TALBOT MILLS DAM REMOVAL TARGETED IMPACT ANALYSIS

Concord River, Billerica, MA

DRAFT REPORT JANUARY 2022

Prepared for:

251 Causeway St, Ste 400, Boston, MA 02114

In partnership with:

TOWN of BILLERICA

Department of Public Works

365 Boston Rd, Room G11, Billerica, MA 01821

NOAA FISHERIES

55 Great Republic Drive, Gloucester, MA 01930

Prepared by:

GOMEZ AND SULLIVAN ENGINEERS

PO Box 2179, Henniker, NH 03242

EXECUTIVE SUMMARY

Purpose

The purpose of this study was to conduct a targeted impact analysis to evaluate potential effects of the proposed removal of Talbot Mills Dam on the Concord River in Billerica, Massachusetts on an upstream raw water intake operated by the Town of Billerica approximately 1.25 miles upstream of the dam, as well as address other Town concerns with the proposed project.

Previous Studies

The *Concord River Diadromous Fish Restoration Feasibility Study* (Feasibility Study) was completed in 2016 by Gomez and Sullivan Engineers, DPC (Gomez and Sullivan), led by the Massachusetts Department of Fish and Game (DFG), Division of Marine Fisheries (DMF) with support from the National Oceanic and Atmospheric Administration (NOAA) Restoration Center, the US Fish and Wildlife Service (USFWS), and the Massachusetts Department of Environmental Protection (MassDEP). The study identified the Talbot Mills Dam in Billerica as the primary impediment to fish passage in the Concord River. A conceptual plan for the removal of the Talbot Mills Dam was developed. This project was approved for implementation by the Nyanza Chemical Waste Dump Superfund Site Natural Resource Damages (NRD) Trustee Council (comprised of the Massachusetts Executive Office of Energy and Environmental Affairs (EEA), represented by MassDEP, USFWS, and NOAA) and has received funding from the Nyanza Site NRD Settlement.

At the request of the Town of Billerica (Town), Streamworks, PLLC (Streamworks) completed a review of Gomez and Sullivan's 2016 Feasibility Study and summarized their findings in a memo titled *Review of Talbot Mills Dam Removal Feasibility Study* dated September 1, 2020. In their review, Streamworks identified current gaps in the analysis and provided suggestions for further analysis to evaluate the feasibility of removing the Talbot Mills Dam. Streamworks also highlighted potential issues regarding impacts to the Town's drinking water and sewer infrastructure, particularly the Town's raw water intake within the dam's impoundment.

Project Approach

Through discussions with project partners, the Streamworks recommendations were prioritized into two phases. The initial phase (the scope of this study) was a targeted impact analysis with the primary goal of identifying any unmitigable impacts to the Town's raw water intakes or water supply, as this is a critical issue for the project. If no significant impacts were found, or if the impacts could be managed with mitigative measures, the remaining issues would be addressed during the design phase of the project.

The DMF, in partnership with NOAA, contracted Gomez and Sullivan to complete the Phase 1 scope in 2021. The following data collection efforts and analyses were conducted for this targeted impact analysis of the proposed Talbot Mills Dam removal as it relates to the Town's water intake and other concerns:

- Bathymetric Survey
- Subsurface Assessment
- Water Level Monitoring
- 1D Hydraulic Model Revisions
- Intake Pump Performance Analysis *(pending, by Town)*
- Superfund Site Preliminary Impact Assessment

Results

The revised hydraulic model developed for this analysis produced existing versus proposed (dam removal scenario) water surface elevations at the Billerica water supply intake for a range of flows. The anticipated drop in water surface elevation at the intake ranges from 0.17 feet for the median annual flow (467 cfs) to 0.43 feet for the 100-year flood (5,675 cfs). The anticipated reduction in water surface elevation at the intake during the 7Q10 drought flow (28 cfs) is 0.35 feet. Model results indicate that the change in water surface elevation at the Billerica water supply intake would be less than 0.5 feet for all modeled flows due to the proposed removal of Talbot Mills Dam. The minimum water depth above the intake invert would be 5.8 feet (down from 6.1 feet for existing conditions) for the 7Q10 drought flow. It should be noted that even though the anticipated reduction in water surface elevations is relatively small, it is expected to result in significant beneficial impacts in reducing upstream flooding of properties and infrastructure.

