Section 6
Sediment Transport Model and Evaluation

6.1 Background

A sediment transport model was developed to understand the future movement of a 20 year long term scenario and short term storm scenario (using a 100 year storm) of sediment and soil in the streambed associated with removal of the Patch Pond Dam (PPD).

6.2 Model Approach

A feasibility-level sediment transport simulation was performed to develop a sediment management strategy and final design considerations should the City elect to move forward with removal of the dam. The most important determinate of long-term erosion upstream of the proposed dam removal is the depth to a non-erodible soil or bedrock layer. Using the native soil samples collected along with knowledge of soil characteristics, CDM Smith performed a sediment transport analysis using a Mobile Boundary Hydraulics (MBH) Hydraulic Engineering Centers (HEC) 6T model (MBH, 2010) to simulate short- and long-term changes in streambed elevation within Patch Pond and its upstream and downstream reaches.

HEC-6T is an advanced and proprietary version of U.S. Army Corps of Engineers' (USACE) HEC-6 model (USACE, 1993), which is a one-dimensional sediment transport model used to simulate a long-term average pattern of scour and deposition in rivers and reservoirs. HEC-6T predicts water surface and sediment bed surface profiles by computing the interaction between sediment material in the riverbed and the sediment carrying capacity of the river flow. As a dynamic model, it can be used to simulate the short- and long-term changes in channel and reservoir bed elevation, and can be used to evaluate existing and proposed river bed stability and sediment transport characteristics.

6.3 Model Development

The model input data for the HEC-6T consists of geometric, hydrologic, and sediment data. The model can be run for long-term erosion and short-term extreme flood scenarios.

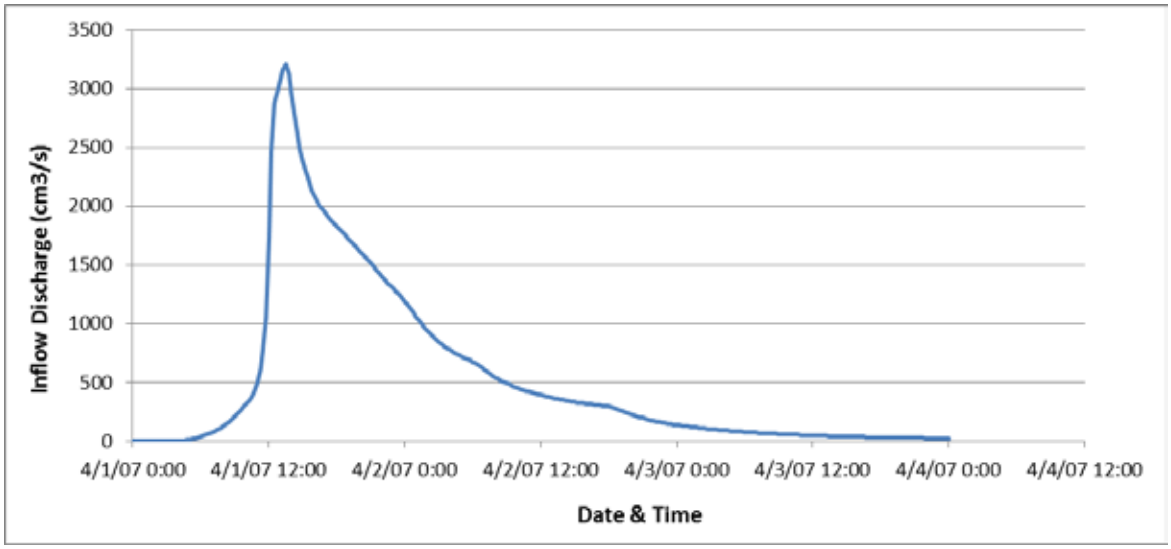
6.3.1 Geometric Data

Geometric input data includes cross section geometry, reach lengths, Manning's roughness, and expansion/contraction coefficients. The HEC-RAS model developed for this study and described in Section 5 was used for geometric data. The cross sections of the developed HEC-RAS model were converted into a HEC-6T input file format. Figure 5-6 in Section 5 shows the model cross sections. The HEC-6T model was developed for two channel geometries; existing geometry with the PPD (the same geometry as the existing conditions HEC-RAS model), and the existing geometry without the PPD (the PPD removed from the geometry of the existing conditions HEC-RAS model).

6.3.2 Hydrology and Input Hydrograph

Hydrologic data required for HEC-6T model development includes time series flow data and a downstream flow boundary condition. For short-term simulation, the 100-year storm hydrograph was used. This hydrograph, shown in **Figure 6-1**, was generated from the HEC-HMS runoff model described in Section 5.3.2 with rainfall depths from the Northeast Regional Climate Center (NRCC). As discussed in Section 5.3.2.3, the NRCC provides reliable extreme precipitation estimates for New England states. For long-term simulation, a long-term set of flows were generated using the same HEC-HMS run off model with the daily rainfall record obtained from the Worcester Regional Airport from 1984 to 2014 describe in Section5.3.2.3. This daily rainfall record can be seen in **Figure 5-4**.

Figure 6-1
Inflow Hydrograph for 100-Year Flood



6.3.3 Sediment and Transport Model

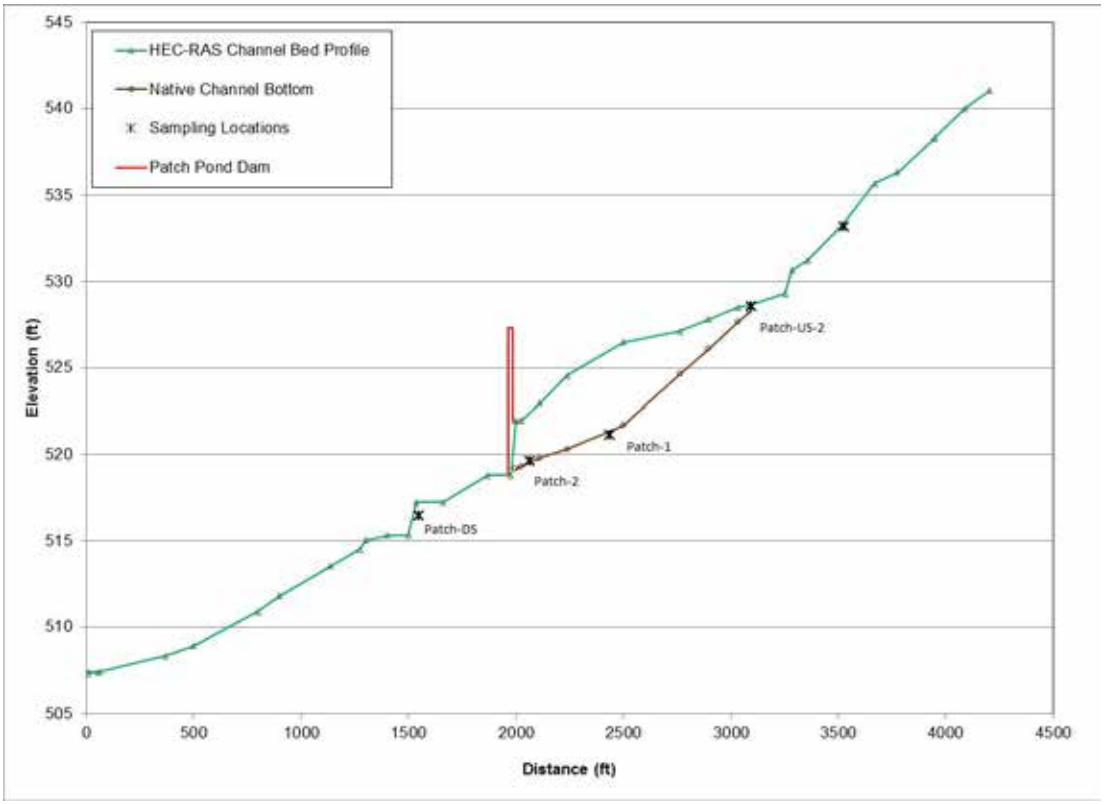
Sediment input data required for the HEC-6T model consists of streambed material gradations and inflowing sediment load data.

Streambed material gradation data was obtained from grain size distribution analyses for soil samples taken during the April 2014 field investigations as described in Section 4. The following five samples were collected:

- **Patch-US-01-04-2014:** A sample collected upstream of the dam impoundment; near the River Cross Section RS 3520.837
- **Patch-US-02-04-2014:** A sample collected within the dam impoundment; near RS 3089.138
- **Patch-1-04-2014:** A sample collected within the dam impoundment; near RS 2497.725
- **Patch-2-04-2014:** A sample collected within the dam impoundment; near RS 2111.411
- **Patch-DS-04-2014:** A sample collected upstream of the dam impoundment; near RS 1401.211

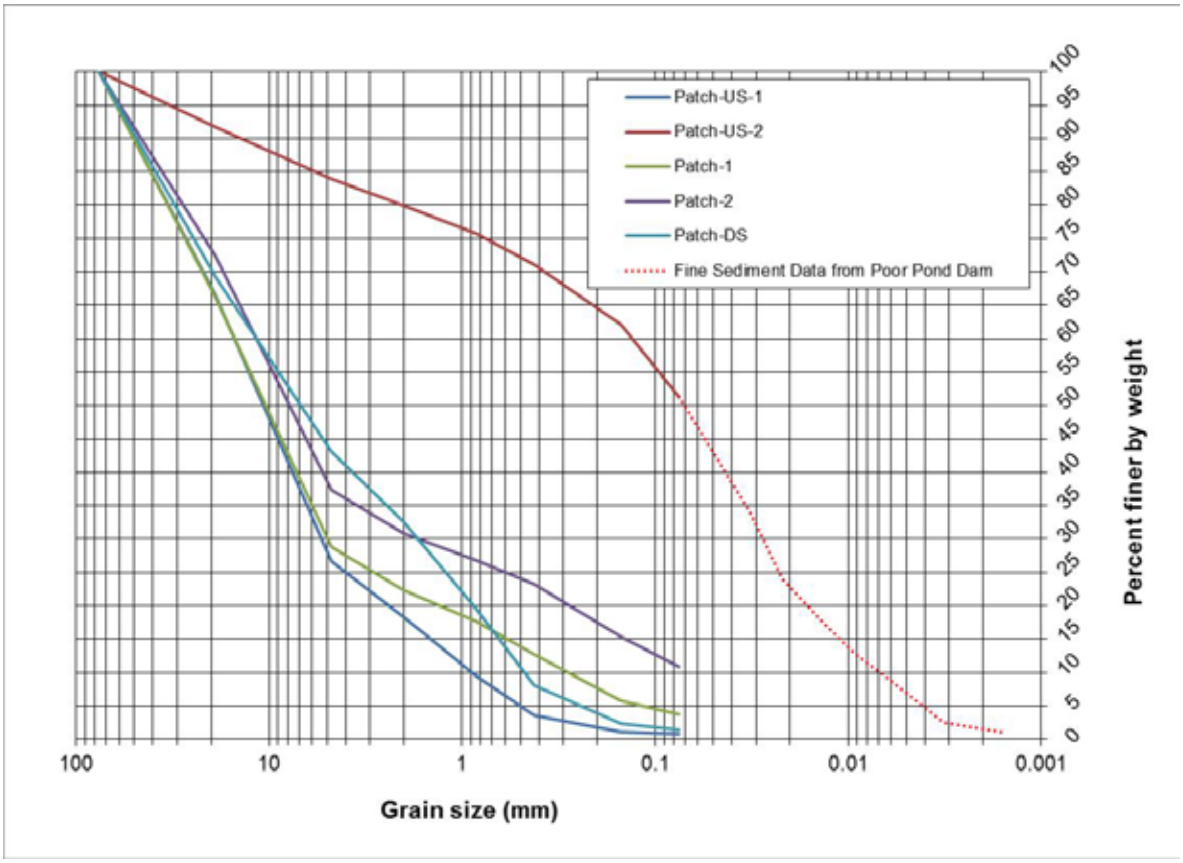
Of the five samples, two (Patch-1-04-2014 and Patch-2-04-2014) represent the native soil below the accumulated sediment within the impoundment, while three (Patch-US-01-04-2014, Patch-US-02-04-2014, and Patch-DS-04-2014) represent the soil at the surface of the channel bed (see **Figure 6-2**). However, to simulate the streambed elevation changes using the HEC-6T model, the bed material gradation data at the surface of the streambed is required. Therefore, for all the cross sections within the impoundment, the gradation data at Patch-US-02-04-2014 was used instead of those at Patch-1-04-2014 and Patch-2-04-2014. This is because samples at Patch-1-04-2014 and Patch-2-04-2014 were collected at the native soil layer below the accumulated sediment, whereas Patch-US-02-04-2014 was collected at the surface of the channel bed.

