:

TOWN OF HOLLISTON
703 WASHINGTON STREET
HOLLISTON, MA 01746

PREPARED BY:

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PARE PROJECT NO. 21214.00/202

May 2022

PARE CORPORATION

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prepared for: Town of Holliston
703 Washington Street
Holliston, MA 01746

prepared by: Pare Corporation
10 Lincoln Road Suite 210
Foxboro, MA 02035

Authority

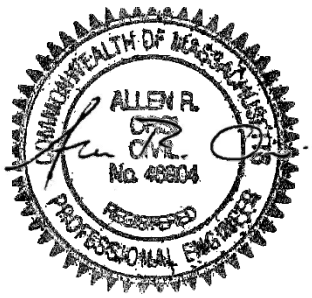
The Town of Holliston, MA has retained Pare Corporation (Pare) to evaluate conditions of the Factory Pond Dam in Holliston, Massachusetts and to develop a report of conceptual design alternatives to address known deficiencies at the dam. This inspection, report, and evaluations were performed in accordance with MGL Chapter 253, Sections 44-50 of the Massachusetts General Laws.

PREFACE

The assessment of the condition of the dam is based upon available data, visual inspections, subsurface investigations, hydrologic and hydraulic studies, topographic surveys and stability analyses as well as supplemental information developed by others during previous evaluations of the dam.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection, along with data available to the inspection team and other information collected as part of the evaluation.

It is critical to note that the condition of the dam is evolutionary in nature and depends on numerous and constantly changing internal and external conditions. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.



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1.0 PROJECT INFORMATION

1.1 General

1.1.1 Authority

The Town of Holliston has retained Pare Corporation (Pare) to develop a report of alternative approaches to address known and/or approximated deficiencies at the dam. This inspection, report, and evaluations were performed in accordance with MGL Chapter 253, Sections 44-50 of the Massachusetts General Laws.

1.1.2 Purpose of Work

The purpose of this study is to utilize available information pertaining to the dam to develop an initial understanding of the level of effort which may be required to advance a variety of alternatives for the dam site including dam removal, dam repair, dam rehabilitation, and no action

This investigation consisted of six parts: 1) Review available reports, investigations, and data previously submitted to the owner pertaining to the dam and appurtenant structures; 2) Complete a field review of existing conditions of the dam; 3) Develop conceptual designs to either remove, repair, or rehabilitate the dam; 4) Develop opinions of probable cost for each of the identified alternatives; and 6) Prepare and submit a final report presenting the findings of the completed work.

1.1.3 Definitions

To provide the reader with a better understanding of the report, definitions of commonly used terms associated with dams are provided in Appendix D. Many of these terms may be included in this report. The terms are presented under common categories associated with dams which include: 1) orientation; 2) dam components; 3) size classification; 4) hazard classification; 5) general; and 6) condition rating.

1.2 Description of Project

1.2.1 General

Sections of this report are based upon available documentation, including previous inspection reports and other available information as identified in Appendix C. Other historical information obtained during the inspection, including information provided by the caretaker, has also been incorporated in this report. This material is intended to provide general information. The accuracy of this referenced information was not verified as part of this study.

Elevations that are included in this evaluation roughly correlate to the North American Vertical Datum of 1988 (NAVD88) based upon available data from MassGIS with approximate conversions of previously reported site elevations to NAVD88. Elevation reference should only be considered accurate to the extent provided by the methods utilized.

1.2.2 Location

Factory Pond Dam is in the Town of Holliston, Middlesex County, Massachusetts. It is located near coordinates 42.20936ºN/71.41783ºW. The dam is accessible from State Route 16 as follows: Follow State Route 16 approximately 0.3 miles west from its northern intersection with State Route 126; turn right onto Woodland Street and go approximately 0.3 miles to the dam. The dam is located at the eastern end of the impoundment, as indicated on Figure 1: Locus Plan.

1.2.3 Owner/Operator

The dam is currently owned by the Town of Holliston. The Town of Holliston DPW is responsible for operation and maintenance of the dam.

Table 1-1: Owner/Operator Information

	Dam Owner	Dam Caretaker
Name	Town of Holliston	Town of Holliston DPW
Mailing Address	703 Washington Street	703 Washington Street
Town	Holliston, MA 01746	Holliston, MA 01746
Daytime Phone	508.429.0608	508.429.0615
Emergency Phone	508.429.4631 (Fire Dept)	508.429.4631 (Fire Dept)
Email Address		

1.2.4 Purpose of Dam

The dam, which was originally constructed for water supply purposes for a mill, currently impounds water for recreational use.

1.2.5 Description of the Dam and Appurtenances

As shown on Figure 3: Site Sketch, Factory Pond Dam is an earthen dam about 135 feet long oriented primarily north/south. A dam was originally constructed at the site in 1873 and subsequently modified during the 1900's. The current structure has a maximum structural height of approximately 13 feet.

The crest carries Woodland Street, a 24-foot wide bituminous roadway with a 7-foot wide bituminous sidewalk on the west (upstream) side. Upstream of the roadway, the crest is a 25-foot wide grass and gravel area. The upstream slope is vegetated with no protection on its 4H:1V slope. A concrete wall replaces the upstream slope within about 25 feet on either side of the spillway.

Image 1: *Factory Pond Dam impoundment and primary spillway looking northwest from the Upper Charles Rail Trail Bridge*

The downstream slope is irregular and is largely defined by the presence of the abandoned roadway and dam. Left of the spillway, the abandoned and current roadway grades are at

about the same elevation. Consequently, the downstream slope is rather level in this area to the original downstream slope, which slopes away at about 2H:1V. Vehicle access to this flat area is available through a small grass and gravel driveway. Right of the spillway, the roadway embankment slopes at 2H:1V to a lower, level area of the abandoned roadway. The slope continues approximately level to the original downstream slope.

The right abutment is not well defined. The bank of Factory Pond turns gradually away from the crest starting about 135 feet from the left abutment. On the downstream side of the crest, the slope and embankment from the original dam and roadway continue for approximately 165 feet. A portion of this embankment is supported by a stone masonry wall. A possible outlet structure and downstream channel are present near the right end of the slope. A potential concrete headwall structure is visible on the bank of Factory Pond opposite the downstream structure. The configuration of these structures could not be determined.

Image 2: *Concrete walls at primary spillway approach*

The spillway is a 13-foot wide broad crested overflow concrete weir. Stoplog slots are present within the spillway walls; however, the level of the concrete weir currently regulates the normal pool elevation. Downstream, the training walls are concrete up to the abutments supporting a steel and concrete bridge over the downstream channel. The abutments and downstream walls are stone masonry, including the walls forming the abutments for the abandoned bridge. An abandoned concrete weir lies immediately downstream of the abandoned bridge near the toe of the dam.

Image 3: *Downstream slope right of primary spillway. Arrow indicates approximate location of stone masonry wall and outlet.*

As indicated in the 2017 Phase I Inspection Report, "Visible under the fall of the main spillway wall is another possible low level outlet, measuring approximately 3 feet by 3 feet by 5 feet 6 inches deep. The opening is through the right half of the downstream masonry face of the spillway and approximately 3 feet from the right training wall. The headwall over the opening is approximately 32 inches from soffit to spillway crest. No controls were observed. No "twin" outlet was observed on the left half of the spillway.

A stone headwall and inlet were observed on right shore of the impoundment approximately 135 feet to the right of the spillway. The matching stone masonry discharge headwall was observed across

Woodland Street approximately 150 feet to the right of the spillway. No controls were observed. No further information regarding the outlets were available."

The impoundment, Factory Pond, is located along the Bogastow Brook and is also fed by the Jar Brook. The downstream brook flows under a stone masonry railroad viaduct that supports the Upper Charles recreational Rail Trail, and then through a channel lined by stone masonry walls one to two feet high. The brook continues through a swampy area for approximately 1.5 miles until its confluence with the Dopping Brook.

1.3 Pertinent Data

1.3.1 Size Classification

Factory Pond Dam has a maximum structural height of approximately 13 feet and a reported maximum storage capacity of 50 acre-feet. Therefore, in accordance with Department of Conservation and Recreation Office of Dam Safety classification, under Commonwealth of Massachusetts Dam Safety rules and regulations stated in 302 CMR 10.00, Factory Pond Dam is a **Small** size structure.

1.3.2 DCR Hazard Classification

Factory Pond Dam carries Woodland Street and lies 40 feet upstream of an abandoned railroad viaduct, 0.6 miles upstream of Lowland Street, 0.9 miles upstream of Marilyn and Northway Streets, and 1.1 miles upstream of power transmission lines. Commercial and residential properties are present along this stretch of the Bogastow Brook. Therefore, in accordance with Department of Conservation and Recreation classification procedures, under Commonwealth of Massachusetts dam safety rules and regulations stated in 302 CMR 10.00 failure of the dam "may cause loss of life and damage home(s), industrial or commercial facilities, secondary highway(s) or railroad(s)." As such, Factory Pond Dam is a **Class II** (**Significant**) hazard potential dam.

1.4 Inspection History

Based upon a review of available information provided by the Town of Holliston and the MADCR Office of Dam Safety, the site has a history of developing conditions resulting in the current poor condition rating. The following tables provides a summary of past inspections and noted conditions:

Table 1-2: Inspection History Summary

Date	Inspector	Dam Condition	Noted Deficiencies
8/16/1973	Pizan & Pare	Good	Brush on embankment
10/8/1987	CVP	Fairly Good	Obstructions and dislodged masonry in discharge channel, brush on embankment
5/5/1999	Haley & Aldrich	Fair	Brush on embankment, areas of erosion adjacent to discharge channel and bridge abutments
2/13/2007	Pare	Poor	Concrete deterioration, failing scour apron, eroded channels, seepage at right abutment, failing stone wall on downstream slope, brush & stumps on embankment
5/23/2008	Pare	Poor	Voids in walls, failed scour apron, seepage at right abutment, leakage at left downstream training wall, brush & stumps on embankment

5/25/2010	Fuss & O'Neill	Poor	Deteriorating concrete, failed scour apron, eroded channels, unprotected upstream slope, possible seepage/leakage at right abutment, failing downstream stone wall, brush, trees & stumps on embankment
11/16/2010	Lenard Engineering	Poor	Deteriorating concrete, failed scour apron, eroded channels, unprotected upstream slope, possible seepage/leakage at right abutment, failing downstream stone wall, voids in walls, brush, trees & stumps on embankment, animal burrows, minor depressions, inadequate grass cover, and debris obstruction
5/9/2011	Lenard Engineering	Poor	Deteriorating concrete, failed scour apron, voids in concrete, heavy brush on embankment, inadequate grass cover, failing stone walls, animal burrows & sinkholes on crest and downstream slope, seepage, and leakage
6/8/2012	Lenard Engineering	Poor	Heavy brush and trees on embankment, unprotected slope, inadequate grass cover, failing downstream stone wall, void under concrete slab, deteriorating concrete, failing scour apron, bank erosion, and stained seepage
6/13/2013	Lenard Engineering	Poor	Heavy brush on embankment, unprotected slope, inadequate grass cover, failing downstream stone wall, void under concrete slab, deteriorating concrete, failing scour apron, bank erosion, animal burrows, and stained seepage
11/10/2016	Lenard Engineering	Poor	Unprotected slope, inadequate grass cover, failing downstream stone wall, voids in concrete, deteriorating/missing concrete, failing scour apron, slope erosion, seepage/leakage at abandoned outlet, and animal burrows
10/13/2017	Lenard Engineering	Poor	Heavy brush on embankment, unprotected slope, inadequate grass cover, failing downstream stone wall, void under concrete slab, deteriorating concrete, failing scour apron, and bank erosion
11/26/2018	Lenard Engineering	Poor	Failing guard post, cracked asphalt, seepage, heavy brush on embankment, unprotected slope, inadequate grass cover, deteriorating/missing concrete, voids in concrete, failing scour apron, slope erosion, animal burrows, and debris obstruction
5/10/2021	Lenard Engineering	Poor	Heavy brush on embankment, unprotected slope, inadequate grass cover, failing downstream stone masonry wall, voids in concrete, deteriorating/missing concrete, failing scour apron, and debris obstruction

2.0 ENGINEERING DATA

2.1 General

2.1.1 Drainage Area

As reported in the 2017 Report, "The drainage area for Factory Pond Dam is approximately 5.84 square miles. The drainage area is generally between 0.9 and 1.6 miles wide and extends approximately 3.1 miles south of the dam and 2.9 miles northwest of the dam. The drainage area includes the drainage areas for Lake Winthrop Dam, Houghton Pond Dam, and Linden (aka Mill) Pond Dam. The drainage area also includes the Jar Brook, Bogastow Brook (including the Winthrop Canal), and several other unnamed tributaries and ponds. Topographical features include low to moderate hills, the developed areas of Holliston center and northern Holliston, and swampland upstream and southeast of Lake Winthrop."