Considering available information, including boring data and historical and recent observations, it was determined that the Fordway Bar at Pollard Street is a natural geomorphic feature that is resistant to erosion and would likely serve as the new hydraulic grade controlling upstream water surface elevations at or near its current elevation following a dam removal scenario. The hydraulic model indicates that proposed water surface elevations upstream of the Fordway Bar would be similar to (within 0.5 feet of) existing water levels. Therefore, no significant impact to the Town's raw water intake is anticipated.

Additionally, a review of background information on the nearby Iron Horse Superfund Site and consultation with the US Environmental Protection Agency (EPA) led to a determination that the proposed Talbot Mills Dam removal project is unlikely to result in the migration of contaminated groundwater, surface water, or sediments away from the Superfund Site. Therefore, no impact to the quality of the Town's water supply in the Concord River is expected.

Next Steps

The revised hydraulic model results presented in this draft report will be used by the Town's consultant to analyze potential impacts on intake pump performance due to changes in water level following dam removal. Once the analysis is complete, results will be incorporated into the final report.

Pending any unmitigable impacts to the Town's water supply intake or other resources, which are not expected, it is recommended that the proposed Talbot Mills Dam removal project proceed to the preliminary design and permitting phase. During this phase, the following additional recommendations identified in the 2016 Feasibility Study and 2020 Streamworks review can be addressed as appropriate:

- Upstream Extension of Hydraulic Model (Upstream Impact Analysis)
- 2D Hydraulic Modeling
- Unsteady Hydraulic Modeling (Downstream Impact Analysis)
- Additional Sediment Probing & Sampling
- Sediment Mobility Assessment
- Sediment Management Planning
- Bridge Scour Analysis
- Retaining Wall Stability Analysis
- Fish Passage Contingency Estimate
- Cultural Resources Mitigation Planning
- Recreational/Aesthetic Study
- Resource Delineation

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF ABBREVIATIONS

1D	one-dimensional
B&M	Boston and Maine
DEP	Massachusetts Department of Environmental Protection
DMF	Massachusetts Division of Marine Fisheries
EEA	Massachusetts Executive Office of Energy and Environmental Affairs
EPA	United States Environmental Protection Agency
ERA/WRIA	Ecological Risk Assessment / Wetlands Remedial Investigation Addendum
Feasibility Study	Concord River Diadromous Fish Restoration Feasibility Study
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
ft	feet
Gomez and Sullivan	Gomez and Sullivan Engineers, DPC
HEC-RAS	USACE Hydrologic Engineering Center's River Analysis System
LiDAR	Light Detection and Ranging
M&E	Metcalf & Eddy, AECOM
MNR	Monitored Natural Recovery
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NRD	Natural Resource Damages
OU	Operable Unit
ROD	Record of Decision
sq mi	square miles
Streamworks	Streamworks, P.L.L.C.
Town	Town of Billerica, MA
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

1 Background

Purpose

The purpose of this study was to conduct a targeted impact analysis to evaluate potential effects of the proposed removal of Talbot Mills Dam on the Concord River in Billerica, Massachusetts on an upstream raw water intake operated by the Town of Billerica approximately 1.25 miles upstream of the dam, as well as address other Town concerns with the proposed project.

Previous Studies

The *Concord River Diadromous Fish Restoration Feasibility Study* (Feasibility Study) was completed in 2016 by Gomez and Sullivan Engineers, DPC (Gomez and Sullivan), led by the Massachusetts Department of Fish and Game (DFG), Division of Marine Fisheries (DMF) with support from the National Oceanic and Atmospheric Administration (NOAA) Restoration Center, the US Fish and Wildlife Service (USFWS), and the Massachusetts Department of Environmental Protection (MassDEP). This project was approved for implementation by the Nyanza Chemical Waste Dump Superfund Site Natural Resource Damages (NRD) Trustee Council (comprised of the Massachusetts Executive Office of Energy and Environmental Affairs (EEA), represented by MassDEP, USFWS, and NOAA) and has received funding from the Nyanza Site NRD Settlement. The purpose of the Feasibility Study was to evaluate the feasibility of restoring populations of diadromous fish to the Concord, Sudbury, and Assabet Rivers, collectively known as the SuAsCo Watershed (shown in **Figure 1-1** in **Appendix A**). The study identified the Talbot Mills Dam in Billerica as the primary impediment to fish passage in the Concord River (shown in **Figures 1-2** through **1-4**). A conceptual plan for the removal of the Talbot Mills Dam was developed (shown in **Figure 1-5**).