Figure 6-2
Channel Bed and Native Bottom Profiles with the Sampling Locations



The sample collected at Patch-US-02-04-2014 was not analyzed for silt and clay material, because hydrometer analysis was not performed for the samples collected in 2014. Therefore, the gradation data from the previous Poor Farm Dam Removal Feasibility Study (*CDM Smith, 2013*) was adopted to get the gradation for the silt and clay material of the sample collected at Patch-US-02-04-2014. For this, the gradation curve at Patch-US-02-04-2014 was compared to those of the five samples collected at Poor Farm Dam, and the gradation curve closest to that of Patch-US-02-04-2014 was selected (i.e., sample PFD5-SED). Then, the gradation curve at Patch-US-02-04-2014 was extended using that of PFD5-SED. **Figure 6-3** presents the extended gradation curve at Patch-US-02-04-2014.

Figure 6-3
Bed Material Gradation Curves of Sediment Samples



In the HEC-6T model, the maximum depth below the initial streambed available for scour must be defined at each cross section (maximum erodible depth). Within the impoundment, the depths of the accumulated sediment layer were used as the maximum erodible depth. The streambed of the reaches downstream of the dam and upstream of the impoundment is covered with gravel and cobbles, based on field investigations. Therefore, in the model, for the cross section of these reaches, zero was assigned as the maximum erodible depth; i.e., these reaches were assumed as a non-erodible streambed.

The sediment supply entering the upstream boundary is called the inflow sediment load, which is expressed in tons/day. Usually, in the HEC-6T model, this load is calculated based on the assumption

of an equilibrium condition, which means that there will be no aggradation or degradation at the upstream boundary. However, considering that a reservoir (Patch Reservoir) is located immediately upstream of the modeling reach, and most of inflow sediment load is captured by the reservoir before entering the modeling reach, the inflow sediment load was assumed as zero in the model.

6.4 Sediment Transport Model Findings

The HEC-6T model was run for the short-term and long-term simulation scenarios listed in Table 6-1:

Table 6-1 HEC-6T Model Scenarios

Scenario	Patch Pond Dam Status	Simulation Condition	Flow Condition
S1	In place	Short-term changes	100-year storm hydrograph
S2	Removed	Short-term changes	100-year storm hydrograph
L1	In place	Long-term changes	20-year daily flow hydrograph
L2	Removed	Long-term changes	20-year daily flow hydrograph

For the short-term simulation, the HEC-6T model was run for the 100-year storm hydrograph, and for the long-term simulation, the model was run for 20-year daily flow hydrograph (5/1/1994 through 5/1/2014). The model results for Scenarios S1 and S2 are presented in Figure 6-4, and those for Scenarios L1 and L2 are presented in Figure 6-5.

Figure 6-3 (Scenarios S1 and S2) presents the thalweg (i.e., the lowest point in the stream) profile at the end of the 100-year storm hydrograph. The figure shows that in Scenario S1, almost no streambed elevation change is predicted within the dam impoundment during the 100-year storm. In Scenario S2, streambed lowering (i.e., degradation) is predicted within the impoundment with the maximum scour depth of 1.1 feet. However, it predicts that a significant portion of the accumulated sediment will remain within the impoundment at the end of the 100-year storm hydrograph after dam removal.

Figure 6-4 (Scenarios L1 and L2) presents the thalweg profile after 20 years. The figure shows that in Scenario L1, a small amount of streambed rising (i.e., aggradation) is predicted within the downstream portion of the impoundment, while degradation of the streambed is predicted within upstream portion of the impoundment after 20 years. In Scenario L2, degradation of the streambed is predicted within the impoundment with the maximum scour depth of 1.6 feet. However, it predicts that a portion of the accumulated sediment will still remain within the impoundment 20 years after the dam removal as shown.

6.5 Recommendations

Should the City elect to move forward with dam removal, further investigation of the grain size characteristics of the native soil below the accumulated sediment to be removed during dam removal is recommended to better predict the stabilized channel profile in the Patch Pond. Detailed boring information should be collected in final design to confirm the model results.