2.1.2 Reservoir Information

The following table provides a general overview of impoundment geometric properties. Data is based upon available LiDAR data from MassGIS for above normal pool storage volume and previous reports for below normal pool storage.

Table 2-1: Reservoir Properties

	Elevation	Surface Area (acres)	Storage Volume (acre-feet)
Normal Pool	163.5±	9.9 ±	18 ±
Maximum Pool	166.2±	23 ±	50 ±
SDF Pool	Unknown	Unknown	Unknown

2.1.3 Discharges at the Dam Site

No records of discharges at the dam site were made available during the preparation of this report.

2.1.4 General Elevations (feet)

Elevations are based upon information provided within available inspection reports. As indicated in the 2017 Phase I Report, the previously referenced datum is assumed. Elevations have been roughly converted from the previously reported datum to NAVD88 based upon correlation of spot elevations to available LiDAR data; to approximately convert from the assumed datum to NAVD88, add 64.5 feet. The elevations should only be considered accurate to the level of the methods used.

		Previously Reported (Assumed Datum)	Approximate NAVD88
A.	Top of Dam	102	166.5
B.	Spillway Design Flood Pool	No H&H Available	
C.	Normal Pool	99.0±	163.5±
D.	Downstream Channel		
	1. At toe of Spillway	94.1±	158.6±
	2. Downstream of Former Bridge	89±	153.5±
	3. Downstream of Abandoned Outlet	90.4±	154.9±

E.	Downstream Water	90±	154.5±

2.1.5 Spillway

A.	Type	Concrete Weir with Stoplogs	
B.	Width	13 feet	
C.	Elevations		
	1. Top Stop Log Slots	100.0	164.5
	2. Fixed Crest	99.0	163.5

2.2 Design and Construction Records

No design or construction records were available during the preparation of this report. Information within the MADCR dam database detail indicates that the dam was originally constructed in 1873. Based upon observations at the site, it is inferred that the original dam crest carried a roadway which crossed a timber and concrete bridge constructed in 1920 over the spillway. Later during the 1900's (exact date unknown), the roadway was relocated approximately 30 feet upstream, a new dam and bridge were constructed, and the replaced dam and bridge were abandoned in-place. The abandoned dam and bridge now form a portion of the downstream slope.

3.0 BASIS OF ALTERNATIVES ANALYSIS

The scope of this study provides for the development of alternatives to comply with current state dam safety regulations and to address known deficiencies at the dam. Where available, the study references previously completed studies and detailed analyses. In the absence of detailed evaluations, the scope of the work includes developing approximations of the dam's current compliance with applicable regulations based upon available published information and the engineer's judgment. The following provides the basis for which the dam has been assessed.

3.1 Structural Stability

Available documentation for the dam includes visual inspections and assessments of the dam stability. As indicated in the 2017 Phase I Report:

> Based solely on visual observation alone, the embankments currently appear stable. However, there are deficiencies which if left uncorrected may shorten the service life of the dam. These deficiencies include:
>
> A. Mature trees and brush within 20 feet of the dam area;
> B. Inappropriate or missing grass cover on slopes;
> C. Failing downstream stone masonry wall which supports both the downstream dam embankment and the abandoned roadway embankment at the right of the spillway.
>
> Based solely on visual observation alone, the spillway currently appears stable. There are deficiencies, which if left uncorrected may shorten the service life of the dam. These deficiencies include:
>
> A. Erosion between cap and spillway crest at the joints;
> B. Erosion of top of weir at the center of the spillway;
> C. Poor condition of the concrete overlay;
> D. Missing and cracked portions of the forebay weir walls;
> E. Poor condition of the scour apron.
>
> Although not truly an appurtenance of the dam, should the abandoned roadway bridge collapse, the downstream main channel may become blocked.

In addition to previously reported observations, a void was noted behind the downstream left training wall upstream of the roadway bridge. This void appears to have developed as a result of overtopping of the spillway walls and return flow over the training wall and back to the spillway channel. The extent of void space and damage to the walls has not been determined.

Given available information, the dam has been reported to be structurally stable based upon visual observations with areas of deterioration which may lead to the development of future instability.

3.1.1 Embankment (Slope) Stability

The embankment sections at the dam include the upstream slope beyond the limits of the spillway walls and the downstream slope along the downstream side of the roadway. For the purposes of this assessment, the following conditions are assumed:

1) The upstream slope, reported to be near 4H:1V[1], is presumed to be stable and meeting required factors of safety. Erosion and scarping of the slope appears to warrant provision of slope protection.

2) The downstream slope is steeper than 1.7H:1V[2] in areas approaching the right end of the dam; while no indications of slope movement have been reported, the section of slope is presumed to not meet required factors of safety.

3.1.2 Embankment (Seepage) Stability

Areas of seepage have been reported at the downstream toe near the right end of the dam. However, this seepage has been noted to be related to a potential former outlet structure. Flow rates have generally been low with no indication of sediment transport. No other areas of seepage have been reported.

Given the observed conditions, for the purposes of this study the embankment is assumed to be adequately resistant to seepage through the embankment. While measures to cutoff/reduce seepage do not appear warranted, embankment work to address slope stability in the area of seepage is assumed to require appropriate drainage features.

3.1.3 Retaining Wall Stability

No previous evaluations of the stability of retaining walls at the dam has been completed. The alignment and condition of the walls have generally been reported to be satisfactory as part of previous inspections. As such, the walls have been presumed to be stable for the purposes of this study.

While walls appurtenant to the dam have been considered stable, previous reports have noted concerns with the stability of the bridge abutment walls. For this report, the bridge abutment walls have not been considered as part of the dam structure and are excluded from the scope of this assessment.

3.1.4 Spillway Stability

No previous evaluations of the stability of the spillway and appurtenant training walls at the dam has been completed. The alignment and condition of the walls have generally been reported to be satisfactory as part of previous inspections. As such, the structures are presumed to be stable for the purposes of this study.

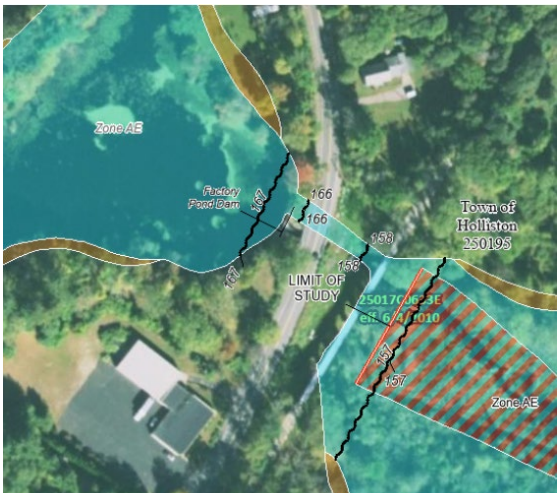


Image 3-1: FIS Panel in Area of Factory Pond Dam

3.2 Spillway Design Flood Compliance

Given the size and hazard potential classification for the dam, the spillway design flood is the 100-year storm event.

The 1987 Phase I Inspection report included the completion of rudimentary hydrologic and hydraulic

[1] Office of Dam Safety Inspection Guidance and Notes suggests a condition rating of 4 or 5 for earthen slopes flatter than 3H:1V.
[2] Office of Dam Safety Inspection Guidance and Notes suggests a condition rating of 1 for earthen slopes steeper than 2H:1V.

analysis. Utilizing ACOE Probable Maximum Flood (PMF) Peak Flow Rate charts, which predict a Probable Maximum Flood flow of 4,730 cfs, the report estimated the 100-year flow to be approximately 1,180 cfs (25% of the full PMF). The study concluded that the dam, with a reported maximum discharge capacity of 495 cfs, would be overtopped by the 100-year storm event.

The effective Flood Insurance Study (FIS) for the dam (FIS Number 25017CV001C, dated July 6, 2016), reports a 100-year flow of 540 cfs from the Bogastow Brook upstream of the impoundment (with a drainage area of 2.9 square miles); this flow does not account for the contributory drainage area from the Winthrop Canal. The FIS reports a 100-year flow of 800 cfs downstream of the dam at the confluence with Dopping Brook (with a drainage area of 6.7 square miles). The FIS predicts that the 100-year water surface elevation will rise to near the crest of the dam; however, no overtopping of Woodland Street is predicted.

Several occurrences of overtopping of the upstream walls and training walls at the spillway have been reported, including August 2011 (Tropical Storm Irene) and most recently after heavy rainfall around September 2, 2021. While the upstream walls and spillway training walls overtopped, no overtopping of the roadway has been reported.

Figure 3-3 High water levels post Tropical Storm Irene (August 28, 2011)

Given available studies and past performance of the dam, it appears that the dam has capacity near the required spillway design flood event; however, modifications to the dam are presumed to be required to protect the dam and spillway structures during high flow events. It is presumed that modification of the existing spillway can meet spillway design flood flows; however, reconstruction or replacement is not required.

To support the development of conceptual designs, flow rates reported within the FIS will be adjusted for the site drainage area using the area ratio of ungaged to gaged watersheds (Equation 1):

$$Q_{\text{ungaged}} = Q_{\text{gaged}} \times \frac{A_{\text{ungaged}}}{A_{\text{gaged}}} \qquad \textbf{Equation 1}$$

For Factory Pond, with a reported drainage area of 5.8 square miles, the corrected flow rate using the reported flow at the confluence with the Dopping Brook is 692 cfs. Given uncertainty and approximate nature of the methods, a conceptual design flow rate of 700 cfs will be utilized for this study. This value falls within the range of peak flows predicted by USGS StreamStats (587 cfs; Upper Limit 1310 cfs, Lower Limit 263 cfs).

3.3 Uncertainty

Detailed evaluations specific to the project site are not available. As such, the accuracy of critical criteria presented above is uncertain.

Detailed hydrologic and hydraulic analysis incorporating current modeling methods and data sets and accounting for routing effects of the impoundment may find SDF flows higher or lower than those presumed herein.