At the request of the Town of Billerica (Town), Streamworks, PLLC (Streamworks) completed a review of Gomez and Sullivan's 2016 Feasibility Study and summarized their findings in a memo titled *Review of Talbot Mills Dam Removal Feasibility Study* dated September 1, 2020. In their review, Streamworks identified current gaps in the analysis and provided suggestions for further analysis to evaluate the feasibility of removing the Talbot Mills Dam. Streamworks also highlighted potential issues regarding impacts to the Town's drinking water and sewer infrastructure, particularly the Town's raw water intake located approximately 1.25 miles upstream of the Talbot Mills Dam and within the dam's impoundment. Streamworks recommended the following items for further study:

1. **Refine hydraulic modeling**, including:
    a. collect and incorporate additional bathymetry data for the area around Fordway Bar, and possibly the bedrock and submerged relic dam near the existing dam;
    b. collect additional survey baseflow water surface elevations near critical infrastructure, and recalibrate model using baseflow survey data and available high-water mark data;
    c. extend the model upstream into the Sudbury and/or Assabet Rivers if water level changes extend into these rivers;
    d. consider developing a two-dimensional (2D) model of the area between the dam and the Town's drinking water intake; and
    e. conduct unsteady hydraulic modeling to confirm no significant increase in downstream peak discharge during flood flows.

2. **Assess potential impacts on performance of the Town's water intake pumps** due to dam removal.
3. **Conduct additional sediment probing and sampling**, including
    a. conduct additional sediment probing downstream and upstream of Pollard Street to better quantify the volume of impounded sediment and identify potentially mobile deposits; and
    b. collect additional sediment samples within the impoundment and upstream and downstream of the impoundment.
4. **Assess the need for active sediment management** through coordination with the DEP, based upon the results of the additional sediment testing.
5. **Conduct sediment mobility assessment** by collecting sediment samples at key locations and evaluating grain size in conjunction with hydraulic modeling output to assess erosion potential.
6. **Conduct scour analyses at upstream bridges** where significant changes in velocities, shear stress, and/or flow depths are anticipated.
7. **Perform a preliminary stability analysis of existing retaining walls** along Faulkner Street and the existing pedestrian park adjacent to the dam abutment and develop a budgetary estimate for any stabilization measures that may be needed during dam removal.
8. **Perform a fish passage assessment** to verify that fish would be able to navigate through the site after the dam is removed and provide a contingency for fish passage measures as part of construction costs in case remnant falls are not adequately passable for target species.
9. **Evaluate potential impacts to the Iron Horse Park Superfund Site** due to of water level changes through coordination with the Environmental Protection Agency (EPA).
10. **Advance other studies recommended in the 2016 Feasibility Study**, including a geophysical survey, additional cultural resources mitigation planning, a recreational/ aesthetic study, a resource delineation, and a topographic survey.

Project Approach

Through discussions with project partners, the Streamworks recommendations were prioritized into two phases. The initial phase (the scope of this study) is a targeted impact analysis with the primary goal of identifying any unmitigable impacts to the Town's raw water intakes or water supply, as this is a critical issue for the project. If no significant impacts are found, or if the impacts could be managed with mitigative measures, the remaining issues identified by Streamworks would be addressed during the design phase of the project. As such, the recommendations were assigned to the two phases of the project as follows:

Phase 1 – Targeted Impact Analysis

- Bathymetric Survey
- Subsurface Assessment
- Water Level Monitoring
- 1D Hydraulic Model Revisions
- Intake Pump Performance Analysis (by Town)
- Superfund Site Preliminary Impact Assessment

Phase 2 – Additional Analyses to Address During Design (as needed)

- Upstream Extension of Hydraulic Model (Upstream Impact Analysis)
- 2D Hydraulic Modeling

- Unsteady Hydraulic Modeling (Downstream Impact Analysis)
- Additional Sediment Probing & Sampling
- Sediment Mobility Assessment
- Sediment Management Planning
- Bridge Scour Analysis
- Retaining Wall Stability Analysis
- Fish Passage Contingency Estimate
- Cultural Resources Mitigation Planning
- Recreational/Aesthetic Study
- Resource Delineation

The DMF, in partnership with the NOAA Restoration Center, contracted with Gomez and Sullivan to complete the Phase 1 Targeted Impact Analysis in 2021. This report summarizes the findings of the analysis.