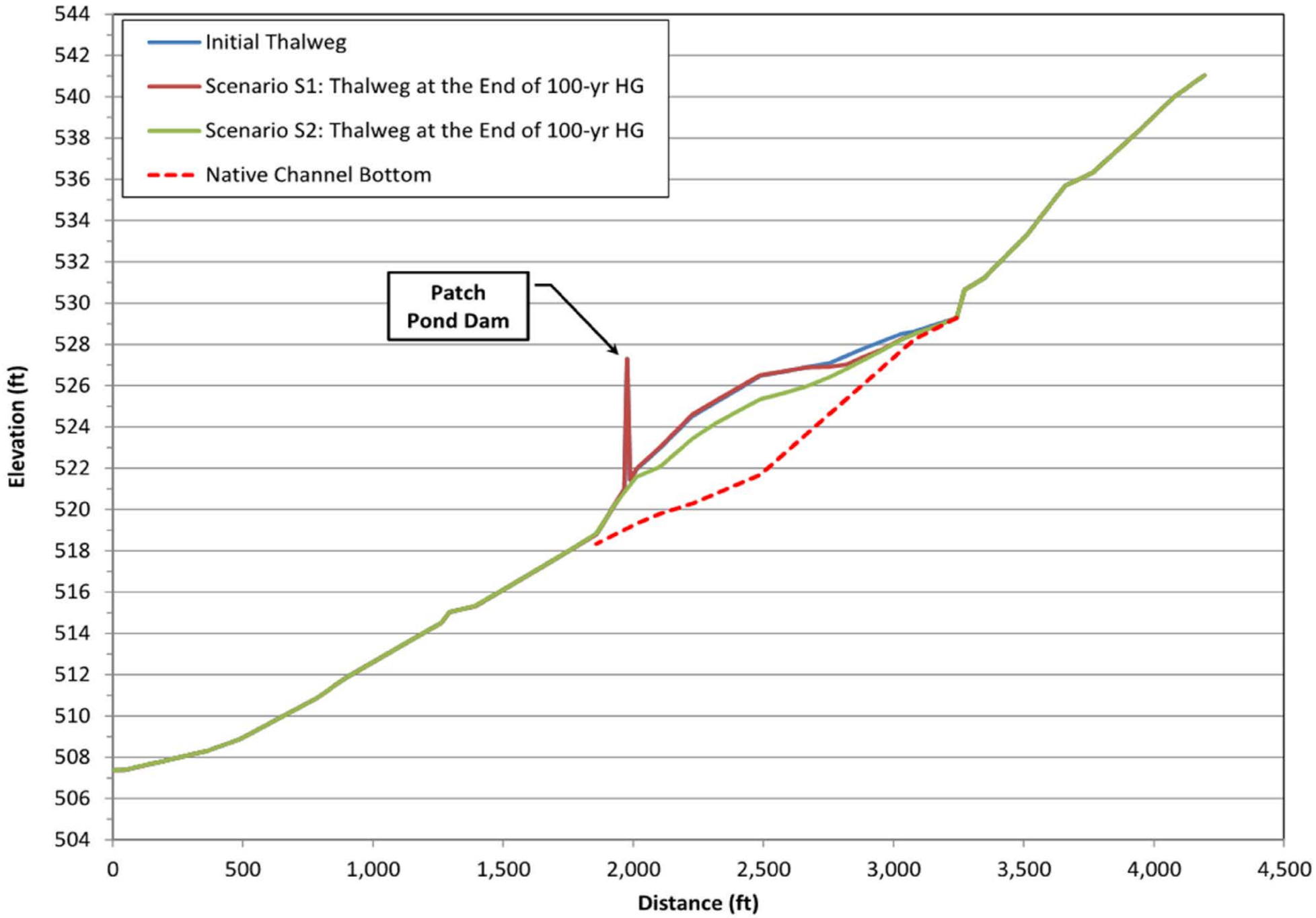


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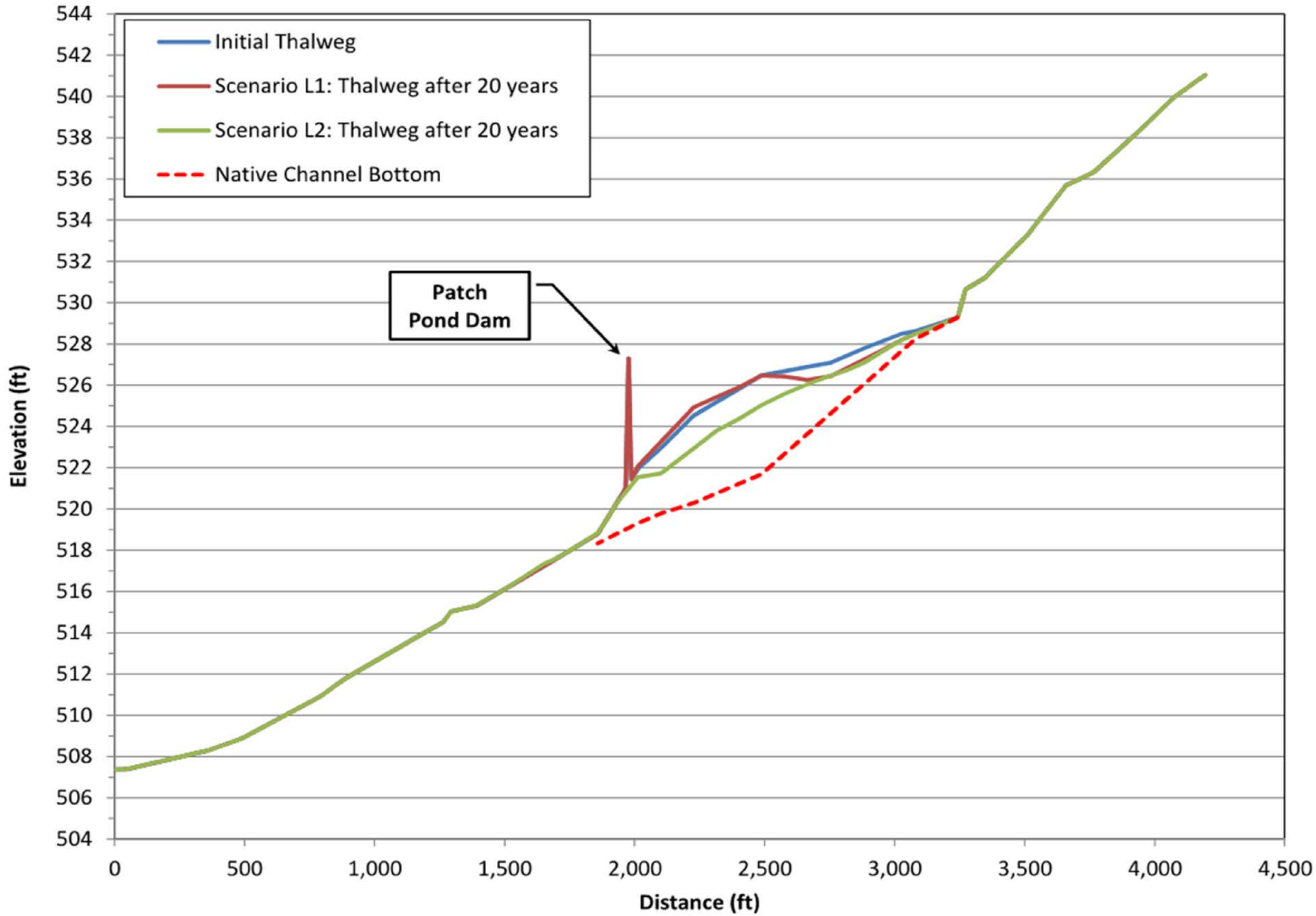
Figure 6-4
Model Results for Scenarios S1 and S2



6/16/2014

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Worcester, Massachusetts
Patch Pond Dam Removal Feasibility Study

Figure 6-5
Model Results for Scenarios L1 and L2

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Per the model results based on currently available data, it is predicted that a portion of the accumulated sediment will still remain within the impoundment 20 years after the dam removal. This may be due to the fact that natural streams are often in a state of equilibrium with sediments entering and leaving at generally constant rates.

Depending on the findings of future investigations, and **without** consideration of the level of contamination of the sediments, consideration could be given to either: (1) allowing the stream to erode the native soil until a more resistant non-erodible streambed layer is reached, or (2) armoring the native soil in the channel to resist further erosion after the dam removal.

The sediment transport analysis was conducted without consideration of sediment contamination, as was previously presented in Section 4. Section 7 (Alternatives) combines the results of each of the study components (i.e., hydrologic/hydraulic, sediment characterization/contamination, sediment transport) to develop scenarios for dam removal, and costs thereof.

6.6 References

U.S. Army Corps of Engineers (1993) "HEC-6, Scour and Deposition in Rivers and Reservoirs, User's Manual." Hydraulic Engineering Center (HEC), Davis, CA.

MBH Software, Inc. (2010) "HEC-6T, Sedimentation in Stream Networks; User's Manual." Mobile Boundary Hydraulic. Clinton, MS.

Section 7
Alternatives

7.1 Background

The City of Worcester recognizes the environmental and public safety benefits associated with removal of the Patch Pond Dam, which no longer serves its intended purpose. This feasibility study evaluated the potential to remove the dam and restore the natural alignment of the Tatnuck Brook, which could result in multiple benefits for the environment, maintenance, available resources, and general safety in the area of the dam.

The Patch Pond Dam is in extremely poor condition and is considered "unsafe" in accordance with the Office of Dam Safety (ODS) Criteria. The primary spillway on the west abutment is partially breached. There is also a second breach area at the east abutment. The spillway discharge channel is covered with light overgrowth including some debris and more mature trees, and embankments and dam crest are overgrown with vegetation. In addition, several areas of erosion exist and there is no low level outlet.

Previous studies investigated alternatives for the Patch Pond Dam, including repairing the dam, restructuring the spillway, breaching a section of the dam, or completely dismantling the dam. These earlier studies concluded that the complete removal of the dam would be the most cost-effective and safest alternative.

7.2 Basis for Development of Alternatives

The Massachusetts dam removal guidance (December 2007) recommends that the entire vertical extent of a dam be removed. Amendments to Wetlands Protection Regulations were proposed in 2013 that would establish a General Permit for Ecological Restoration. The General Permit would apply only to qualifying ecological restoration projects; in the case of dam removal, one criterion for qualification is that the full vertical extent of a dam be removed. Based on this guidance and pending regulations, all alternatives evaluated in this section include removal of the full vertical extent of the Patch Pond Dam. Removing the full vertical extent will eliminate the potential for any structure remnants to become a barrier in the future as streamflow would likely cause scour on the downstream side. Partial removal of the dam was not considered. A comparison of the sediment data in Patch Pond to the Stage I Ecological Screening criteria as well as to the downstream concentrations showed arsenic to be the primary constituent of concern regarding the release of sediment downstream. The concentrations of arsenic in Patch Pond exceed the Stage I criteria and are higher than the concentrations found in downstream samples. While arsenic is naturally occurring at higher concentrations in the Worcester area than other parts of the state, the arsenic concentrations in Patch Pond are higher than what might be considered to be background. Therefore, further investigation is warranted to evaluate the best alternative to minimize the downstream transport of sediment. Additional samples would need to be collected in Patch Pond to determine the best route for a channel to limit the transport of sediment with arsenic at the higher concentrations. Samples would be collected in the downstream channel as well as Williams Mill Pond to better assess the local conditions downstream. In addition, samples will be collected upstream at the Mill Street culvert/stream since this appears to be a source of high concentrations of arsenic and other

constituents, possibly due to road runoff. Any sediment removed as part of the dam removal project will be handled and disposed of in accordance with all applicable regulations.

Alternative sediment removal approaches were discussed with the MassDEP in May 2014. Based on this discussion, the sediment upstream of the dam should either be removed or stabilized. Based on the data collected for this feasibility-level study, the sediment could not be released to areas downstream of the dam under the Department's anti-degradation guidelines. Additional samples would be needed to more thoroughly characterize the sediments throughout the pond should dam removal move forward. The results obtained from future sampling events would be used to refine the approach to sediment management. For this study, two options were developed that provide a range of sediment management approaches, and associated costs thereof.

The sediment/soil characteristics (Section 4) and the hydrologic and hydraulic aspects of the brook (Section 5) were evaluated together to develop alternatives that met the overall goals of the project – to improve public safety and restore Tatnuck Brook to its natural condition. Sediment mobility/transport, soil types, slope stability, historical resources, aesthetics and cost were also factored into the development of the alternatives.

Three alternatives were developed for this study and differ only in their approach to sediment management to provide a range of costs for decision-making purposes. Alternative 1 includes 100% removal of the upstream sediments (within the Patch Pond). Alternative 2 includes a limited sediment removal approach, with in-situ stabilization of the remaining sediment. In Alternative 3, no sediment is removed from the impoundment area. Under Alternative 3, the sediments are redistributed throughout the impoundment where they are stabilized to inhibit movement downstream.

Table 7-1 summarizes the options for dam removal evaluated in this feasibility study.

Table 7-1
Patch Pond Dam Removal Alternatives

Alternative	Removal of the Entire Dam Structure	Removal of All Sediment Within 50 Feet Upstream of the Dam	Extent of Sediment Removal in Patch Pond	Pond Stabilization	Channel Details	Notes
1	Yes	1,050 cubic yards	18,000 cubic yards	Seed Mixture / Stabilization Matt	Simple Channel With Stable Materials Added for Structural Support	Channel With Defined Path and Geometry
2	Yes	1,050 cubic yards	3,000 cubic yards	Seed Mixture / Stabilization Matt	Engineered Channel using Rip Rap or Advanced Natural Channel Design Techniques	Channel With Defined Path and Geometry
3	Yes	In-Situ Sediment Stabilization (No Sediment Removed)	In-Situ Sediment Stabilization (No Sediment Removed)	Seed Mixture / Stabilization Matt	Engineered Channel using Rip Rap or Advanced Natural Channel Design Techniques	Channel With Defined Path and Geometry

7.3 Description of Alternatives

7.3.1 Alternative 1 – Full Sediment Removal

Under Alternative 1, the full vertical and horizontal extent of the dam would be removed along with removal of all of the sediment in Patch Pond. Approximately 19,000 cubic yards of sediment would be removed until the natural bottom of the pond is uncovered. A channel would be constructed in the existing native soils to simulate a natural alignment of Tatnuck Brook. The channel would be approximately 20-feet wide and sized to pass the 10-year peak discharge (approx. 1,240 cfs). Flows in excess of the 10-year peak discharge would rise above the active channel and spread onto the hydrologic floodplain. Within the flood channel, a smaller flow channel would be constructed using "natural channel design techniques" to form a suitable armored bottom and habitat during average flows.

Erosion mats would be placed in the channel and seeded with a natural wetlands seed mix to allow for natural vegetation to establish and stabilize the surrounding area. Since all of the sediment would be removed, natural soil materials will be utilized that will create a well-defined, stable channel. By sizing the channel to accommodate the 10-year peak discharge, the potential for erosion would be minimized from storm events thereby allowing time for the surrounding hydrologic floodplain area beyond the channel to be adequately stabilized through seeding and temporary stabilization methods.

7.3.2 Alternative 2 – Limited Sediment Removal

Under Alternative 2, approximately 1,050 cubic yards of sediment would be removed immediately upstream of the dam to allow for construction access in and around the dam structure. The full vertical and horizontal extent of the dam would be removed. Approximately 3,000 cubic yards of sediment would be removed as part of constructing a stream channel within the pond to simulate a natural alignment of Tatnuck Brook. As with Alternative 1, this 20-foot-wide channel would be sized to pass the 10-year peak discharge (1,240 cfs). Within the flood channel, a smaller flow channel would be constructed using "natural channel design techniques" to form a suitable armored bottom and habitat during average flows.