The assessment also assumes that past performance of structural components of the dam indicates adequate stability; however, detailed assessment may indicate that while stable, factors of safety for stability meeting current dam safety regulations requirements may not be met.

4.0 ALTERNATIVES ANALYSIS

4.1 Alternatives Analysis

For the purposes of this evaluation, four design alternatives were considered to address the concerns at the site. These alternatives include 1) Dam Repair; 2) Dam Rehabilitation; 3) Dam Removal; and 4) No Action. The general scope of each of these alternatives includes the following:

1) ***Dam Repair:*** Includes maintenance, repair, and/or replacement of existing features at the dam to restore their original design functionality. Repair generally includes upgrading existing facilities to address known structural deficiencies; however, measures to address regulatory deficiencies are beyond the scope of a repair program.

2) ***Dam Rehabilitation:*** Includes repairs and modifications to the dam to address physical deficiencies as well as to upgrade the dam to comply with applicable design requirements, such as spillway design flood requirements and meeting required factors of safety. In general, dam rehabilitation alters the current design to provide a structure compliant with all design requirements.

3) ***Dam Removal:*** Includes complete removal of the spillway control structure and portions of the dam as necessary to fully drain the impoundment. The extent of removal for the purposes of this evaluation assumes that the difference in water surface elevation across the former dam location is less than 6-feet, which would classify the remaining structure as non-jurisdictional.. It should be noted that ecological restoration permit process requires that the removal results in no increase to water surface elevation upstream of the dam location during a 500-year storm event; as such, extent of required removal may exceed that considered as part of this study.

4) ***No Action:*** Includes maintaining the current level of operations, maintenance, and inspection at the dam; no repairs or remedial measures are to be completed.

4.1.1 Dam Repair

The scope of a dam repair program may include:

1. Control of Water and Diversions: A temporary bypass would likely be required to allow for work on the spillway to be completed; this bypass would likely consist of a siphon structure over the crest of the dam. Phasing of the construction work will be designed to allow for continued flow of water past the work area to facilitate completing the work in the dry.

   In conjunction with the diversion, control of water will also be required. It is anticipated that this would include a drawdown of the impoundment on the order of 1 to 3 feet and the installation of a temporary cofferdam (Port-A-Dam or bulk sand bags).

2. Clearing and grubbing of trees and other unwanted vegetation along the length of the dam. Fill and compact resulting holes. Clearing would extend a minimum of 20 feet beyond the limits of the embankment downstream of the dam as well as into each abutment.

3. Structural repairs to the spillway and associated walls including:
   - Patching damaged concrete and sealing cracks in concrete
   - Repointing masonry wall sections

- Filling areas of observed voids
- Repairing the scour apron

4. Restoring upstream slope protection where previously provided; this is assumed to include lining the normal pool waterline with boulders.

5. Regrading slopes to uniform sections; establish a maintainable surface covering within the limits of the dam embankment.

The dam repair program is expected to extend the serviceable life of the structure and enable the implementation of a routine maintenance program. The program may not fully address all dam safety deficiencies at the dam. For example, this repair program would not address any concerns regarding the spillway design flood compliance or seepage or stability issues that may exist and have not been visually apparent during past inspections.

The general character and limits of the dam repair program are shown on Figure 3.1: Dam Repair Concept.

4.1.2 Dam Rehabilitation

The scope of a dam rehabilitation program may include:

1. Control of Water and Diversions: A temporary bypass would likely be required to allow for work on the spillway to be completed; this bypass would likely consist of a temporary culvert excavated through the embankment to either side of the spillway to accommodate base and storm flows during construction. Phasing of the construction work will be designed to allow for continued flow of water past the work area to facilitate completing the work in the dry.

   In conjunction with the diversion, control of water will also be required. It is anticipated that this would include a drawdown of the impoundment on the order of 3 feet and the installation of a temporary cofferdam (Port-A-Dam or bulk sand bags).

2. Clearing and grubbing of trees and other unwanted vegetation along the length of the dam. Fill resulting holes. Clearing would extend a minimum of 20 feet beyond the limits of the embankment downstream of the dam as well as into each abutment.

3. Evaluate for the presence of and formerly abandon the reported potential outlet through the right end of the dam; this may include an open cut and replacement, a grouting program, or driven sheet pile cutoff.

4. Modify the spillway to accommodate the spillway design flood (100-year storm event) without overtopping of the roadway or spillway walls. Based upon conceptual designs, high stage weirs to both sides of the existing spillway, each approximately 30 feet long, would provide required capacity:
   - Construct overflow weirs 6-inches above the existing spillway and extending 30 feet to either side of the spillway.
   - Excavate the embankment to either side of the spillway between the pond and the roadway to lower the grade approximately 2.5 feet.

- Install concrete slab scour aprons to convey flow from the new channel back to the spillway channel upstream of the bridge.

Alternatively, a 60-foot-long weir could be provided to one side of the spillway; however, depth of excavation for the scour slab would be increased.

Given the age and condition of the existing spillway, complete replacement may be warranted. If complete replacement is the preferred approach to provide a rehabilitated dam with a longer design life, the new spillway could take the form of a single cycle labyrinth spillway with an effective weir length designed to match required total discharge capacity while maintaining some of the flood routing benefits of the impoundment (i.e, provide high and low stage weirs). The reconstructed spillway could also be designed to provide a low level outlet via a gated conduit through the spillway as well as a bay of stoplogs at an accessible location to allow for pre-storm or seasonal drawdowns to be implemented (as presented below).

5. Provide low level outlet discharge capacity. The low level outlet should be designed to meet regulatory requirements and also to provide sufficient freeboard during a spillway design flood event.
   - Demolish the existing spillway weir
   - Dredge an approach channel
   - Reconstruct the weir to include a gated outlet (slide gate or valve)
   - Install a catwalk across the conceptual high stage overflow weirs and/or discharge slabs to provide access to the gate controls

6. Regrade the downstream slope to provide a stable, maintainable section:
   - Clear and grub the slope; strip organics
   - Regrade to stable section; provide drainage if required in the area of the former outlet structure near the right abutment

7. Install stone riprap along the upstream slope of the dam

8. Establish a maintainable surface covering within the limits of the dam embankment (i.e. grass, riprap in areas prone to scarping and erosion)

The dam rehabilitation program is expected to fully address the noted deficiencies at the dam and provide a structure that satisfies or exceeds regulatory requirements.

The general character and limits of the dam rehabilitation program are shown on Figure 4.2: Dam Rehabilitation Concept.

4.1.3 Dam Removal

As for all dams, breaching of the dam and river restoration is an alternative for addressing the dam safety concerns. Factory Pond currently only supports passive recreational activities. No water supply, wells, or other resources supported by the impoundment or the dam have been identified as part of the current evaluation. Removal of the dam would also have limited impact on peak flows during storm events to the downstream area due to the small size of the impoundment, limited flow attenuation offered by the outlet structures, and relatively large floodplain immediately downstream of the dam. As such, breaching of the dam may be a feasible approach for this site.

No information pertaining to the quantity or quality of sediment is available for this site; as such, it is unknown if sediment mitigation measures would be required. Additional consideration of sediment upon the feasibility of dam removal would be required if removal is a preferred approach.

A dam removal program would likely consist of complete demolition and removal of the vertical extents of the dam in the vicinity of the spillway. Preliminary hydraulic evaluations indicate that the 100-year flow would result in 8 feet of water within the channel at the Woodland Street bridge. This does not satisfy the design requirement for non-jurisdictional dams to impound less than 6 feet of differential head. Widening of the bridge would likely be required for the dam to be considered adequately removed. To meet non- jurisdictional requirements, the bridge would need to be approximately 20 feet wide. However, to meet Massachusetts Stream Crossing Standards, an approximately 35-foot-wide bridge would be required to meet the optimum goal of 1.2 times the bankfull width (given a bankfull width of 29 feet predicted by USGS StreamStats).

To enable completion of the dam removal and bridge replacement program, temporary traffic control will be required. As part of design development, traffic studies would be required to determine if Woodland Street could be closed to thru traffic between Linden Street and Washington Street; if closure and detour is not possible, then phasing of the work would be required which would significantly impact the project cost and duration.

Impoundment area restoration would likely include a natural revegetation program with supplemental planting and bank stabilization measures as deemed necessary during final design activities; should sediment characterization and quantification indicate concerns with in-stream management of sediment, additional measures to either remove and dispose of sediment, stabilize sediment in place, or otherwise remove sediment from the system will need to be implemented.

In addition to environmental considerations, public outreach would also play a critical role in a dam removal program.

4.1.4 No Action / Status Quo

Implement and continue maintenance activities at the dam. This option would not address the existing deficiencies at the dam or result in compliance with current state dam safety regulations. As such, this option was not considered further.

4.2 Opinions of Probable Cost

The following opinions of probable cost have been developed for the conceptual alternatives noted above based upon limited information as presented within Section 3.0. The costs shown herein are based on a limited investigation and are provided for general information only. This should not be considered an engineer's estimate, as actual construction costs may be somewhat less or considerably more than indicated. For more detailed information utilized for the development of the opinions of probable cost, refer to Appendix C.

Table 4-1: Conceptual Opinion of Probable Costs

Work Item	Alternative		
	Repair	Rehabilitation	Removal
General Requirements	$28,220.00	$66,690.00	$79,220.00
Mobilization / Demobilization	$17,000.00	$30,000.00	$90,000.00
Clearing and Grubbing	$8,850.00	$8,850.00	$3,790.00
E&S Controls	$10,200.00	$10,200.00	$10,200.00
Control of Water	$40,600.00	$35,600.00	$28,300.00
Embankment Work	$72,210.00	$77,450.00	N/A
Spillway Work	$123,500.00	$122,500.00	N/A
Low Level Outlet Work	N/A	$9,000.00	N/A
Bridge Work	N/A N/A	$400,000.00 (Repair)	$1,371,000.00 (Replacement)
Dam Removal Work	N/A	N/A	$120,000.00
Sediment Management	N/A	N/A	Unknown
Subtotal w/ Bonds	**$304,580.00**	**$768,290.00**	**$1,720,510.00**
Design Contingency	$105,350.00	$228,300.00	$510,900.00
Engineering and Design	$55,000.00	$80,000.00	$150,000.00
Permitting	$15,000.00	$30,000.00	$80,000.00
Construction Administration	$60,000.00	$80,000.00	$50,000.00
Conceptual Opinion of Probable Cost	$540,000.00	$1,187,000.00	$2,512,000.00

When comparing costs, the total cost including design, engineering, permitting, construction and long-term maintenance should be considered. The applicability of environmental permits needs to be determined prior to undertaking maintenance activities that may occur within resource areas under the jurisdiction of MADEP, local conservation commissions, or other regulatory agencies.

4.3 Life Cycle Analysis

An analysis was conducted to estimate the life cycle cost of each of the alternatives over a period of 30 years in order to develop a better understanding of the true costs of each alternative. The National Institute of Standards and Technology (NIST) Life Cycle Cost Manual Handbook 135 with the 2019 Supplement was used to determine the life cycle costs for the proposed alternatives (NIST, 1995). At this level of study, a simple method was utilized that accounts for initial investment, capital replacement, energy, and operation, maintenance, and repair.