Water Supply Intake Background Information

The Billerica Department of Public Works (DPW) Water Division withdraws water from the Concord River to supply drinking water to the Town of Billerica[1]. The facility has an average annual permitted withdrawal rate of 5.3 million gallons per day (MGD) and a maximum permitted withdrawal of 14 MGD (DEP, 2010). Actual average daily use from 1992 to 2014 averaged 4.53 MGD (Gomez and Sullivan, 2016).

The water supply intake is located approximately 6,700 feet (about 1.25 miles) upstream of the Talbot Mills Dam and about 1,200 feet downstream of the Boston Road (Route 3A) bridge, which is within the dam's impoundment. The intake structure was built in 1955 and consists of a screened wet well and three pumps used to withdraw water from the river (J. McGovern, personal communication, 2014). **Figure 1-6** provides an excerpt from the 1954 engineering plans for the intake structure. **Table 1-6** provides a summary of key elevations from the water intake drawing along with a comparison to corresponding water surface elevations modeled in this study. According to the elevations in the drawing, the minimum low water elevation for the intake structure is approximately 107.2 feet in the North American Vertical Datum of 1988 (NAVD 88)[2].

As part of this study, potential effects of the proposed removal of Talbot Mills Dam on the Billerica water intake (e.g., lower water surface elevations at the intake) were investigated.

---

[1] Public Water System (PWS) ID No. 3031000-01S.

[2] Although not specified, it is assumed that elevations in the plans are given in the National Geodetic Vertical Datum of 1929 (NGVD 29), as NAVD 88 had not yet been introduced at the time of publication (1954). Elevations in this report have been converted to NAVD 88.

2 Data Collection & Analysis

Representative photos collected during the project are provided in **Appendix B**.

2.1 Bathymetric Survey

A bathymetric survey was conducted in the area between the dam and just upstream of the Route 3A Bridge (a distance of approximately 1.5 miles) to refine the existing hydraulic model for the project. The goals of the bathymetric survey were to:

- better define bathymetry in the lower impoundment downstream of the Pollard Street Bridge (depicted in **Figure 2.1-1**);
- better define the hydraulic control known as the Fordway Bar near the Pollard Street Bridge;
- collect survey data near the raw water intake to confirm elevations at this key location; and
- provide sufficient bathymetric detail for potential 2D hydraulic modeling during Phase 2

The bathymetric survey was conducted on July 29, 2021 using a SonTek Acoustic Doppler Current Profiler (ADCP) coupled with an RTK GPS. A small boat was used to traverse the impoundment and collect bathymetric data. Flow at the downstream gage[3] was around 1,030 cubic feet per second (cfs) during the survey, which was significantly higher than the median for July 29 of 179 cfs[4], and flow remained much higher than normal through October 2021. Because of safety concerns due to the high flows, bathymetric survey could not be collected immediately upstream or downstream of the dam, which was spilling a significant amount of flow during the entire field season. However, the hydraulic model was updated for the proposed dam removal section to reflect more accurate bathymetry at the toe of the dam, as described in **Section 2.4**.

The bathymetric data was post-processed, analyzed to determine elevations of the channel bottom[5], and prepared in GIS format. A terrain model was created using the bathymetric data, shown in **Figures 2.1-2 and 2.1-3**. Sediment transect data and additional survey data from the 2016 Feasibility Study were incorporated into the terrain model to extend the model to Talbot Mills Dam. The terrain model was tied into the 2010 FEMA LiDAR data, which was used for overbank areas and islands (NOAA, 2010). Bathymetric survey data and the terrain model were used to refine the hydraulic model as described in **Section 2.4**.