Erosion mats would be placed in the channel and seeded with a natural wetlands seed mix to allow for natural vegetation to establish and stabilize the surrounding area. The channel would be an engineered channel constructed with rip rap or advanced natural channel design techniques that minimize erosion and ensure the long term stability of the channel. Sizing the flood channel to accommodate the 10-year peak discharge provides time for the remaining sediments and surrounding area to be adequately stabilized through seeding and temporary stabilization methods.

7.3.3 Alternative 3 – In Situ Sediment Stabilization

Under Alternative 3, no sediment would be removed from the site. The sediment immediately upstream of the dam would be redistributed and stabilized within the impoundment to allow for construction access in and around the dam structure. The full vertical and horizontal extent of the dam would be removed. Approximately 3,000 cubic yards of sediment would also be redistributed and stabilized within the impoundment as part of constructing a stream channel within the pond to simulate a natural alignment of Tatnuck Brook. Similar to Alternatives 1 and 2, this 20-foot-wide channel would be sized to pass the 10-year peak discharge (1,240 cfs). Within the flood channel, a smaller flow channel would be constructed using "natural channel design techniques" to form a suitable armored bottom and habitat during average flows.

Erosion mats would be placed in the channel and seeded with a natural wetlands seed mix to allow for natural vegetation to establish and stabilize the surrounding area. The channel would be an engineered channel constructed with rip rap or advanced natural channel design techniques that minimize erosion and ensure the long term stability of the channel. Sizing the flood channel to accommodate the 10-year peak discharge provides time for the remaining sediments and surrounding area to be adequately stabilized through seeding and temporary stabilization methods.

7.3.4 Features Common to All Alternatives

For all three alternatives, the invert of the brook would be taken down to its original level to restore it to its natural condition and aid in fish passage. The original channel depth was determined by profiling the existing brook bed (top of sediment) along with the sediment depth at each sampling location. The slope through the dam was chosen by connecting the original brook invert at the upstream end of the Patch Pond and the downstream end of the pond below the dam. Rubble from the dam structure will be placed where the partial breach exists to direct the flow to the desired alignment. All areas outside of the channel and abutments will be appropriately seeded and/or replanted. Scour and erosion control strategies will be implemented on the side slopes around the dam.

7.3 Downstream Stream Channel Consolidation

After the dam is removed, the existing stream channel on the east side of the dam formed from the partial breach would be eliminated. The flow to the west side of the dam would be redirected to where the natural channel of Tatnuck Brook exists. For this feasibility study, the proposed channel section was assumed to be equal to the current channel width (approximately 20 feet) upstream and downstream of the Patch Pond. The consolidation of the two stream channels downstream of the dam (the spillway channel and the channel created as a result of the partial breach at the east embankment) will enhance the fishery resource by creating a deeper single channel that is beneficial to migrating fish during low flow periods.

7.4 Dam Removal Components

The dam removal alternatives presented in this section include the following components:

- Full removal of the dam
- Construction staging
- Flood channel construction upstream of the dam to a width of about 20 feet
- Slope stabilization at the dam
- Slope stabilization downstream of the dam
- Demolish and remove apron and spillway
- Rebuild the apron to match grade of the brook
- Access road/area for construction
- Varying degrees of sediment removal and disposal (Alternatives 1 and 2):
  - Immediately upstream of the dam
  - Within the entire Patch Pond (Alternative 1)
  - Within the newly constructed 10-year flood channel (Alternative 2)

- Sediment redistribution and in situ stabilization within the impoundment (Alternative 3):
  - Immediately upstream of the dam and within the newly constructed 10 year flood channel
- Tree clearing
- Overall site restoration including slope stabilization, where needed
- Bypass flow management and/or pumping

As mentioned earlier, the three alternatives include removal of the full vertical and horizontal extent of the dam. Because of the removal of the structure, the opportunity to redefine the brook alignment is introduced. On the east side of the dam, the rubble from the dam will be placed to direct the brook away from the partial breach area and promote greater flow in the Tatnuck Brook to the west. The rubble will also be used to stabilize existing side slopes, when needed. Trees and brush will be cleared and the site will restored to a more natural setting.

Figures 7-1 and 7-2 present a visual representation of the existing conditions.

Figure 7-3 shows a cross section and **Figure 7-4** shows a plan view representation of the proposed conditions.

Figure 7-5 provides a plan view of the immediate dam and spillway area, showing the removal of the structure.

7.5 Dam Removal Considerations

7.5.1 Impacts to the Surrounding Area

The removal of the dam will result in the replacement of the impoundment with a free-flowing natural stream and adjacent wetland, both of which provide scenic views of varying types. Removal of the impoundment would reduce the risk of drowning and adjacent landowner liability.

There is expected to be no significant impact on public recreation as the pond's use is limited, and the area would remain dedicated conservation land. Removal of the dam would turn a stagnant system into a free-flowing system, which promotes water quality and improves dissolved oxygen. The habitat within and downstream of the impoundment area would be restored, favoring native species. Dam removal will allow passage of migratory fish and other aquatic species.

The dam is no longer in use and the impoundment is not used as a water source, negating any cultural or business impacts. Removing the dam and maintaining a constant channel slope will eliminate the ponding north of the dam and maintain steady flow to the south into the Coes Reservoir. The more continuous, natural flow will not disturb any surrounding neighborhoods. Other benefits of dam removal include reduced upstream flooding, as well as the hazard of catastrophic dam failure.

7.5.2 Impoundment and Brook Restoration/Stabilization

Within the 20 foot wide flood channel (10-year peak discharge), a flow channel will be constructed using natural channel design techniques. For average day flow, the channel design will utilize an armored channel (rip rap, stones and / or well graded materials) that will provide additional depth to maximize the passage of fish and a suitable habitat. The goal of this armored channel will be to have sufficient scour protection while providing a natural habitat (including small boulders, and hiding places etc.) for fish and other aquatic life.

6/16/2014

Water
Dam

CDM Smith

Worcester, Massachusetts
Patch Pond Dam Removal Feasibility Study

N

0 250 500 1,000 Feet

Figure 7-1
Existing Conditions

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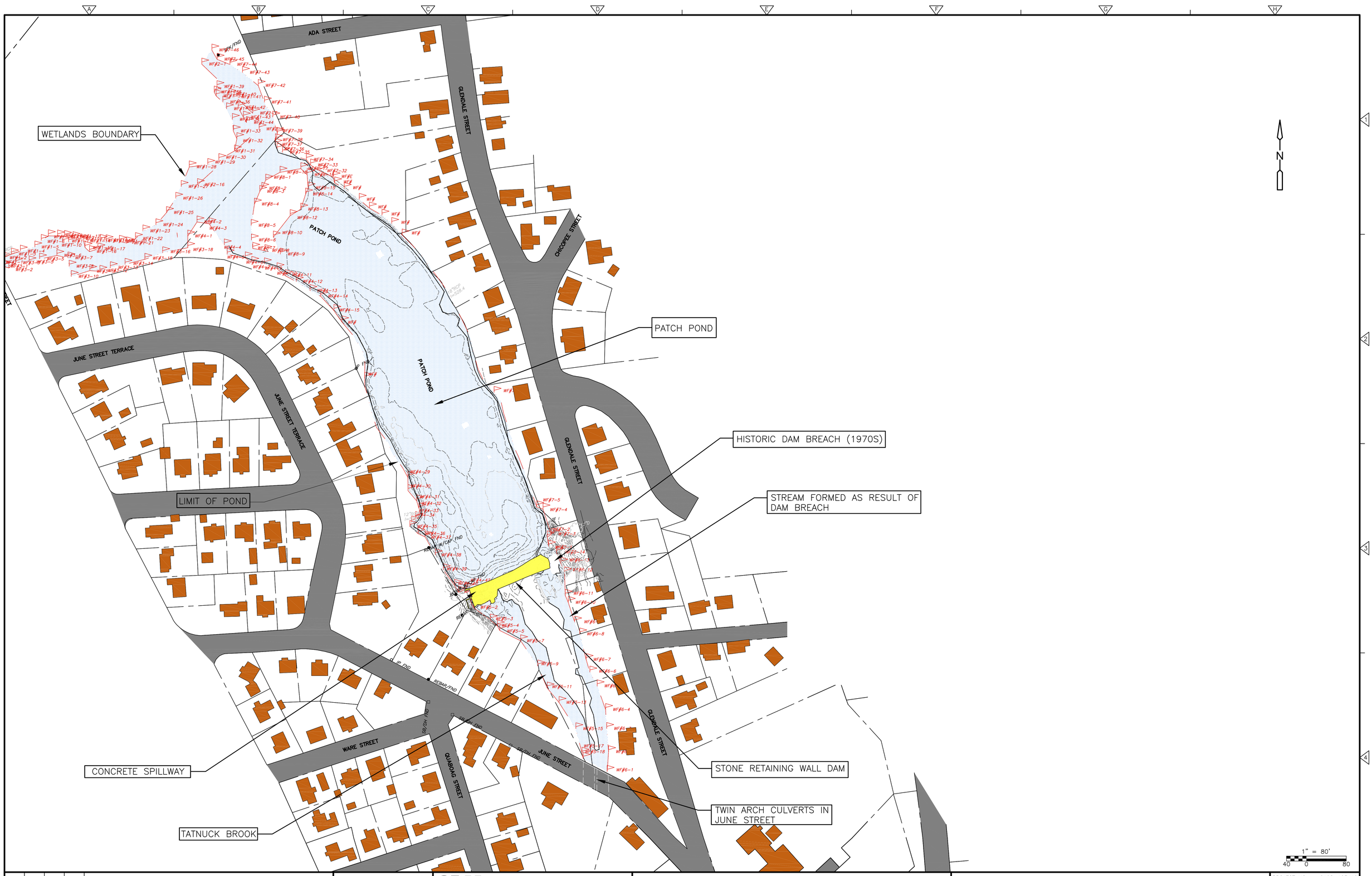


REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: J.COY
DRAWN BY: J. COY
SHEET CHK'D BY: X
CROSS CHK'D BY: X
APPROVED BY: R. MUSCI
DATE: JUNE 2014