Operations and Maintenance (O&M) costs for the dam structure consists of gate operation (if provided/installed), mowing and other vegetation maintenance, debris removal, and other miscellaneous items. O&M includes routine activities but does not account for intermittent repairs or other minor repairs to address identified deficiencies.

The estimated yearly O&M cost estimate is $4,000 for Alternatives 1, 2, and 4. Estimated O&M costs for Alternative 3 are $500 to account for post-dam removal maintenance (mowing, cleanup, etc.) of any publicly accessible areas created or restored as part of the dam removal program.

The present cost for each alternative was determined based on a 30-year analysis period, considering initial capital costs, assumed design life, and yearly O&M costs. Capital replacement costs were determined based on the assumed remaining design life at the end of the 30-year analysis period. Note that the costs in Table 4-1 do not include environmental restoration components, allowing for a focused analysis on the

infrastructure costs. Additional life cycle costs may be realized should sediment management or invasive species management be required as part of dam removal activities.

Table 4-2: Life Cycle Cost Analysis (30 Year Analysis)

	Alternative		
	Repair	Rehabilitation	Removal
Initial Capital Investment			
Discount Factor	1	1	1
Initial Capital Cost	$540,000	$1,187,000	$2,512,000
Capital Replacement Cost			
Assumed Design Life (yrs)	25	50	N/A
Assumed CIP Cost Percentage	100%	40%	0%
Discount Factor	0.412	0.412	0.412
Operations & Maintenance			
O&M Costs	$6,000	$4,000	$250
Discount Factor	19.6	19.6	19.6
Total Present Cost	**$ 880,080**	**$ 1,461,018**	**$ 2,516,900**

4.4 Potential Permitting Requirements

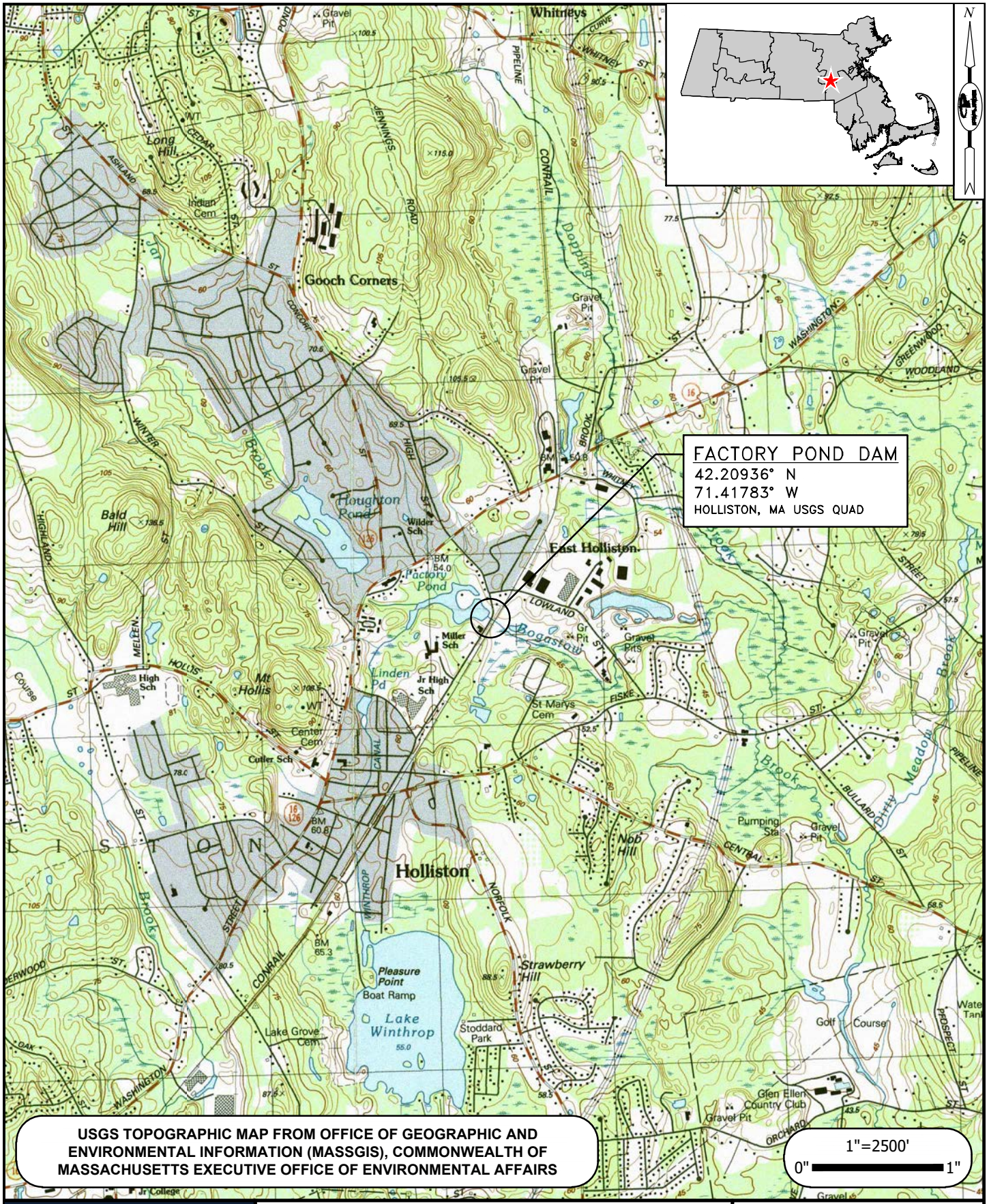
The following table presents the potential permitting requirements for each of the alternatives considered. Depending upon the final scope of work, the required permitting may vary from that set forth below.

Table 4-3: Potential Permitting Requirements

	Alternative			
	#1 Dam Repair	**#2 Dam Rehabilitation**	**#3 Dam Removal**	**#4 No Action**
NOI	Yes	Yes	Yes	Not Applicable
MEPA	Potentially	ENF/EENF	EIR	Not Applicable
ACOE GP	SV	PCN	IP	Not Applicable
DCR Dam Safety	Part A & B	Part A & B	Part A & B	Not Applicable
WQC	No	YES	Yes	Not Applicable

FIGURES

Factory Pond Dam
Holliston, Massachusetts



USGS TOPOGRAPHIC MAP FROM OFFICE OF GEOGRAPHIC AND ENVIRONMENTAL INFORMATION (MASSGIS), COMMONWEALTH OF MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS

PARE CORPORATION

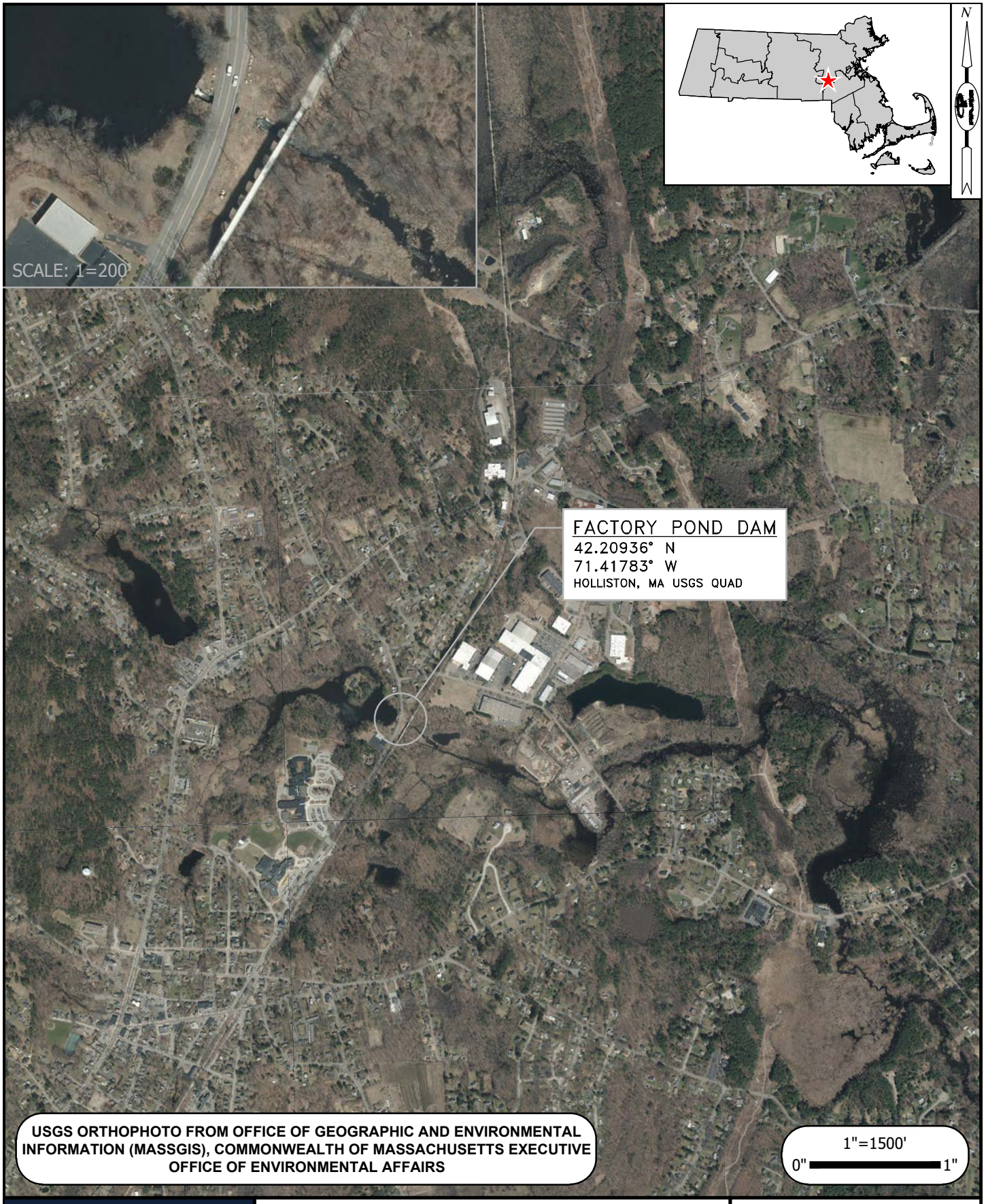
FACTORY POND DAM

MA02952 / 4-9-136-7

HOLLISTON, MASSACHUSETTS

LOCUS PLAN

NOVEMBER 2021 FIGURE 1



PARE CORPORATION

FACTORY POND DAM

MA02952 / 4-9-136-7

HOLLISTON, MASSACHUSETTS

AERIAL PLAN

NOVEMBER 2021 FIGURE 2

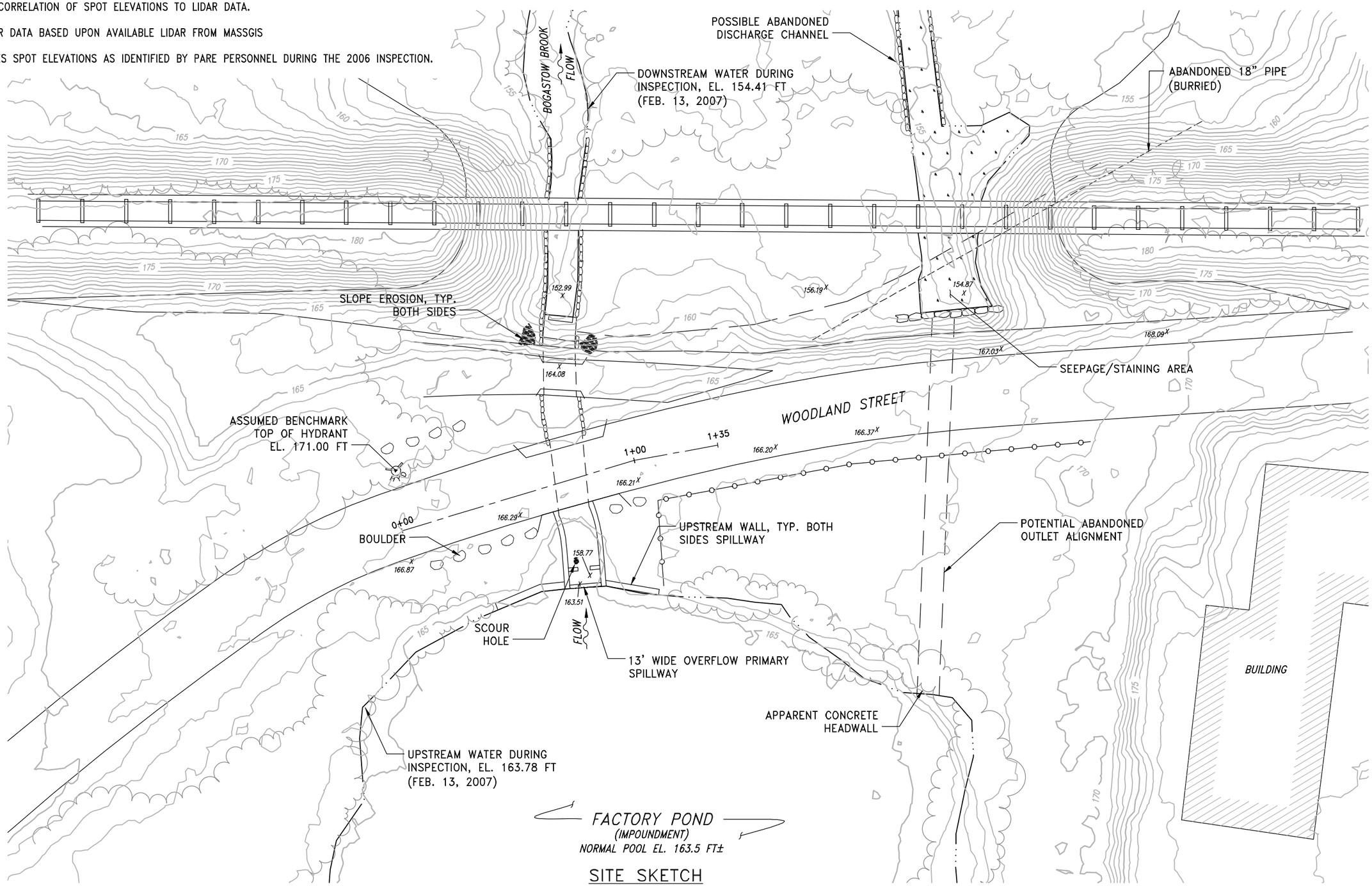
NOTES AND LEGEND

1. SKETCH DEVELOPED FROM INFORMATION OBTAINED DURING THE INSPECTION AND AVAILABLE AERIAL PHOTOGRAPHY. THE INFORMATION INCLUDED ON THE SKETCH IS PROVIDED FOR REFERENCE PURPOSES ONLY.

2. ELEVATIONS BASED UPON A RELATIVE ELEVATION SURVEY PERFORMED BY PARE PERSONNEL DURING THE 2006 INSPECTION. ELEVATIONS APPROXIMATELY REFERENCE NAVD88 BASED UPON ROUGH CORRELATION OF SPOT ELEVATIONS TO LIDAR DATA.

3. CONTOUR DATA BASED UPON AVAILABLE LIDAR FROM MASSGIS

100.00X INDICATES SPOT ELEVATIONS AS IDENTIFIED BY PARE PERSONNEL DURING THE 2006 INSPECTION.



SITE SKETCH
SCALE: 1"=40'

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10 LINCOLN ROAD, SUITE 210
FOXBORO, MA 02035
508-543-1755

SCALE ADJUSTMENT GUIDE
0" 1"
BAR IS ONE INCH ON ORIGINAL DRAWING.

FACTORY POND DAM
MA02952 / 4-9-136-7
HOLLISTON, MASSACHUSETTS
TOWN OF HOLLISTON

REVISIONS:

PROJECT NO.:	21214.00/202
DATE:	NOVEMBER 2021
SCALE:	AS NOTED
DESIGNED BY:	ARO
CHECKED BY:	JMB
DRAWN BY:	LMC
APPROVED BY:	ARO

SITE SKETCH

FIGURE NO.: 3

Y:\JOBS\21 Jobs\21214.00 Holliston-HollistonDamsAlternatives-MA\Task 202 - Factory Pond Dam Alternatives\FIG 3 SITE SKETCH.dwg

SEEPAGE/STAINING AREA

ABANDONED 18" PIPE (BURRIED)

CLEAR SLOPE OF UNWANTED VEGETATION; REGRADE TO EVEN SLOPES; LOAM AND SEED

WOODLAND STREET

ASSUMED BENCHMARK
TOP OF HYDRANT
EL. 171.00 FT

RESTORE APRON INTEGRITY
(ADDRESS SCOUR HOLE)

REPAIR UPSTREAM WALLS
(REMORTAR MASONRY/SEAL
AND PATCH CONCRETE)

UPSTREAM WALL, TYP.
BOTH SIDES SPILLWAY

BOULDER

FILL VOIDS; REGRADE DISTURBED

POTENTIAL ABANDONED
OUTLET ALIGNMENT

13' WIDE OVERFLOW
PRIMARY SPILLWAY

FLOW

REPAIR UPSTREAM WALLS
(REMORTAR MASONRY/SEAL
AND PATCH CONCRETE)

UPSTREAM WATER DURING INSPECTION,
EL. 163.78 FT (FEB. 13, 2007)

GRADE SLOPE; RESET BOULDER SLOPE
PROTECTION (TYP. BOTH SIDES OF SPILLWAY)

CLEAR AND GRUB UPSTREAM SLOPE

FACTORY POND
(IMPOUNDMENT)
NORMAL POOL EL. 163.5 FT±

GRADE SLOPE; RESET BOULDER SLOPE
PROTECTION (TYP. BOTH SIDES OF SPILLWAY)

APPARENT CONCRETE HEADWALL

CLEAR AND GRUB UPSTREAM SLOPE

REPAIR CONCEPT

SCALE: 1"=20'

Y:\JOBS\21 Jobs\21214.00 Holliston-HollistonDamsAlternatives-MA\Task 202 - Factory Pond Dam Alternatives\dwgs\FIG 4.1 REPAIR.dwg

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SCALE ADJUSTMENT GUIDE

0" 1"

BAR IS ONE INCH ON ORIGINAL DRAWING.

FACTORY POND DAM

MA02952 / 4-9-136-7

HOLLISTON, MASSACHUSETTS

TOWN OF HOLLISTON

REVISIONS:

PROJECT NO.:	21214.00/202
DATE:	NOVEMBER 2021
SCALE:	AS NOTED
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CHECKED BY:	JMB
DRAWN BY:	LMC
APPROVED BY:	ARO

REPAIR CONCEPT

FIGURE NO.:

4.1

SEEPAGE/STAINING AREA

ABANDONED 18" PIPE (BURRIED)

CLEAR SLOPE OF UNWANTED VEGETATION; REGRADE TO EVEN SLOPES; LOAM AND SEED

WOODLAND STREET

REPAIR BRIDGE ABUTMENT WALLS

1+35

1+00

ASSUMED BENCHMARK
TOP OF HYDRANT
EL. 171.00 FT

0+00

BOULDER

PROPOSED APRON AND BAFFLE BLOCKS

REMOVE AND DISPOSE EXISTING SLAB, SPILLWAY, AND WALLS

UPSTREAM WALL, TYP. BOTH SIDES SPILLWAY

POTENTIAL ABANDONED OUTLET ALIGNMENT

FORMALLY ABANDON OUTLET

13' WIDE OVERFLOW PRIMARY SPILLWAY

FLOW

PROPOSED STOP LOG BAY

PROPOSED SINGLE CYCLE LABYRINTH SPILLWAY WEIR

PROPOSED GATED POND DRAIN

UPSTREAM WATER DURING INSPECTION, EL. 163.78 FT (FEB. 13, 2007)

GRADE SLOPE; RESET BOULDER SLOPE PROTECTION (TYP. BOTH SIDES OF SPILLWAY)

CLEAR AND GRUB UPSTREAM SLOPE

FACTORY POND
(IMPOUNDMENT)
NORMAL POOL EL. 163.5 FT±

GRADE SLOPE; RESET BOULDER SLOPE PROTECTION (TYP. BOTH SIDES OF SPILLWAY)

APPARENT CONCRETE HEADWALL

CLEAR AND GRUB UPSTREAM SLOPE

REHABILITATION CONCEPT

SCALE: 1"=20'

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SCALE ADJUSTMENT GUIDE

0" 1"

BAR IS ONE INCH ON ORIGINAL DRAWING.

FACTORY POND DAM

MA02952 / 4-9-136-7

HOLLISTON, MASSACHUSETTS

TOWN OF HOLLISTON

REVISIONS:

PROJECT NO.:	21214.00/202
DATE:	NOVEMBER 2021
SCALE:	AS NOTED
DESIGNED BY:	ARO
CHECKED BY:	JMB
DRAWN BY:	LMC
APPROVED BY:	ARO

REHABILITATION CONCEPT

FIGURE NO.:

4.2

Y:\JOBS\21 Jobs\21214.00 Holliston-HollistonDamsAlternatives-MA\Task 202 - Factory Pond Dam Alternatives\dwgs\FIG 4.2 REHAB.dwg

REMOVE AND DISPOSE EXISTING DOWNSTREAM BRIDGE; CONSTRUCT OPEN CHANNEL

SEEPAGE/STAINING AREA

ABANDONED 18" PIPE (BURRIED)

152.99

156.19

154.87

160

167.03

164.08

165

WOODLAND STREET

166.37

166.20

20' CLEAR NEW BRIDGE

20'

35'

1+35

1+00

0+00

ASSUMED BENCHMARK
TOP OF HYDRANT
EL. 171.00 FT

166.21

166.29

REMOVE AND DISPOSE EXISTING SPILLWAY, SLABS, AND WALLS; CONSTRUCT CHANNEL

35' CLEAR BRIDGE TO MEET STREAM CROSSING STANDARDS

BOULDER

166.87

UPSTREAM WALL, TYP. BOTH SIDES SPILLWAY

158.77

163.51

POTENTIAL ABANDONED OUTLET ALIGNMENT

FLOW

13' WIDE OVERFLOW PRIMARY SPILLWAY

165

UPSTREAM WATER DURING INSPECTION, EL. 163.78 FT (FEB. 13, 2007)

FACTORY POND
(IMPOUNDMENT)
NORMAL POOL EL. 163.5 FT±

COMPLETE SEDIMENT MANAGEMENT ACTIVITIES AS/IF REQUIRED

APPARENT CONCRETE HEADWALL

REMOVAL CONCEPT

SCALE: 1"=20'

Y:\JOBS\21 Jobs\21214.00 Holliston-HollistonDamsAlternatives-MA\Task 202 - Factory Pond Dam Alternatives\dwgs\FIG 4.3 REMOVAL.dwg

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SCALE ADJUSTMENT GUIDE

0" 1"

BAR IS ONE INCH ON ORIGINAL DRAWING.