The terrain model developed from the bathymetric data depicts the previously reported high point in the channel bed (hydraulic grade control) at the Fordway Bar in the vicinity of the Pollard Street Bridge, as well as a series of pools and shallower sections between the Fordway Bar and Boston Road (Route 3A). The elevation of the Fordway Bar grade control was found to be approximately 106.8 ft NAVD88 at its highest measured point within the thalweg. Downstream of the Fordway Bar, there is a pool followed by a higher channel bed area in the vicinity of a series of rocky islands and outcrops. Approximately 500 feet downstream of these islands, the channel bottom drops significantly from around 105 feet to 96 feet over 200 feet of channel length. Downstream of the pool at the end of this drop is another higher area with islands followed by another fall into the lower impoundment. This series of drops captured by the

[3] USGS Gage 01099500 Concord River Below R Meadow Brook, at Lowell, MA.

[4] Median flow for July 29 for the period of record at the gage from 1937 to 2021.

[5] All elevations for this study were collected relative to the North American Vertical Datum of 1988 (NAVD88).

bathymetric survey corresponds to an area referred to as "Falls" on historical maps drawn prior to the construction of the Talbot Mills Dam (Ingraham, 1995) (**Figure 2.1-4**).

2.2 Subsurface Assessment

Subsurface Conditions at Talbot Mills Dam

Though the Streamworks report did not specifically recommend a geophysical survey, it did recommend confirming the elevation of bedrock underlying the dam and attempting to locate the submerged 1798 dam directly upstream. As such, a geophysical survey was initially proposed to be conducted in the area immediately upstream of the Talbot Mills Dam spillway during the Phase 1 scope to obtain this information. However, as discussed in **Section 2.1**, flows remained significantly higher than normal during the 2021 field season. Due to safety concerns of working in the proximity of the spilling dam, a geophysical survey was not conducted during Phase 1. The lack of this optional data did not affect the results of the study, as it was determined that bedrock elevations at the dam do not impact water surface elevations at the water intake in a dam removal scenario.

Since the geophysical survey was not conducted, existing data and information along with the results of the bathymetric survey were utilized in refining the hydraulic model, as discussed further in **Section 2.4**.

Assessment of the Erodibility of Fordway Bar

A review of existing information and recent observations was conducted to assess the erodibility of the Fordway Bar to determine the likelihood that it would serve as a grade control following dam removal.

The Fordway Bar is a natural bar of hard gravel that is about 700 feet in length and was formerly used as a ford to cross the river. According to an 1861 survey, the Fordway Bar lies between points approximately 2,700 to 3,400 feet upstream of the dam, passing through the location of the present-day Pollard Street Bridge (which is 2,935 feet upstream of the dam). About 400 feet below the downstream end of the bar, the river flows swiftly through an approximately 500-foot-long section of narrow, rocky channel formed by broken ledge and obstructed by boulders and small islands (Alvord, Storrow, & Shedd, 1862). This bedrock formation likely serves as the hydraulic control for the bar and may have led to its formation. **Figure 2.2-1** shows a historical plan and cross-sections of the Fordway Bar and the downstream islands and rapids (Avery, Jr., 1859).

Attempts were made in the 1600s to cut into the Fordway Bar in order to reduce flooding in the meadows along the Concord River upstream of the bar. However, "despite some digging and blasting, cutting through the bedrock obstruction of the Fordway lay beyond their engineering capabilities" (Thorson, 2017, p. 55). Henry David Thoreau spent many years studying the Concord, Sudbury, and Assabet Rivers, in part to support the dam removal effort at that time. Robert Thorson's book *The Boatman: Henry David Thoreau's River Years*, provides historic and modern accounts of the hydraulics and features of the Concord River, including at the Fordway Bar:

> At "the Fordway and the rapids immediately below it…the combined flow of the main stem drains through a notch cut slightly down into the bedrock lip of the Musketaquid[6] basin by subglacial streams. There Thoreau found many "lumpish boulders" carved by flowing sand and pebbles into the shape of low pedestals that were stained "black as ink" below the water. He interpreted this as having once been the bed of a rushing gravel stream like those he had seen in the Maine wilderness. This is indeed what had happened during the transition between the Pleistocene and

[6] Native American name for the flat alluvial valley upstream of the Fordway Bar (Thorson, 2017, p. 40)

> Holocene epochs. At the Fordway, the solid granite bedrock in a long channel of low slope was very resistant to being widened or cut down, and the roughness of its "lumpish" boulders forced the water to flow above and around these obstacles" (Thorson, 2017, pp. 182-183).