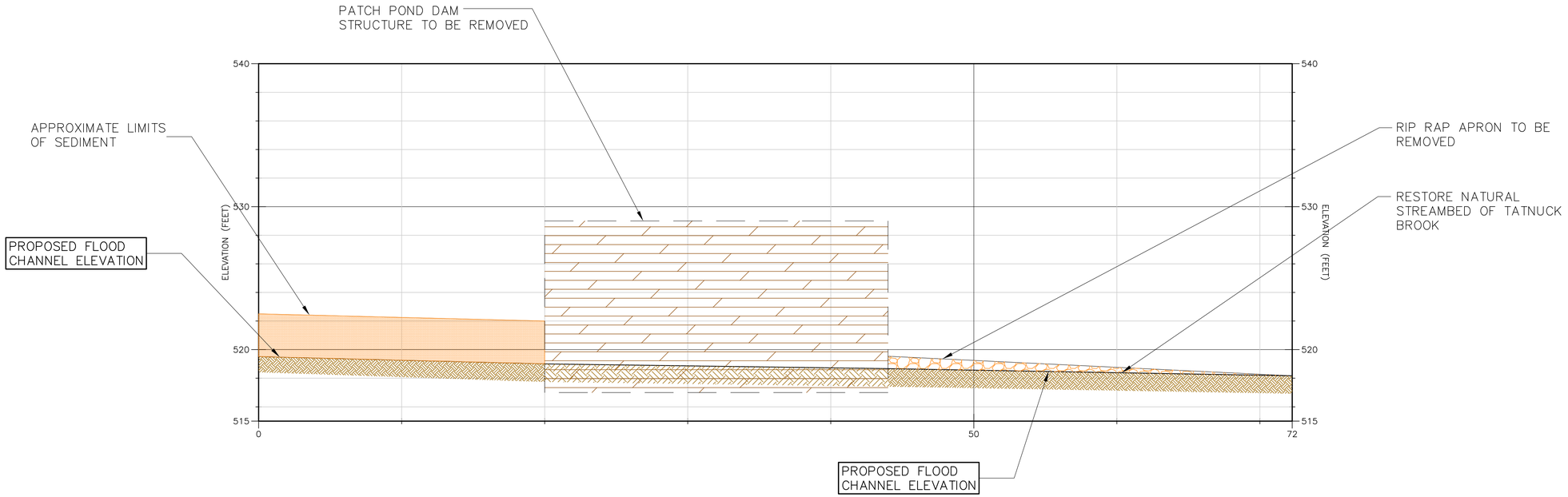
CDM Smith
50 Hampshire Street
Cambridge, MA 02139
Tel: (617) 452-6000

CITY OF WORCESTER, MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS AND PARKS
PATCH POND DAM REMOVAL
FEASIBILITY STUDY

EXISTING CONDITIONS WITH CONTOURS INCLUDING BATHYMETRY PLAN

PROJECT NO. 0198-103419
FILE NAME: CBRPL001.DWG
SHEET NO. 7-2

30% SUBMITTAL - NOT FOR CONSTRUCTION



SECTION THROUGH DAM

ELEVATION

1"=10'

LEGEND

- EXISTING STRUCTURE TO BE REMOVED
- CONDITIONS AFTER CONSTRUCTION
- EXISTING SEDIMENT
- PROPOSED BROOK BED ELEVATION
- PATCH POND DAM STRUCTURE TO BE REMOVED
- RIP RAP APRON TO BE REMOVED

NOTES:

1. WIDTH OF DAM RANGES FROM 16 TO 25-FT.
2. DAM IS APPROX 12-FT DEEP.

2 1 0 2 4

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: J.RICCIO
DRAWN BY: J. RICCIO
SHEET CHK'D BY: X
CROSS CHK'D BY: X
APPROVED BY: R. MUSCI
DATE: JUNE 2014

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50 Hampshire Street
Cambridge, MA 02139
Tel: (617) 452-6000

CITY OF WORCESTER, MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS AND PARKS
PATCH POND DAM REMOVAL
FEASIBILITY STUDY

PROPOSED BROOK ELEVATION
AFTER CONSTRUCTION

PROJECT NO. 0198-103419
FILE NAME: CSDPR001.DWG
SHEET NO.
7-3

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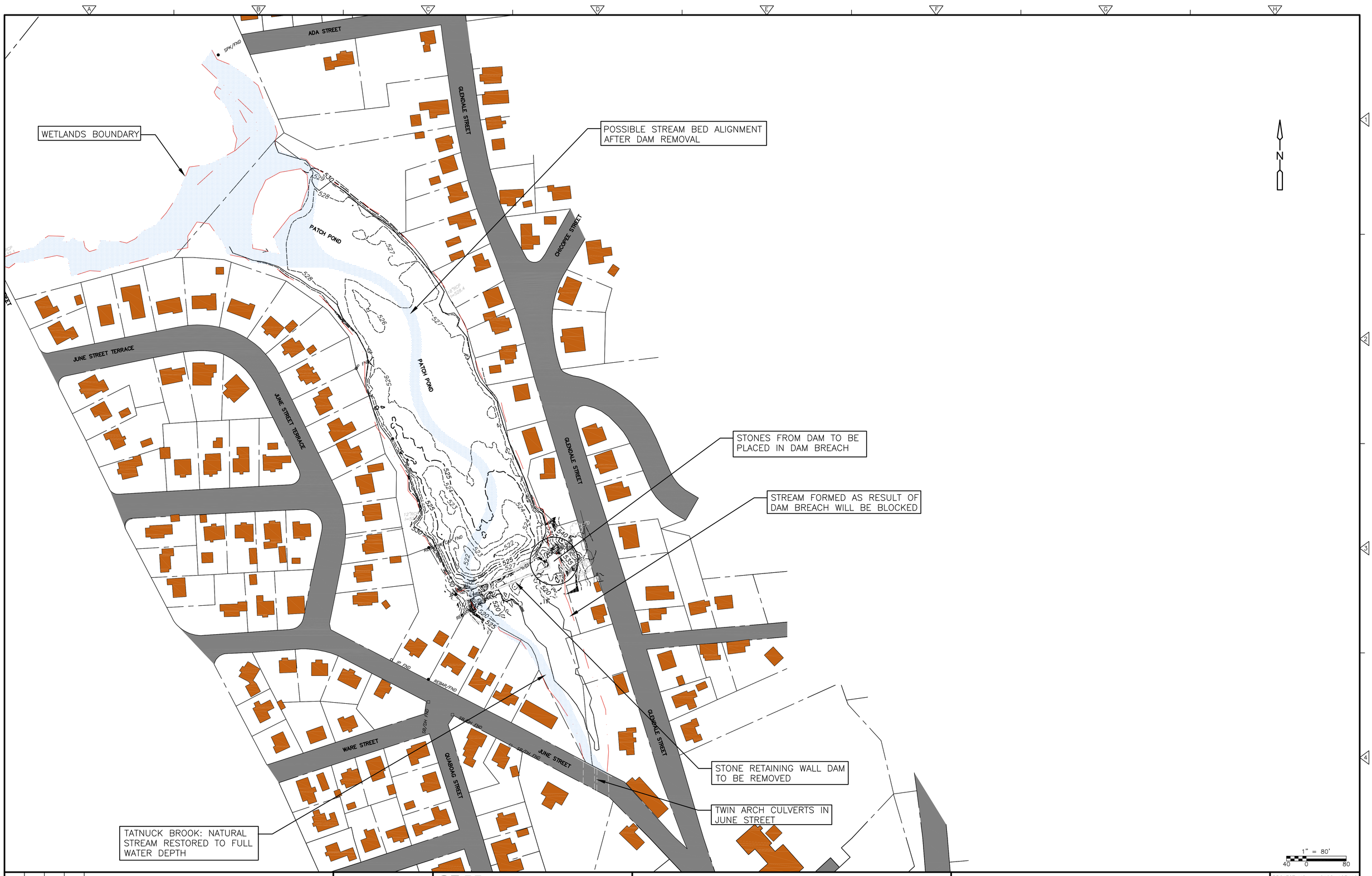

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: J.COY
DRAWN BY: J. COY
SHEET CHK'D BY: X
CROSS CHK'D BY: X
APPROVED BY: R. MUSCI
DATE: JUNE 2014

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CITY OF WORCESTER, MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS AND PARKS
PATCH POND DAM REMOVAL
FEASIBILITY STUDY

PROPOSED DAM REMOVAL

PROJECT NO. 0198-103419
FILE NAME: CBRPL001.DWG
SHEET NO. 7-4

30% SUBMITTAL - NOT FOR CONSTRUCTION

APPROXIMATE STREAM BED ALIGNMENT AFTER DAM REMOVAL

WETLANDS BOUNDARY

STABILIZE SLOPE BOTH SIDES

CONCRETE SPILLWAY

RIPRAP SPILLWAY. REPLACE AND REPAIR AFTER DAM REMOVAL.

TATNUCK BROOK: NATURAL STREAM RESTORED TO FULL WATER DEPTH

STREAM FORMED AS RESULT OF DAM BREACH WILL BE BLOCKED

STONE RETAINING WALL DAM TO BE REMOVED

STONES FROM DAM TO BE PLACED IN DAM BREACH

WATER ELEV=528.1 @12:30PM, 4-14-2014

WATER ELEV=528.4 @5:15PM, 4-9-2014

WATER ELEV=519.1 @12:30PM, 4-10-2014

WATER ELEV=520.8 @1:15PM, 4-10-2014

WATER ELEV=519.6 @12:25PM, 4-10-2014

REBAR W/CAP FND

1" = 10'

REV. NO.	DATE	DRWN	CHKD	REMARKS

DESIGNED BY: J.COY
DRAWN BY: J. COY
SHEET CHK'D BY: X
CROSS CHK'D BY: X
APPROVED BY: R. MUSCI
DATE: JUNE 2014

CDM Smith
50 Hampshire Street
Cambridge, MA 02139
Tel: (617) 452-6000

CITY OF WORCESTER, MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS AND PARKS
PATCH POND DAM REMOVAL
FEASIBILITY STUDY

PROPOSED DAM REMOVAL

PROJECT NO. 0198-103419
FILE NAME: CBRPL001.DWG
SHEET NO. 7-5

30% SUBMITTAL - NOT FOR CONSTRUCTION

For higher, storm flows, the full flood channel will be sized to carry all of the flows expected in a 10 year flood. The slopes and sides of this channel will be constructed with a more natural mat protection to stabilize the remaining sediments, promote natural growth and control erosion. This channel design will be revisited during design and permitting to ensure whether letting the stream more naturally develop after the dam removal is feasible. More field data will be gathered to confirm the feasibility of letting the stream develop naturally. Costs were developed on the basis of the more conservative design for purposes of decision-making.

7.5.3 Construction Issues

Construction access to the dam and pond would be via City-owned land on Glendale Street. The access consists of a steep slope immediately adjacent to the east embankment of the dam and would require some preparation (clearing, backfilling, etc.) for use. Preliminary discussions with local contractors indicated that accessing the dam site from Glendale Street is feasible. A likely scenario would involve constructing two platform areas within the slope embankment to lift the rubble and equipment from the level of the dam to the street elevation at Glendale Street. A construction staging area would need to be identified within reasonable proximity to the dam site for storage of materials, refueling of equipment, parking of construction employee vehicles, etc.