FACTORY POND DAM

MA02952 / 4-9-136-7

HOLLISTON, MASSACHUSETTS

TOWN OF HOLLISTON

REVISIONS:

PROJECT NO.:	21214.00/202
DATE:	NOVEMBER 2021
SCALE:	AS NOTED
DESIGNED BY:	ARO
CHECKED BY:	JMB
DRAWN BY:	LMC
APPROVED BY:	ARO

REMOVAL CONCEPT

FIGURE NO.:

4.3

APPENDIX A
Visual Dam Inspection Limitations
Factory Pond Dam
Holliston, Massachusetts

VISUAL DAM INSPECTION LIMITATIONS

Visual Inspection

1. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigations and analyses involving topographic mapping, subsurface investigations, testing and detailed computational evaluations are beyond the scope of this report.

2. In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection, along with data available to the inspection team.

3. In cases where an impoundment is lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions, which might otherwise be detectable if inspected under the normal operating environment of the structure.

4. It is critical to note that the condition of the dam is evolutionary in nature and depends on numerous and constantly changing internal and external conditions. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Use of Report

1. The applicability of other environmental permits (ie., NOI, PGP, Water Quality Certificate, etc.) needs to be determined prior to undertaking maintenance activities that may occur within resource areas under the jurisdiction of MADEP, the local conservation commission or other regulatory agency.

2. This report has been prepared for the exclusive use of the Town of Holliston for specific application to the reference Factory Pond Dam in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made.

3. This report has been prepared for this project by Pare. This report is for preliminary evaluation purposes only and is not necessarily sufficient to support design or repairs or recommendations or to prepare an accurate bid.

APPENDIX B
Opinion of Probable Costs
Factory Pond Dam
Holliston, Massachusetts

PARE CORPORATION

Project:	Factory Pond Dam	**Project No.:**	21214.00
Subject:	Opinions of Probable Costs		
Computation By:	MLP	**Date:**	January 2022
Check By:		**Date:**	

CONCEPTUAL DESIGN OPINION OF PROBABLE COST

Alternate 1: Dam Repair

Item	Quantity	Unit	Unit Price	Total	Source	Notes
General Bid Items						
Construction Trailer and Utilities	2	MON	$ 2,700.00	$ 5,400.00	Engineering Judgement	
Project Superintendent	2	MON	$ 8,200.00	$ 16,400.00	Engineering Judgement	
QC Plans	10	HR	$ 75.00	$ 750.00	Engineering Judgement	
Submittals	10	HR	$ 75.00	$ 750.00	Engineering Judgement	
Schedules	10	HR	$ 75.00	$ 750.00	Engineering Judgement	
Meetings	8	EA	$ 150.00	$ 1,200.00	Engineering Judgement	
Project Sign	1	LS	$ 1,000.00	$ 1,000.00	Engineering Judgement	
Proctor Tests	1	TEST	$ 225.00	$ 200.00	Laboratory Quote plus markup	
Sieve Analyses	2	EA	$ 110.00	$ 220.00	Laboratory Quote plus markup	
Concrete Sampling/Testing	2	EA	$ 500.00	$ 1,000.00	Recent project bids	
Concrete Compression Tests	1	EA	$ 50.00	$ 50.00	Laboratory Quote plus markup	
Field Density Testing	1	DAY	$ 500.00	$ 500.00	Recent project bids	
Chemical Soil Tests	0	EA	$ 1,000.00	$ -	Recent project bids	
Subtotal				**$ 28,220.00**		
Mobilization & Demobilization						
Mobilization	1	LS	$ 12,000.00	$ 12,000.00	Engineering Judgment	Assume 5% M&D total
Demobilization	1	LS	$ 5,000.00	$ 5,000.00	Engineering Judgment	
Subtotal				**$ 17,000.00**		
Clear and Grub						
Clear and Grub	0.5	ACRE	$ 5,000.00	$ 2,500.00	RSMEANS 31 11 10.10 0200	
Clear Trees up to 24"	10	EA	$ 500.00	$ 5,000.00	RSMEANS 31 13 13 20 3150	
Engineered Fill Imported	30	TN	$ 25.00	$ 750.00	Recent Project Costs	
Engineered Fill Placed	15	CY	$ 40.00	$ 600.00	Recent Project Costs	
Subtotal				**$ 8,850.00**		
Erosion Control						
Hay bales	300	LF	$ 9.00	$ 2,700.00	RSMEANS 31 25 14 16 0600	
Silt Fence	300	LF	$ 5.00	$ 1,500.00	RSMEANS 31 25 14 16 1000 + markup	
Maintenance and Removal	1	LS	$ 3,000.00	$ 3,000.00	Engineer's Judgment	
Turbidity Barrier	100	LF	$ 30.00	$ 3,000.00	Recent project bids	
Subtotal				**$ 10,200.00**		
Control of Water / Water Diversion						
Implement Drawdown	1	LS	$ 15,000.00	$ 15,000.00	Engineer's Judgment	
Small Sand Bag	100	EA	$ 6.00	$ 600.00	Engineer's Judgment	0.5'x2'x1'
Large Sand Bag	35	EA	$ 200.00	$ 7,000.00	Engineer's Judgment	3'x3'x3'
Install and Remove Sand Bag	1	LS	$ 8,000.00	$ 8,000.00	Engineer's Judgment	
Install and Remove Siphon for drawdown	1	LS	$ 10,000.00	$ 10,000.00	Engineer's Judgment	
Subtotal				**$ 40,600.00**		
Embankment Work						
Regrade Upstream and Downstream Slope	340	CY	$ 40.00	$ 13,600.00	Engineering's Judgement	
Import EF	680	TN	$ 25.00	$ 17,000.00	Engineering's Judgement	
Upstream Slope Riprap	220	SY	$ 85.00	$ 18,700.00	RSMEANS 31 37 13 10 0200	
Import Riprap	221	TN	$ 40.00	$ 8,840.00	RSMEANS 31 37 13 10 0350	
Geotextile Fabric	220	SY	$ 6.00	$ 1,320.00	RSMEANS 3132 19 16 1550 plus markup	
Loam DS Slope	1000	SY	$ 7.00	$ 7,000.00	RSMEANS 32 91 19 13 0800	
Import Loam	230	TN	$ 25.00	$ 5,750.00	Local Price	
Subtotal				**$ 72,210.00**		
Spillway work						
Scour Apron	30	CY	$ 1,250.00	$ 37,500.00	Engineering's Judgement	
Seal and Patch Concrete	1	LS	$ 50,000.00	$ 50,000.00	Engineering's Judgement	
Repoint Upstream Wall	800	LF	$ 45.00	$ 36,000.00	RSMEANS 04 01 20 41 01 32	
Subtotal				**$ 123,500.00**		
			SUBTOTAL	$ 300,580.00		
			Contract Bonds	$ 4,000.00		
			Design Contingency	**$ 105,350.00**	35%	
			OPINION OF PROBABLE CONSTRUCTION COST	**$ 410,000.00**		
			Engineering & Design	$ 55,000.00		
			Permitting	$ 15,000.00		
			Construction Phase Services	$ 60,000.00		
			OPINION OF PROBABLE CONSTRUCTION COST	**$ 540,000.00**		

PARE CORPORATION

Project: Factory Pond Dam **Project No.:** 21214.00
Subject: Opinions of Probable Costs
Computation By: MLP **Date:** January 2022
Check By: **Date:**

CONCEPTUAL DESIGN OPINION OF PROBABLE COST

Alternate 2: Dam Rehabilitation

Item	Quantity	Unit	Unit Price	Total	Source	Notes
General Bid Items						
Construction Trailer and Utilities	5	MON	$ 2,700.00	$ 13,500.00	Engineering Judgement	
Project Superintendent	5	MON	$ 8,200.00	$ 41,000.00	Engineering Judgement	
QC Plans	20	HR	$ 75.00	$ 1,500.00	Engineering Judgement	
Submittals	20	HR	$ 75.00	$ 1,500.00	Engineering Judgement	
Schedules	20	HR	$ 75.00	$ 1,500.00	Engineering Judgement	
Meetings	20	EA	$ 150.00	$ 3,000.00	Engineering Judgement	
Project Sign	1	LS	$ 1,000.00	$ 1,000.00	Engineering Judgement	
Proctor Tests	1	TEST	$ 200.00	$ 200.00	Laboratory Quote plus markup	
Sieve Analyses	4	EA	$ 110.00	$ 440.00	Laboratory Quote plus markup	
Concrete Sampling/Testing	5	EA	$ 500.00	$ 2,500.00	Recent project bids	
Concrete Compression Tests	1	EA	$ 50.00	$ 50.00	Laboratory Quote plus markup	
Field Density Testing	1	DAY	$ 500.00	$ 500.00	Recent project bids	
Chemical Soil Tests	0	EA	$ 1,000.00	$ -	Recent project bids	
Subtotal				**$ 66,690.00**		
Mobilization & Demobilization						
Mobilization	1	LS	$ 20,000.00	$ 20,000.00	Engineering Judgment	
Demobilization	1	LS	$ 10,000.00	$ 10,000.00	Engineering Judgment	
Subtotal				**$ 30,000.00**		
Clear and Grub						
Clear and Grub	0.5	ACRE	$ 5,000.00	$ 2,500.00	RSMEANS 31 11 10.10 0200	
Clear Trees up to 24"	10	EA	$ 500.00	$ 5,000.00	RSMEANS 31 13 13 20 3150	
Engineered Fill Imported	30	TN	$ 25.00	$ 750.00	Recent Project Costs	
Engineered Fill Placed	15	CY	$ 40.00	$ 600.00	Recent Project Costs	
Subtotal				**$ 8,850.00**		
Erosion Control						
Hay bales	300	LF	$ 9.00	$ 2,700.00	RSMEANS 31 25 14 16 0600	
Silt Fence	300	LF	$ 5.00	$ 1,500.00	RSMEANS 31 25 14 16 1000 + markup	
Maintenance and Removal	1	LS	$ 3,000.00	$ 3,000.00	Engineer's Judgment	
Turbidity Barrier	100	LF	$ 30.00	$ 3,000.00	Recent project bids	
Subtotal				**$ 10,200.00**		
Control of Water / Water Diversion						
Implement Drawdown	1	LS	$ 10,000.00	$ 10,000.00	Engineer's Judgment	
Small Sand Bag	100	EA	$ 6.00	$ 600.00	Engineer's Judgment	0.5'x2'x1'
Large Sand Bag	35	EA	$ 200.00	$ 7,000.00	Engineer's Judgment	3'x3'x3'
Install and Remove Sand Bag	1	LS	$ 8,000.00	$ 8,000.00	Engineer's Judgment	
Install and Remove Siphon for drawdown	1	LS	$ 10,000.00	$ 10,000.00	Engineer's Judgment	
Subtotal				**$ 35,600.00**		
Embankment Work						
Regrade Upstream and Downstream Slope	340	CY	$ 40.00	$ 13,600.00	Engineering's Judgement	
Import EF	680	TN	$ 25.00	$ 17,000.00	Engineering's Judgement	
Upstream Slope Riprap	260	SY	$ 85.00	$ 22,100.00	RSMEANS 31 37 13 10 0200	
Import Riprap	261	TN	$ 40.00	$ 10,440.00	RSMEANS 31 37 13 10 0350	
Geotextile Fabric	260	SY	$ 6.00	$ 1,560.00	RSMEANS 3132 19 16 1550 plus markup	
Loam DS Slope	1000	SY	$ 7.00	$ 7,000.00	RSMEANS 32 91 19 13 0800	
Import Loam	230	TN	$ 25.00	$ 5,750.00	Local Price	
Subtotal				**$ 77,450.00**		
Abandon Outlet						
Flowable Fill	60	CY	$ 150.00	$ 9,000.00	RSMEANS 03 31 13 35 43 50 plus mark up	
Subtotal				**$ 9,000.00**		
Spillway work						
Spillway demolition	1	LS	$ 20,000.00	$ 20,000.00	Engineering's Judgement	
Excavation & Prep	200	CY	$ 25.00	$ 5,000.00	Engineering's Judgement	
Proposed Apron and Baffle Blocks	45	CY	$ 1,000.00	$ 45,000.00	Engineering's Judgement	
Stop Log	1	LS	$ 6,000.00	$ 6,000.00	Engineering's Judgement	
Gated Pond Drain	1	LS	$ 12,000.00	$ 12,000.00	Recent Project Quotes Plus Install	
Labyrinth Weir	14	CY	$ 1,500.00	$ 21,000.00	Engineering's Judgement	
Spillway backfill	150	CY	$ 40.00	$ 6,000.00	Engineering's Judgement	
Import EF	300	TN	$ 25.00	$ 7,500.00	Engineering's Judgement	
Subtotal				**$ 122,500.00**		
Bridge Repair						
Bridge Repair	1	LS	$ 400,000.00	$ 400,000.00		
Subtotal				**$ 400,000.00**		
			SUBTOTAL	$ 760,290.00		
			Contract Bonds	$ 8,000.00		
			Design Contingency	**$ 228,300.00**	30%	
			OPINION OF PROBABLE CONSTRUCTION COST	**$ 997,000.00**		
			Engineering & Design	$ 80,000.00		
			Permitting	$ 30,000.00		
			Construction Phase Services	$ 80,000.00		
			OPINION OF PROBABLE CONSTRUCTION COST	**$ 1,187,000.00**		