According to the borings conducted for construction of the Pollard Street Bridge at the Fordway Bar in 1994, the channel substrate in the area consists of very dense sand and gravel atop granite bedrock (boring plan and logs shown in **Figures 2.2-2** through **2.2-4**).

Observations by local project partners indicate that the substrate at the Pollard Street Bridge / Fordway Bar consists of gravel that is hard packed or founded on bedrock (E. Reiner, personal communication, September 27, 2021). Additionally, when Streamworks conducted a site visit during low flow conditions on July 29, 2020, field staff observed large cobbles and some boulders in the vicinity of the Pollard Street Bridge. Regarding the extent of the Fordway Bar, Streamworks observed a noticeable decrease in overall flow depth along the Fordway Bar as compared to downstream and upstream reaches of the Concord River. While the flow depth was found to vary laterally across the bar, Streamworks observations indicate that the Fordway Bar spans the entirety of the Concord River, from bank to bank (Streamworks, 2020).

As similar material was not observed in the same proportions upstream, Streamworks inferred, and Gomez and Sullivan concurs, that the material composing the Fordway Bar predates the Talbot Mills Dam and was not deposited as the result of the dam. Considering the historical persistence of this feature over centuries, Streamworks would anticipate the Fordway Bar to have a low susceptibility to downcutting or erosion (i.e., the Fordway bar appears to be a stable feature) (Streamworks, 2020).

Considering the available information, including boring data and historical and recent observations, it was determined that the Fordway Bar is a natural geomorphic feature that is resistant to erosion and would likely serve as the new hydraulic grade controlling upstream water surface elevations at or near its current elevation following a dam removal scenario.

2.3 Water Level Monitoring

To provide additional data for this study, continuous water level monitoring was conducted in the Talbot Mills Dam impoundment from May through September 2021 at key locations for the purpose of recalibrating the hydraulic model and providing baseline data to the Town.

Water Level Logger Installation

Two water level loggers were installed in the Talbot Mills Dam impoundment, as shown in **Figure 2.3-1**: one just upstream of the Talbot Mills Dam, and one near the Town's raw water intake. A third logger was installed on a tree near the Town's water intake to monitor barometric pressure for the purpose of adjusting the water level logger data to account for changes in atmospheric pressure.

The water level loggers were installed on May 6, 2021. At least one benchmark was set at each site using an RTK GPS. Water surface elevations were measured after the loggers were placed in the river by surveying the benchmark and water surface. Site visits were conducted to check the water level loggers and download data approximately monthly on June 4, July 1, July 29, and August 26. The loggers were removed on September 23, 2021. During each visit, data from the loggers were offloaded and water surface elevations were checked using a stadia rod and survey level. Updated logger and water surface elevations were used to recalibrate the water surface elevation data following each visit.

Water Surface Elevation Data

Water surface elevations at Talbot Mills Dam ranged from a minimum of 108.73 feet to a maximum of 111.23 feet, with a median water surface elevation of 109.67 feet NAVD 88 for the monitoring period from May 6 to September 23, 2021. For reference, the dam's spillway crest elevation is approximately 108.2 feet NAVD 88. Water surface elevations at the Town water intake ranged from a minimum of 109.38 feet to a maximum of 114.01 feet, with a median elevation of 111.22 feet NAVD 88 for the same period. For reference, the reported minimum low water elevation for the intake structure is approximately 107.2 feet NAVD 88 (shown in **Figure 1-6**).

Water levels were correlated to corresponding estimated flows at Talbot Mills Dam. Flows observed at the downstream US Geological Survey (USGS) gage[7] were downloaded for the study period (USGS, 2021). The gage is located 3.7 miles downstream of Talbot Mills Dam and has a drainage area of approximately 400 square miles, compared a drainage area of 370 square miles at Talbot Mills Dam. Gage flows were prorated by a ratio of the drainage areas (i.e., 370 sq. mi./400 sq. mi.) to estimate flows at Talbot Mills Dam. Selected water stage-discharge relationships were used for the hydraulic model recalibration as discussed in **Section 2.4**.