Crane mats would be placed such that construction equipment is stabilized as well as to limit the influence of construction during excavation. Sediment and erosion control methods including stone check-dams and silt fences would be utilized throughout construction. The work would be scheduled for the seasonal low-flow period (June – August), and whatever flow is present in Tatnuck Brook at the time of construction would be directed toward the current breach area on the east side of the dam as the new flow channel is constructed. A temporary bypass pump, or gravity bypass, would be utilized to convey average daily flow (9.7 cfs) from upstream of the Patch Pond to an area downstream of the dam. When storms are encountered during construction, the upstream bypass would be suspended and the flow would be directed through the impoundment. Within 100 feet of the Patch Pond Dam, larger bypass culverts in conjunction with a temporary portable dam would be utilized to convey the flow around the dam structure and into the east channel that flows to June Street. It is anticipated that a temporary portable dam will be utilized throughout the construction period as a safety measure to mitigate the effects of a significant storm. An inclement weather contingency plan will also be developed so that all stakeholders have a clear understanding of the appropriate plan of action in case of large rainfall events and subsequent flooding. After the dam is removed, the flow would be redirected from the breach area to the new channel constructed on the west side of the pond and dam.

7.6 Community Meeting

As with any public works study, it is important to address community interest and concerns. The functionality of the dam has to be considered, as well as if there is any opportunity to implement additional public benefits after the removal of the dam. Other concerns may arise from the historic relevance of the dam.

A public meeting was held on June 18, 2014 as part of a regular meeting of the Public Works Committee of the Worcester City Council. The advertisement for the meeting can be found online through the City of Worcester Public Meeting Notices and in Appendix H. A June 19th news article from the Worcester Telegram and Gazette describing the meeting can also be found in Appendix H.

The purpose of the meeting was informational as the City of Worcester was clear in its intention that a decision between dam removal and repair has not been made. The City noted that the Patch Pond Dam was one of the highest priority dams owned by the City in terms of the immediacy of its condition, and the dam has to be either repaired or removed.

The environmental benefits and reduction of potential flooding as a result of removing the dam were discussed, as well as reduced liability for the City, decrease in long-term maintenance costs, and improved public safety. The option of removing the dam met with opposition from neighborhood residents who expressed concerns that their property values would be negatively affected as Patch Pond is considered a valuable resource. Residents were concerned that the pond would be turned into a less-valuable swamp, with the potential for elevated levels of mosquitoes. Most of those who offered public comment did not agree that there would be significant environmental benefits, and urged the City to consider repairing the dam, even at a higher potential project cost, rather than removing it. Some commenters suggested partial removal of the dam as an alternative. The City committed to additional public meetings on the subject of the dam, no matter which direction (repair or removal) is taken.

Section 8
Environmental Permitting Requirements

8.1 Anticipated Permits

Should the City of Worcester elect to move forward with removal of the Patch Pond Dam, the environmental permitting requirements for the project will include local, state, and federal regulatory coordination and permits. It is recommended that pre-application coordination with the Worcester Conservation Commissions and other local, state, and federal environmental regulatory agencies be scheduled after completion of the Preliminary Design to ensure that all regulatory requirements are addressed and to facilitate the permit approval process.

Under the proposed revisions to the Massachusetts Wetlands Protection Act (310 CMR 10.00)(WPA) anticipated to be implemented in 2014, dam removal projects qualify for a General Ecological Restoration Project Order of Conditions provided they are consistent with MassDEP's guidance entitled Dam Removal and the Wetlands Regulation, dated December 2007 and meet the eligibility criteria set forth in the proposed regulations.

A proposed revision to the 401 Water Quality Certification Regulations (314 CMR 9.03(8)) exempts projects utilizing dredging or discharge of dredged or fill material in association with an Ecological Restoration Project from filing a 401 Water Quality Certification, provided that: (1) the dredging or discharge of dredged or fill material is in compliance with a valid final General Ecological Restoration Project Order of Conditions issued pursuant to 310 CMR 10.11 through 310 CMR 10.14; (2) the project does not require an application pursuant to 314 CMR 9.04; and (3) the project does not require an individual 404 permit from the U.S. Army Corps of Engineers. The Patch Pond Dam removal project is anticipated to be authorized by the U.S. Army Corps of Engineers as a Category 2 General Permit (an individual permit is not required). The proposed dredging of sediments will not require a 401 Water Quality Certification (WQC) as long as the work complies with the performance standards for dredging listed in 314 CMR 9.07(3). Furthermore, since the project meets the criteria for an Ecological Restoration Project, it would be exempt from the environmental review under the Massachusetts Environmental Policy Act (MEPA).

Anticipated regulatory coordination, review, and permit requirements include the following:

8.1.1 Notice of Intent for General Ecological Restoration Project Order of Conditions - Worcester Conservation Commission

The issuance of an Order of Conditions is required under the state WPA and its regulations for alterations of wetland resource areas and buffer zones by the local Conservation Commission.

To obtain a General Ecological Restoration Project Order of Conditions a number of actions are required by the applicant prior to the filing of a Notice of Intent (NOI) per proposed revisions to 310 CMR 10.11(1) through 6. The actions applicable to the Patch Pond Dam Removal project are as follows:

At least 14 days prior to filing a NOI for an Ecological Restoration Project, the applicant has to submit written notification of the proposed filing for publication in the Environmental Monitor.

Since silt generating in-water work will impact a non-tidal perennial stream, the in-water work shall occur between May 1 and August 30 OR the applicant needs to obtain a written determination from the Division of Fisheries and Wildlife (DFW) if the work requires a Time-Of-Year (TOY) restriction. The written determination shall specify the TOY restriction, if required.

Since the project will involve dredging greater than 100 cubic yards of sediment, the applicant needs to submit a Sediment Management Plan to MassDEP for review and approval. The Sediment Management Plan needs to meet the following requirements:

At a minimum, the Sediment Management Plan needs to include all actions necessary to ensure that sediment will be managed in accordance with 314 CMR 9.07 and 314 CMR 4.04 (401 WQC regulations).

The Sediment Management Plan needs to include an analysis of the quantity and quality of sediments that may be mobilized as a result of the project. This analysis shall meet the requirements of 314 CMR 9.07(2)(b)1-6 and include a characterization of background and local conditions. The analysis shall determine whether any chemical in the sediment have the potential to substantially reduce the capacity of any affected Resource Areas to provide the habitat functions provided in 310 CMR 10.60(2). A chemical detected in sediment is presumed to have no substantial adverse impact on the ability of the affected Resource Areas to provide habitat functions if its concentration is below the applicable Probable Effect Concentration (PEC) and Threshold Effect Concentration (TEC) (per Mass Contingency Plan Interim Technical Update entitled "Revised Screening Values", dated 2005).

The Sediment Management Plan needs to provide for the implementation of Best Management Practices to avoid turbidity in upstream and downstream waters and use erosion and sedimentation controls.

The Sediment Management Plan needs to include a schedule for sequencing construction that avoids times of year when the work may adversely impact aquatic species, and/or habitats.

Furthermore, the NOI for an Ecological Restoration Project needs to comply with all requirements of 310 CMR 10.12. A project eligible for a General Ecological Restoration Project Order of Conditions is exempt from the requirement to perform a wildlife habitat evaluation per 310 CMR 10.60.

8.1.2 Clean Water Act (CWA) Section 404 Dredge and Fill Permit

The dam removal will require a CWA Section 404 permit, which is issued by the U.S. Army Corps of Engineers (the Corps), for discharge of dredged materials. In Massachusetts, the Corps has developed the General Permit (GP) to expedite their evaluation of permit applications and to streamline the permitting process. There are two categories associated with the GP, Category 1 (for alterations less than 5,000 sf) and Category 2 (alterations between 5,000 square feet and up to 1 acre). Projects affecting more than 1 acre of wetlands/water bodies require issuance of an Individual Permit, which has more rigorous review requirements and a longer review period. The Corps, along with other federal resource agencies (U.S. Fish and Wildlife Service, National Marine Fisheries Service, EPA and the Massachusetts CZM Office), reviews this application and determines that either: 1) the project

meets the criteria of the GP and can proceed with no changes and no additional Corps review is needed; 2) additional information is needed before making a permitting decision; or 3) the project does not meet the GP criteria and an Individual Permit is required. It is anticipated that the Patch Pond Dam removal will be authorized as a GP Category 2 activity.

8.1.3 Chapter 253 Permit from Massachusetts Department of Conservation and Recreation (DCR) Office of Dam Safety (ODS)

Removal of an existing dam requires a permit from the Commissioner or authorization that a permit is not required. It is expected that the ODS will require a Chapter 253 permit for removal of Patch Pond Dam.

8.1.4 Coordination with Massachusetts Historical Commission for Compliance with Section 106 and Coordination with Worcester Historical Commission

The Massachusetts Historical Commission (MHC) is the state agency that functions as the State Historic Preservation Officer (SHPO) in Massachusetts and identifies, evaluates, and protects the state's significant cultural resources under Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (36 CFR 800), M.G.L. Chapter 9, Sections 26?27c (950 CMR 71) and/or MEPA (301 CMR 11). Copies of any state and federal permits required for the dam removal should be submitted to MHC and the Worcester Historical Commission for review and comment.

8.1.5 Beneficial Use Determination (BUD Permit) for Re-use of the Concrete Demolitions Debris (coordination with MassDEP during design development)

A BUD Permit is required if any of the demolition debris will be reused commercially, which is termed "beneficial use" of a solid waste by MassDEP. If MassDEP determines that the proposed use of solid waste is beneficial and will not harm public health or the environment, the material is reclassified as a secondary material and not as a solid waste.

8.1.6 Applicability of Chapter 91 Waterways License/Permit

It is anticipated that a Chapter 91 Waterways License/Permit would not be required; however, this should be confirmed with MassDEP during Preliminary Design. The Public Waterfront Act M.G.L. Chapter 91 and its regulations (310 CMR 9.00) has jurisdiction over any non-tidal navigable river or stream on which public funds have been expended for channel improvements and/or flood control. Patch Pond and Tatnuck Brook above and below the dam are not believed to be considered navigable waters. The proposed revisions to the WPA regulations include a Combined Application which means that one application may serve as the Notice of Intent, the 401 Water Quality Certification application, and/or the Chapter 91 license, permit, or other written application for a water-dependent use project.

8.2 Local Permitting Requirements

8.2.1 Conservation Commission

The City of Worcester has a Wetlands Protection Ordinance & Wetlands Protection Regulations, which in addition to regulating the resource areas and 100?foot Buffer Zone under the state WPA, also regulate activities within one hundred (100) feet of any existing or proposed inlet to any storm drain,

catch basin, or other storm drain system component discharging to any lake, pond, river, stream, or wetland.

8.2.2 Division of Planning and Regulatory Services

The Division of Planning and Regulatory Services (P&RS) participates in the development of Comprehensive Long-Range Plans that support strategic land use and policy decisions. The P&RS also supports various City commissions and boards including the Conservation Commission, Historical Commission, Planning Board and Zoning Board of Appeals.