PARE CORPORATION

Project:	Factory Pond Dam	**Project No.:**	21214.00
Subject:	Opinions of Probable Costs		
Computation By:	MLP	**Date:**	January 2022
Check By:		**Date:**	

CONCEPTUAL DESIGN OPINION OF PROBABLE COST

Alternate 3: Dam Removal

Item	Quantity	Unit	Unit Price	Total	Source	Notes
General Bid Items						
Construction Trailer and Utilities	6	MON	$ 2,700.00	$ 16,200.00	Engineering Judgement	
Project Superintendent	6	MON	$ 8,200.00	$ 49,200.00	Engineering Judgement	
QC Plans	30	HR	$ 75.00	$ 2,250.00	Engineering Judgement	
Submittals	30	HR	$ 75.00	$ 2,250.00	Engineering Judgement	
Schedules	30	HR	$ 75.00	$ 2,250.00	Engineering Judgement	
Meetings	24	EA	$ 150.00	$ 3,600.00	Engineering Judgement	
Project Sign	1	LS	$ 1,000.00	$ 1,000.00	Engineering Judgement	
Proctor Tests	1	TEST	$ 225.00	$ 200.00	Laboratory Quote plus markup	
Sieve Analyses	2	EA	$ 110.00	$ 220.00	Laboratory Quote plus markup	
Concrete Sampling/Testing	4	EA	$ 500.00	$ 2,000.00	Recent project bids	
Concrete Compression Tests	1	EA	$ 50.00	$ 50.00	Laboratory Quote plus markup	
Field Density Testing	0	DAY	$ 500.00	$ -	Recent project bids	
Chemical Soil Tests	0	EA	$ 1,000.00	$ -	Recent project bids	
Subtotal				**$ 79,220.00**		
Mobilization & Demobilization						
Mobilization	1	LS	$ 60,000.00	$ 60,000.00	Engineering Judgment	
Demobilization	1	LS	$ 30,000.00	$ 30,000.00	Engineering Judgment	
Subtotal				**$ 90,000.00**		
Clear and Grub						
Clear and Grub	0.25	ACRE	$ 5,000.00	$ 1,250.00	RSMEANS 31 11 10.10 0200	
Clear Trees up to 24"	4	EA	$ 500.00	$ 2,000.00	RSMEANS 31 13 13 20 3150	
Engineered Fill Imported	12	TN	$ 25.00	$ 300.00	Recent Project Costs	
Engineered Fill Placed	6	CY	$ 40.00	$ 240.00	Recent Project Costs	
Subtotal				**$ 3,790.00**		
Erosion Control						
Hay bales	300	LF	$ 9.00	$ 2,700.00	RSMEANS 31 25 14 16 0600	
Silt Fence	300	LF	$ 5.00	$ 1,500.00	RSMEANS 31 25 14 16 1000 + markup	
Maintenance and Removal	1	LS	$ 3,000.00	$ 3,000.00	Engineer's Judgment	
Turbidity Barrier	100	LF	$ 30.00	$ 3,000.00	Recent project bids	
Subtotal				**$ 10,200.00**		
Control of Water / Water Diversion						
Implement Drawdown	1	LS	$ 5,000.00	$ 5,000.00	Engineer's Judgment	
Small Sand Bag	50	EA	$ 6.00	$ 300.00	Engineer's Judgment	0.5'x2'x1'
Large Sand Bag	75	EA	$ 200.00	$ 15,000.00	Engineer's Judgment	3'x3'x3'
Install and Remove Sand Bag	1	LS	$ 8,000.00	$ 8,000.00	Engineer's Judgment	
Subtotal				**$ 28,300.00**		
Structures Demolition						
Concrete Disposal	120	TN	$ 300.00	$ 36,000.00	Engineering's Judgement	
Channel Excavation	2100	CY	$ 15.00	$ 31,500.00	Engineering's Judgement	
Dispose Material	2100	CY	$ 25.00	$ 52,500.00	Engineering's Judgement	
Downstream Bridge Removal	70	TN	$ 300.00	$ 21,000.00	RSMEANS 04 01 20 41 01 32	
Subtotal				**$ 141,000.00**		
Bridge Replacement						
Existing Bridge Demolition	1	LS	$ 250,000.00	$ 250,000.00		
Substructure Demolition	1	LS	$ 100,000.00	$ 100,000.00		
Bridge Replacement	1	LS	$ 1,000,000.00	$ 1,000,000.00		
Subtotal				**$ 1,350,000.00**		
Sediment Management						
Dredging & Disposal	TBD	-	-	$ -	Sediment Management Reqts Unknown	
Subtotal				**$ -**		

SUBTOTAL	$	1,702,510.00
Contract Bonds	$	18,000.00
Design Contingency	**$**	**510,900.00**
OPINION OF PROBABLE CONSTRUCTION COST	**$**	**2,232,000.00**
Engineering & Design	$	150,000.00
Permitting	$	80,000.00
Construction Phase Services	$	50,000.00
OPINION OF PROBABLE CONSTRUCTION COST	**$**	**2,512,000.00**

30%

APPENDIX C
Previous Reports and References
Factory Pond Dam
Holliston, Massachusetts

PREVIOUS REPORTS AND REFERENCES

The following documents were identified within the dam safety database or reference as part of this work:

1. "Emergency Action Plan for Factory Pond Dam", Lenard Engineering. August 25, 2021
2. "Office of Dam Safety Poor and Unsafe Condition Dam Follow-up Inspection Form – Factory Pond Dam", Lenard Engineering. Date of Inspection: May 10, 2021
3. "6-Month Follow-up Dam Safety Visual Inspection – Factory Pond Dam", Lenard Engineering. Date of Inspection: November 26, 2018
4. "Factory Pond Dam Phase I Inspection/Evaluation Report", Lenard Engineering. Date of Inspection: October 13, 2017
5. "6-Month Follow-up Dam Safety Visual Inspection – Factory Pond Dam", Lenard Engineering. Date of Inspection: November 10, 2016
6. "6-Month Follow-up Dam Safety Visual Inspection – Factory Pond Dam", Lenard Engineering. Date of Inspection: June 13, 2013
7. "Factory Pond Dam Phase I Inspection/Evaluation Report", Lenard Engineering. Date of Inspection: June 8, 2012
8. "6-Month Follow-up Dam Safety Visual Inspection – Factory Pond Dam", Lenard Engineering, Date of Inspection: May 9, 2011
9. "6-Month Follow-up Dam Safety Visual Inspection – Factory Pond Dam", Lenard Engineering. Date of Inspection: November 16, 2010
10. "Followup Inspection Report – Factory Pond Dam", Fuss & O'Neill. Date of Inspection: May 25, 2010
11. "Poor Condition Follow-Up Inspection – Factory Pond Dam", Pare. Date of Inspection: May 23, 2008
12. "Factory Pond Dam Phase I Inspection/Evaluation Report", Pare. Date of Inspection: February 13, 2007
13. "Municipally Owned Dam Inspcetion/Evaluation Report, Factory Pond Dam", Gifford, D.G. (Haley & Aldrich. Date of Inspection: May 5, 1999
14. "Factory Pond Dam Inspection Report", Smith, R.W. (CVP). Date of Inspection October 8, 1987
15. "Inspection Report – Dams and Reservoirs, Factory Pond Dam", Pare & Pizan. Date of Inspection: August 16, 1973

The following references were utilized during the preparation of this report and the development of the recommendations presented herein:

1. "Design of Small Dams", United States Department of the Interior Bureau of Reclamation, 1987
2. "ER 110-2-106 - Recommended Guidelines for Safety Inspection of Dams", Department of the Army, September 26, 1979.
3. "Guidelines for Reporting the Performance of Dams" National Performance of Dams Program, August 1994.
4. 302 CMR: Department of Conservation and Recreation Section 10.00 Dam Safety
5. Massachusetts State Building Code Sec. 1612.4.9
6. Massachusetts Wetlands Protection Act Regulations 310 CMR 10.00

APPENDIX D
Common Dam Safety Definitions
Factory Pond Dam
Holliston, Massachusetts

COMMON DAM SAFETY DEFINITIONS

For a comprehensive list of dam engineering terminology and definitions refer to 302 CMR10.00 Dam Safety, or other reference published by FERC, Dept. of the Interior Bureau of Reclamation, or FEMA. Please note should discrepancies between definitions exits, those definitions included within 302 CMR 10.00 govern for dams located within the Commonwealth of Massachusetts.

Orientation

Upstream – Shall mean the side of the dam that borders the impoundment.

Downstream – Shall mean the high side of the dam, the side opposite the upstream side.

Right – Shall mean the area to the right when looking in the downstream direction.

Left – Shall mean the area to the left when looking in the downstream direction.

Dam Components

Dam – Shall mean any artificial barrier, including appurtenant works, which impounds or diverts water.

Embankment – Shall mean the fill material, usually earth or rock, placed with sloping sides, such that it forms a permanent barrier that impounds water.

Crest – Shall mean the top of the dam, usually provides a road or path across the dam.

Abutment – Shall mean that part of a valley side against which a dam is constructed. An artificial abutment is sometimes constructed as a concrete gravity section, to take the thrust of an arch dam where there is no suitable natural abutment.