Section 9
Costs

9.1 Purpose and Scope

This section presents an Opinion of Probable Project Cost for the Patch Pond Dam removal alternatives as described in Section 7. The opinion of probable project costs presented in this section includes construction, escalation to mid-point of construction, contingencies, engineering and implementation costs for each alternative.

In Section 10, the preferred alternative is discussed based on both project costs and non-cost considerations.

9.2 Dam Removal Alternatives

The three dam removal alternatives are described in Section 7 and include:

- Alternative 1 – Full removal of the dam and full removal of the sediment in Patch Pond.
- Alternative 2 – Full removal of the dam and limited removal of the sediment in Patch Pond.
- Alternative 3 – Full removal of the dam and in-situ sediment stabilization of in Patch Pond.

9.3 Opinion of Probable Project Costs

The total project cost includes several components as follows:

- Construction (including stream flow bypass) and construction contingency
- Escalation to mid-point of construction
- Project contingency, engineering and implementation
- Stream flow bypass

9.3.1 Construction and Construction Contingency

The construction cost is the sum of direct construction costs, such as labor and materials, and indirect construction costs, such as permits and insurance. The unit costs that comprise the direct construction cost are estimated based on the Engineering News Record (ENR) Construction Cost Index (CCI) of 9800 (20-City Average).

The indirect construction costs include building permits, sales tax, builders risk insurance, general liability insurance, general contractor bonds, general contractor field conditions, and contractor overhead and profit. Industry and experience averages on bid data was used to develop average percentage “mark-ups” of the direct construction costs to calculate the indirect construction costs.

A 25 percent construction contingency was included in the opinion of probable project costs to account for the fact that this evaluation is at the feasibility/conceptual stage, and many aspects are yet to be developed in detail.

9.3.1.1 Stream Flow Bypass

Proper management of the sediment behind the Patch Pond Dam and within the impoundment is important from a regulatory and a public safety perspective. As a result, the cost estimate presented in this feasibility study utilizes comprehensive stream flow bypass methods and sediment protection scenarios that are reflected in the cost estimate. Several possible stream flow bypass methods that divert the flow into Patch Pond while preventing the sediments from moving downstream were considered in this cost estimate. The final method of bypass would be determined in the final design, with approval from the appropriate regulatory agencies. Because of this uncertainty, a range of total cost is presented in the opinion of probable cost to reflect the various bypass methods considered.

9.3.2 Escalation to Mid-Point of Construction

The opinions of probable project costs were estimated in June 2014 dollars based on an ENR Construction Cost Index (20-City Average) of 9800. To account for the continued increase in construction materials, an escalation to mid-point of construction has been estimated. An annual escalation factor of 3 percent per year has been added to the opinions of probable project costs presented in this report. The escalation factor is linearly applied to the number of months until the mid-point of construction, which is projected to be August 2016.

9.3.3 Project Contingency, Engineering and Implementation

Several factors can impact the overall bidding environment of a project, including contractor competition and project funding. Contractor competition may be limited based on the difficulty of a project or number of other projects being constructed simultaneously. CDM Smith applied a 10 percent project contingency to the sum of the costs above (construction, and escalation to mid-point of construction).

Engineering and implementation costs can range from 15 to 40 percent of the escalated construction costs and are developed on a project specific basis. Engineering and implementation costs can include permitting, finance bonding costs, geotechnical program (including borings), survey, engineering design, legal, construction oversight, administrative, and public participation. CDM Smith included 20 percent of the above costs (sum of construction, and escalation to mid-point of construction) as the engineering and implementation costs.

9.4 Opinion of Probable Project Cost

Table 9-1 summarizes the Opinions of Probable Project Cost for the three alternatives presented.

Table 9-1
Opinion of Probable Project Cost Summary

Cost Item	*Alternative 1 Full Removal of the Dam and Full Removal of the Sediment*	*Alternative 2 Full Removal of the Dam and Limited Removal of the Sediment*	*Alternative 3 Full Removal of the Dam and In-Situ Sediment Stabilization*
Construction[1]	$5,660,000 to $5,770,000	$2,130,000 to $2,250,000	$1,060,000 to $1,190,000
Escalation to Mid-Point of Construction[2]	$370,000 to $380,000	$140,000 to $150,000	$70,000 to $80,000
Project Contingency, Engineering and Implementation[3]	$1,210,000 to $1,960,000	$450,000 to $770,000	$362,000 to $405,000
Total[4]	**$7,240,000 to $8,110,000**	**$2,720,000 to $3,170,000**	**$1,500,000 to $1,700,000**

Table Notes:

[1] Construction includes a construction contingency of 25%.

[2] Escalation to mid-point of construction assumes mid-point of construction occurs in August 2016. Escalation assumed to be 3% per year of the sum of the construction and construction contingency.

[3] Project contingency is 10% of the sum of the construction, and escalation to mid-point of construction. Engineering & Implementation is 20% of the sum of construction, and escalation to mid-point of construction.

[4] The range of costs for each alternative is presented to account for various flow bypass methods and various project contingencies that would be further defined in the final design should the project move forward.

Section 10
Preferred Alternative and Future Considerations

10.1 Preferred Alternative Analysis

This section evaluates several non-cost issues for the three Patch Pond Dam removal alternatives (as identified in Section 7) to meet the overall goals of this feasibility study. The costs related to the project were discussed in Section 9.

The preferred alternative is identified based on the strengths and weaknesses of the non-cost factors, as well as the costs.

10.1.1 Non-Cost Evaluation Criteria

A comparative matrix was developed for the three alternatives. Ten major aspects of the dam removal project were selected for comparison:

- Safety liability
- Upstream and downstream issues
- Fisheries restoration
- Permitting requirements
- Existing resources
- Contaminated sediments
- Hydraulic conditions
- Water quality
- Constructability
- SWMI

All criteria were compared based on whether or not it was more or less advantageous to implement each alternative. Since the three alternatives are very similar from the perspective of the extent of the removal of the dam structure itself, eight of the ten criteria show no advantage for either alternative immediately after construction. The advantage between the three alternatives diminishes even further a few seasons after construction due to the long term stabilization of sediments within the Patch Pond. The definition and approach for each criterion is described below. Table 10-1 presents all of the criteria.

Table 10-1
Non-Cost Criteria Matrix for Removal Alternatives
Patch Pond Dam

Item	Alternative 1 Full Dam Removal, Full Sediment Removal	Alternative 2 Full Dam Removal, Limited Sediment Removal	Alternative 3 Full Dam Removal, In Situ Sediment Stabilization
Safety liability	Low liability – all structures removed		
Upstream and downstream issues	Reduced impact on flooding upstream and downstream of dam		
Fisheries restoration	Fluvial fishery spawning and nursery habitat restored		
Permitting requirements	Permitting expected to be similar		
Existing resources	No permanent negative impacts on resources identified		
Contaminated sediments	Removal of all sediment. Less liability since sediment does not need to be stabilized.	Increased liability in the short-term since sediment would be stabilized with native vegetation. Additional time is required to establish mature vegetation. In the long-term, with proper maintenance these alternatives would approach the advantages offered by Alternative 1.	
Hydraulic conditions	Dam removal would not have adverse impacts to hydraulics of stream. Flooding would be reduced.		
Water quality	In-stream dissolved oxygen improved. Free flowing stream restored. Deep single channel flow enhanced.		
Constructability	Civil and demolition work similar. Significant sediment removal would impact project duration and logistics.	Civil and demolition work similar. Sediment removal reduced.	Civil and demolition work similar. Sediment removal eliminated.
SWMI	Habitat improvement credit equal		

Each individual criterion was considered on its own merits to reflect the perceived advantages. The discussion below details the considerations included in the evaluation.

Safety Liability

Safety Liability: A safety liability for the City would be eliminated under the three alternatives because the entire dam superstructure above grade would be removed and the site/structure would no longer be regulated as a dam by the Office of Dam Safety. The City would no longer be obligated to regularly inspect and maintain any structures at the site. The side slopes of the dam would be regraded and

restored to a natural state. The rubble from the dam structure would be moved to the east along Glendale Street and would be spread low along the non-native stream that was formed as a result of the breach at the east embankment. The rubble would become part of the landscape.

Result: The alternatives are equal and would eliminate the safety liability for the City.

Upstream and Downstream Issues

Upstream and Downstream Issues: Under the three alternatives, upstream and downstream issues related to flooding, wetlands, channel protection, structures and long-term erosion of the restored channel are considered. The impacts are considered to be equivalent for the three alternatives.

Result: The alternatives are equal and would result in similar upstream and downstream issues.

Fisheries Restoration

Fisheries Restoration: Under the three alternatives, the channel would be designed to maximize the migration of cold water fish to upstream reaches. The proposed channel is considered to be equivalent for the three alternatives in terms of habitat restoration. The consolidation of the two stream channels downstream of the dam (the spillway channel and the channel created as a result of the partial breach at the east embankment) would enhance the fishery resource by creating a deeper single channel that is beneficial to migrating fish during low flow periods. It is expected that the change of the Patch Pond from a pond to a stream will support restoration of fluvial fish which are present downstream of the dam.

Result: The alternatives are equal and would result in a restoration of a fluvial fishery spawning and nursery habitat.

Permitting Requirements

Permitting Requirements: Under the three alternatives, the permitting requirements are expected to be similar. The differences between the three alternatives are not expected to trigger any additional or different permitting requirements.

Result: The alternatives are considered equal.

Existing Resources

Existing Resources: Under the three alternatives, the existing resources would not be negatively impacted on a permanent basis, and similar restoration of the natural resources is expected.

Result: The alternatives are considered equal.

Contaminated Sediments

Contaminated Sediments: Under Alternative 1, all of the contaminated sediments in the Patch Pond would be removed and the liability of a downstream sediment release would be minimized. Under Alternative 2, contaminated sediments 50 feet upstream of the dam and within in the stream channel would be taken away to prevent movement of these sediments downstream. The sediments that remain in Alternative 2 would be stabilized in situ and seeded with native species to further stabilize the area. Under Alternative 3, contaminated sediments 50 feet upstream of the dam and within in the

stream channel would be redistributed within the Patch Pond and stabilized to prevent movement of these sediments downstream.

Alternatives 2and 3 carry a higher risk due to the possibility that a large storm immediately after construction (before the seeded plant species take root) could wash contaminated sediments downstream.

Result: Alternatives 2and 3 carry an elevated risk of release of contaminated sediments downstream in the short-term. In the long-term, Alternatives 2 and 3 would provide adequate stabilization, but would require diligence and maintenance until permanent stabilization is achieved. Alternative 1 is considered more advantageous on the basis of maintenance requirements.

Hydraulic Conditions

Hydraulic Conditions: Under the three alternatives, hydraulic conditions in the stream channel would be similar. Removal of the dam would decrease flooding in the immediate vicinity of the dam.

Result: The alternatives are equal.

Water Quality

Water Quality: Under the three alternatives, in-stream dissolved oxygen levels would be improved as removal of the dam would turn a stagnant system into a free-flowing system, which promotes water quality. Removal of the dam would eliminate the warmer water in the impoundment as well as the build-up of nutrients (e.g., nitrogen, phosphorous) both of which promote plant and algae growth, which in turn deplete oxygen levels.

Result: The alternatives are equal since water quality is expected to improve under the three alternatives.

Constructability

Constructability: Under Alternative 1, more site work would need to take place to remove all of the contaminated sediments. Under Alternative 1, an additional estimated 15,000 cubic yards of sediment would need to be removed and disposed of. This would add considerable time to the construction duration due to the limited site access at the dam. Under Alternative 2, less site work is anticipated because most of the existing contaminated sediments would be stabilized in-situ rather than removed. Alternative 3 requires the least amount of site work because the existing sediments would be moved within the site and stabilized in-situ rather than dewatered, removed and transported to an out of state facility.

The constructability of the three alternatives is feasible, but Alternative 3 is a considerably easier project to implement because of the reduced amount of earthwork required. The cost differential among the three Alternative reflects the significant difference in offsite contaminated sediment removal.

Result: Alternative 3 is preferred due to reduced construction time and less complex logistics.

SWMI

SWMI: Recently, the Commonwealth of Massachusetts launched the Sustainable Water Management Initiative (SWMI) to develop and implement water policy decisions that support ecological needs while meeting the needs of economic growth. The successful removal of the dam is an implementable management decision that would give an equal amount of SWMI habitat improvement credits under all alternatives.

Result: The alternatives are equal.

10.2 Preferred Alternative

Based on both the non-cost issues presented in this section and the cost analysis presented in Section 9, Alternative 3 is the preferred alternative for this project.

10.3 Future Steps

The technical evaluations and analyses in this study determined that the removal of the Patch Pond Dam is feasible. Upon acceptance of this feasibility study and should the City of Worcester decide to move forward with removal of the dam, it would need to begin the permitting, design (preliminary and final design), and public participation process. During the design process, the specifics of the project must be considered in greater depth than what was possible in this feasibility study. To begin, the Executive Office of Energy and Environmental Affairs (EOEA) dam removal guidance document would be reviewed to ascertain the detailed design requirements. State and local agencies would need to be contacted to determine the approach to the project that considers the best practices required to protect the environment (fish, wildlife and wetlands), schedule the construction, plant and stabilize the sediment/soil, develop an appropriate sediment management plan (placement and disposal), conduct additional soils/sediment sampling, and develop appropriate short- and long-term monitoring programs needed to ensure the desired result is achieved.

10.3.1 Monitoring Plan/ Follow-Up Monitoring

Follow-up monitoring and maintenance of the Patch Pond Dam site would be necessary to ensure that the restored area around the dam remains stable. There are two types of monitoring at dam removal projects, post-construction monitoring and habitat/long-term monitoring.

Post-Construction Monitoring

The post-construction monitoring begins when the majority of the construction work is completed. It includes an evaluation of the project site for any risks to infrastructure such as nearby utilities, residences, bank side slopes, downstream bridges, and culverts with an evaluation of the new channel (including the inlet and outlet of the channel) for excessive erosion or sediment deposition. A project evaluation would initially be completed by the contractor and construction manager immediately following project completion. However, the City would also conduct regular walkthroughs of the site.

The vegetation selected for restoration must be checked for adaptation to actual field conditions. Since the main flow channel through the impoundment area would be designed to convey a 10 year storm, erosion control measures must remain in place to minimize migration of sediments in the event of a larger storm. Larger storm events would be mitigated using a combination of rapid growth

annual grasses and appropriate matting utilizing stakes or other anchoring techniques. These erosion control measures must be monitored and maintained for several seasons. A checklist would be developed to assist in visual inspection, which might include vegetation growth, erosion, and scour around infrastructure, such as pipes, retaining walls, and other structures.

The project must also be monitored to ensure that colonization of the site by invasive species is kept to a minimum. The anticipated monitoring schedule would consist of three to four visits during the first one or two growing seasons, followed by semi-annual visits for two to three more years. This schedule would be adjusted depending on the degree to which control of invasive species may be necessary.

Habitat / Long-Term Monitoring

Habitat and long-term monitoring are also important for the success of the project. Photo stations could be set up as part of the monitoring to regularly document the site over time. Habitat monitoring would also be completed to assess the development of habitat features of particular interest at the project site. The long term monitoring would also evaluate the stabilization of any sediment left in place. It would also be used to assess the degree to which control of invasive species may be necessary.

10.4 Additional Issues for Consideration

10.4.1 Agency Review Meeting – June 24, 2014

At the June 24, 2014 draft report meeting for the Patch Pond Dam removal feasibility study, several additional issues were raised that may need to be further considered [outside of the scope of this feasibility study]. Those issues are listed below:

1. It was acknowledged that additional investigations may be required to further characterize the sediments in the Patch Pond. The representatives from Massachusetts Department of Environmental Protection suggested that if follow-up sampling showed contaminated sediments were present in the Patch Pond, those sediments would likely need to be removed and/or stabilized in place, but should not be released downstream.

2. This feasibility study adopted a conservative approach to sediment management by utilizing an armored channel for the area upstream of the dam and stabilization measures for the sediments to be left in place. It was generally understood that a natural channel would be a desired feature for the project, and the need to manage contaminated sediments would likely require the use of a highly engineered channel. It was suggested at the meeting that an engineered channel with natural features to encourage native species would be desired.

3. The representatives from Massachusetts Department of Environmental Protection also suggested the following:

    a. Consolidation of the two streams south of the Patch Pond dam into one stream to restore the Tatnuck Brook to a single stream.

b. Implementation of an appropriate follow up program to ensure that unwanted invasive species do not overrun the project site. These agencies noted that measures are available to minimize the establishment of invasive species after construction.

10.5 Funding Opportunities

The Patch Pond Dam is one of 29 dams owned by the City of Worcester. Funds for operation and maintenance of this dam are obtained from the general property tax levy. Given the ecological benefits associated with removal of the dam, as well as the forthcoming regulatory requirements that are likely under the Sustainable Water Management Initiative (SWMI), this dam removal project is an ideal candidate for funding support from various grant and loan programs. Table 10-2 presents a summary of potential funding sources that can be pursued should the City of Worcester proceed with implementation of the dam removal project at Patch Pond dam.

Table 10-2
Summary of Dam Removal Funding Opportunities

Program Category/Program	*Description*	*Available Funding/ Deadlines*
National/Federal		
Challenge Grants National Fish and Wildlife Foundation	Matching grants to projects that address priority actions promoting fish and wildlife conservation and habitats	Funding range $10,000 - $150,000. Two step application process: pre-proposal and full proposal by invitation.
NOAA Community-Based Habitat Restoration National Marine Fisheries Service in Partnership with American Rivers, Nature Conservancy, Conservation Law Foundation, and others	Long-term national and regional partnerships to leverage funding to support community-based restoration efforts. In addition to financial assistance, provides restoration science and technical guidance, including assistance with environmental compliance, and monitoring. Grants available for Engineering Design and Construction.	Previous funding range $50,000 – $200,000 Last program awards in 2013. No funding announcement of program availability in 2014 thus far. Application deadline and award amount varies by partner organization.
National Fish and Wildlife Foundation Bring Back the Natives/More Fish Program	Funding for projects to restore, protect, and enhance native populations of sensitive or listed fish species, especially on lands on or adjacent to federal agency lands. Projects must identify measureable conservation outcomes for native fish species of special concern. Projects that address habitat alteration and lack of adequate instream flows are of particular interest. Projects benefitting selected fish species are priorities for funding, including native eastern brook trout and associated native aquatic species.	Up to $1,250,000 in grant funds is available. Grant awards generally range in size from $25,000 to $100,000, although grants greater than $100,000 will be considered. Annual grant cycle, RFP typically released in the spring (May). Two step process – preproposals due in June, final proposals due in August. Applicants must provide non-federal match of at least $2 for every $1 of grant funds requested.

Table 10-2 (Cont'd)
Summary of Dam Removal Funding Opportunities

Program Category/Program	*Description*	*Available Funding/ Deadlines*
In-Kind Federal Assistance	In-kind non-monetary assistance in the form of Staff expertise in fisheries, aquatic ecosystem restoration, dam deconstruction.	
State		
Dam and Seawall Repair or Removal Fund Executive Office of Energy and Environmental Affairs (Chapter 448 of the Acts of 2012 and 301 CMR 15.00)	Grants and loans. High and significant hazard dams in poor or unsafe condition anticipated to receive highest priority. Most costs are eligible including engineering and construction. Preference to projects that are shovel-ready and have commitment of matching funds.	Final regulations promulgated August 2013. Two rounds of funding have been made available (Fall 2013) and current request for responses (RFR) due June 17, 2014. Maximum award for dams is $1,000,000. Future rounds of funding are anticipated.
Massachusetts Environmental Trust (MET) General Grant Program	Grants to organizations that have made a remarkable impact on protecting and enhancing the state's water resources. Requires collaboration between communities and conservation partners. Matching funds are a preferred but not mandatory. Preference to projects that leverage additional funding or in-kind resources to maximize impact of MET funds.	Two stage application process - RFR published August of each year with letters of inquiry due in October. Selected applicants invited to submit full proposals in March of the following year. Announcement of grant awards is typically made in June. $500,000 FY'15 grant budget; grants generally between $10,000 and $40,000 per year, per award.
Department of Fish and Game (DFG) Division of Ecological Restoration (DER) Wetlands and River Restoration and Revitalization Priority Projects	Grants to support sustainable river and wetland restoration projects that restore natural processes, remove ecosystem stressors, increase resilience of the ecosystem, support river and wetland habitat, and promote passage of fish and wildlife through dam and other barrier removal. In-kind non-monetary technical assistance also available.	Funding Available: N/A Average Grant Size: $5,000 to $55,000 Estimated Application Deadline: October
Executive Office of Energy & Environmental Affairs Department of Environmental Protection Sustainable Water Management Initiative Grant	Designed to assist eligible public water suppliers and municipalities with Water Management Act permits by providing funds for planning assistance, demand management, and withdrawal impact mitigation projects in local communities. Funding available for planning projects for specific watersheds or subwatersheds to identify implementation projects to improve ecological conditions. Also for mitigation projects that improve or increase instream flow, habitat improvement, and other projects that can be demonstrated to mitigate the impacts of water withdrawals.	Competitive procurement process. Program in its second year. FY'13 $929,000 awarded among 11 projects. Maximum grant $139,000. FY'14 $1,100,000 in funding awarded among 17 projects.