Appurtenant Works – Shall mean structures, either in dams or separate therefrom. including but not be limited to, spillways; reservoirs and their rims; low level outlet works; and water conduits including tunnels, pipelines, or penstocks, either through the dams or their abutments.

Spillway – Shall mean a structure over or through which water flows are discharged. If the flow is controlled by gates or boards, it is a controlled spillway; if the fixed elevation of the spillway crest controls the level of the impoundment, it is an uncontrolled spillway.

Size Classification

(as listed in Commonwealth of Massachusetts, 302 CMR 10.00 *Dam Safety*)

Large – structure with a height greater than 40 feet or a storage capacity greater than 1,000 acre-feet.

Intermediate – structure with a height between 15 and 40 feet or a storage capacity of 50 to 1,000 acre-feet.

Small – structure with a height between 6 and 15 feet and a storage capacity of 15 to 50 acre-feet.

Non-Jurisdictional – structure less than 6 feet in height or having a storage capacity of less than 15 acre-feet.

Hazard Classification

(as listed in Commonwealth of Massachusetts, 302 CMR 10.00 *Dam Safety*)

High Hazard (Class I) – Shall mean dams located where failure will likely cause loss of life and serious damage to home(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).

Significant Hazard (Class II) – Shall mean dams located where failure may cause loss of life and damage to home(s), industrial or commercial facilities, secondary highway(s) or railroad(s), or cause the interruption of the use or service of relatively important facilities.

Low Hazard (Class III) – Dams located where failure may cause minimal property damage to others .Loss of life is not expected.

General

EAP – Emergency Action Plan - Shall mean a predetermined plan of action to be taken to reduce the potential for property damage and/or loss of life in an area affected by an impending dam break.

O&M Manual – Operations and Maintenance Manual; Document identifying routine maintenance and operational procedures under normal and storm conditions.

Normal Pool – Shall mean the elevation of the impoundment during normal operating conditions.

Acre-foot – Shall mean a unit of volumetric measure that would cover one acre to a depth of one foot. It is equal to 43,560 cubic feet. One million U.S. gallons = 3.068 acre feet

Height of Dam – Shall mean the vertical distance from the lowest portion of the natural ground, including any stream channel, along the downstream toe of the dam to the crest of the dam.

Spillway Design Flood (SDF) – Shall mean the flood used in the design of a dam and its appurtenant works particularly for sizing the spillway and outlet works, and for determining maximum temporary storage and height of dam requirements.

Condition Rating

Unsafe - Major structural, operational, and maintenance deficiencies exist under normal operating conditions.

Poor - Significant structural, operation and maintenance deficiencies are clearly recognized for normal loading conditions.

Fair - Significant operational and maintenance deficiencies, no structural deficiencies. Potential deficiencies exist under unusual loading conditions that may realistically occur. Can be used when uncertainties exist as to critical parameters.

Satisfactory - Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result in deficiencies.

Good - No existing or potential deficiencies recognized. Safe performance is expected under all loading including SDF.

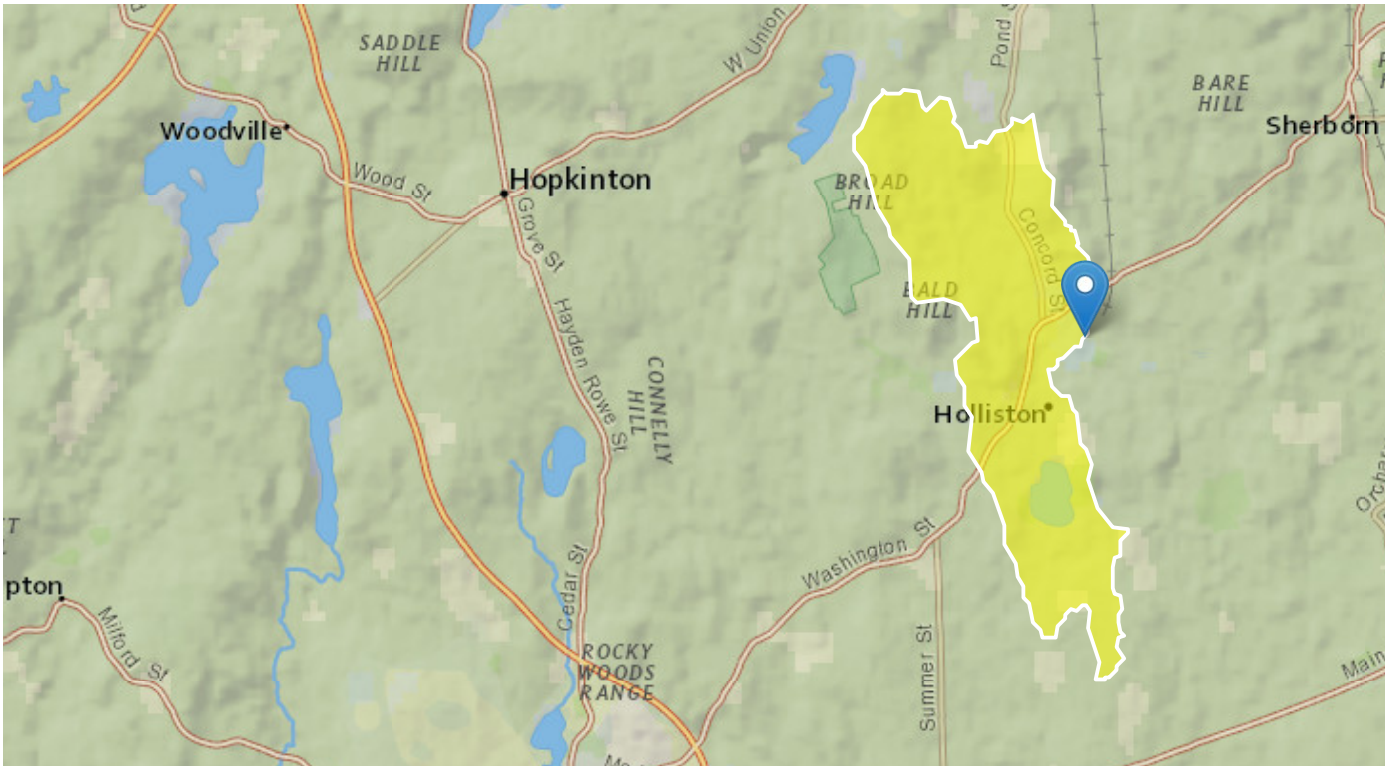
APPENDIX E
Supporting Information

Factory Pond Dam
Holliston, Massachusetts

1. Hydrologic and Hydraulic Analyses Output

Factory Pond StreamStats Report

Region ID: MA
Workspace ID: MA20211130220316285000
Clicked Point (Latitude, Longitude): 42.20930, -71.41802
Time: 2021-11-30 17:03:35 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	5.84	square miles
ELEV	Mean Basin Elevation	243	feet
LC06STOR	Percentage of water bodies and wetlands determined from the NLCD 2006	11.74	percent
BSLDEM10M	Mean basin slope computed from 10 m DEM	5.737	percent

Peak-Flow Statistics Parameters [Peak Statewide 2016 5156]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	5.84	square miles	0.16	512
ELEV	Mean Basin Elevation	243	feet	80.6	1948
LC06STOR	Percent Storage from NLCD2006	11.74	percent	0	32.3

Peak-Flow Statistics Flow Report [Peak Statewide 2016 5156]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	ASEp
50-percent AEP flood	143	ft^3/s	73.3	279	42.3
20-percent AEP flood	235	ft^3/s	119	465	43.4
10-percent AEP flood	307	ft^3/s	152	622	44.7
4-percent AEP flood	411	ft^3/s	196	861	47.1
2-percent AEP flood	497	ft^3/s	230	1070	49.4
1-percent AEP flood	587	ft^3/s	263	1310	51.8
0.5-percent AEP flood	686	ft^3/s	299	1570	54.1
0.2-percent AEP flood	827	ft^3/s	344	1990	57.6

Peak-Flow Statistics Citations

Zarriello, P.J.,2017, Magnitude of flood flows at selected annual exceedance probabilities for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2016–5156, 99 p. (https://dx.doi.org/10.3133/sir20165156)

Bankfull Statistics Parameters [Bankfull Statewide SIR2013 5155]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	5.84	square miles	0.6	329
BSLDEM10M	Mean Basin Slope from 10m DEM	5.737	percent	2.2	23.9

Bankfull Statistics Parameters [Appalachian Highlands D Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	5.84	square miles	0.07722	940.1535

Bankfull Statistics Parameters [New England P Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	5.84	square miles	3.799224	138.999861

Bankfull Statistics Parameters [USA Bieger 2015]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	5.84	square miles	0.07722	59927.7393

Bankfull Statistics Flow Report [Bankfull Statewide SIR2013 5155]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	ASEp
Bankfull Width	29	ft	21.3
Bankfull Depth	1.53	ft	19.8
Bankfull Area	44.1	ft^2	29
Bankfull Streamflow	119	ft^3/s	55

Bankfull Statistics Flow Report [Appalachian Highlands D Bieger 2015]

Statistic	Value	Unit
Bieger_D_channel_width	31.6	ft
Bieger_D_channel_depth	1.86	ft
Bieger_D_channel_cross_sectional_area	59.7	ft^2

Bankfull Statistics Flow Report [New England P Bieger 2015]

Statistic	Value	Unit
Bieger_P_channel_width	41.4	ft
Bieger_P_channel_depth	2.03	ft
Bieger_P_channel_cross_sectional_area	85.1	ft^2

Bankfull Statistics Flow Report [USA Bieger 2015]

Statistic	Value	Unit
Bieger_USA_channel_width	23	ft
Bieger_USA_channel_depth	1.76	ft
Bieger_USA_channel_cross_sectional_area	44.3	ft^2

Bankfull Statistics Flow Report [Area-Averaged]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	ASEp
Bankfull Width	29	ft	21.3
Bankfull Depth	1.53	ft	19.8
Bankfull Area	44.1	ft^2	29
Bankfull Streamflow	119	ft^3/s	55
Bieger_D_channel_width	31.6	ft	
Bieger_D_channel_depth	1.86	ft	
Bieger_D_channel_cross_sectional_area	59.7	ft^2	
Bieger_P_channel_width	41.4	ft	
Bieger_P_channel_depth	2.03	ft	
Bieger_P_channel_cross_sectional_area	85.1	ft^2	
Bieger_USA_channel_width	23	ft	
Bieger_USA_channel_depth	1.76	ft	
Bieger_USA_channel_cross_sectional_area	44.3	ft^2	

Bankfull Statistics Citations

Bent, G.C., and Waite, A.M.,2013, Equations for estimating bankfull channel geometry and discharge for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2013–5155, 62 p., (http://pubs.usgs.gov/sir/2013/5155/)

Bieger, Katrin; Rathjens, Hendrik; Allen, Peter M.; and Arnold, Jeffrey G.,2015, Development and Evaluation of Bankfull Hydraulic Geometry Relationships for the Physiographic Regions of the United States, Publications from USDA-ARS / UNL Faculty, 17p. (https://digitalcommons.unl.edu/usdaarsfacpub/1515?utm_source=digitalcommons.unl.edu%2Fusdaarsfacpub%2F1515&utm_medium=PDF&utm_campaig

Application Version: 4.6.2
StreamStats Services Version: 1.2.22
NSS Services Version: 2.1.2