A graph of measured water surface elevations at Talbot Mills Dam and the Billerica water supply intake between May 6, 2021 and September 23, 2021 is provided in **Figure 2.3-2**. A graph of water surface elevations compared to prorated flow at Talbot Mills Dam and prorated median flows for the period of record at the gage (1937-2021) is provided in **Figure 2.3-3**.

Stage-Discharge Relationship at Talbot Mills Dam

A stage-discharge relationship was also developed using prorated gage flows and water level data from July 14, 2021 through September 23, 2021. The data from May 6 to July 13 was not included due to the sluice gate damage which occurred on July 14 as discussed below. The stage-discharge relationship is shown in **Figure 2.3-4**[8].

July 14, 2021 High Flow Event and Sluice Gate Damage

Multiple rounds of heavy rainfall occurred in the watershed in the first two weeks of July 2021, including 3 to 4 inches of rainfall from Post-Tropical Storm Elsa (NOAA, 2021). Flows peaked at the downstream gage on July 14, 2021 at a discharge of 2,400 cfs, over 13 times higher than the median July 14 flow of 180 cfs for the period of record at the gage of 1937 to 2021 (USGS, 2021). The Talbot Mills Dam impoundment water level peaked at around 111.2 feet NAVD88 on July 14, 2021 as measured at the water level logger upstream of dam.

During the high flow event on July 14, 2021, the Talbot Mills Dam sluice gates on river right[9] were damaged so that leakage increased significantly, resulting in flooding in the Faulkner Mills building and attracting

---

[7] USGS Gage 01099500 Concord River below R Meadow Brook at Lowell, MA.

[8] Note that there are a small number of data which are outliers to the stage-discharge relationship. These outliers occur at the beginning of storms, when the flow at the downstream gage increases much faster than the water level rises at Talbot Mills Dam. This is likely due to the fact that the watershed at the gage includes the more urban area of Lowell, whereas the watershed upstream of Talbot Mills Dam is more forested with floodplain storage areas. The runoff hydrograph for urban areas has a peak runoff flow which is generally higher and peaks sooner as compared to forested areas.

[9] River right and river left refer to the directions when facing downstream.

hundreds of carps into the sluiceway (E. Hutchins, personal communication, July 14, 2021). **Photos 5-1** through **5-6** in **Appendix B** show the high flows at the dam and sluice gate leakage.

The sluice gate was not repaired following the damage on July 14, 2021, so gate leakage in the hydraulic model was primarily recalibrated to the increased leakage rates as observed between July 14 and September 23, 2021 at the water level logger upstream of Talbot Mills Dam as discussed in **Section 2.4**.

High-Water Mark Survey

The field effort for this study also included survey of previously documented high-water marks at the Pollard Street Bridge, Boston Road Bridge, River Street Bridge, and Nashua Road Bridge using the RTK GPS. These observations (and others) were documented by local resident Ed Reiner during the March-April 2010 floods by marking the peak water level with red paint on bridge abutments or piers. These high-water marks were surveyed by Gomez and Sullivan during the September 2021 field visit and used as additional checks in model recalibration as described in **Section 2.4**.

2.4 Hydraulic Model Revisions

The existing one-dimensional (1D) hydraulic model developed for the 2016 Feasibility Study was initially based on the preliminary 2014 Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) hydraulic model for the Concord River. The FIS model was updated at that time to correct elevations and dimensions of the Talbot Mills Dam and to reflect Gomez and Sullivan's field survey. The model was calibrated to observed water surface elevations by adjusting the sluice gate opening height to account for leakage.

The existing 1D model was revised for this study in accordance with the comments in the Streamworks report and to incorporate the additional data obtained as described in **Sections 2.1** and **2.3** above, including the following updates:

- incorporation of new bathymetry and new cross-sections;
- recalibration to baseflows;
- recalibration to existing high water marks;
- revision of bridge modeling approach; and
- revision of roughness coefficients.

These revisions are described in more detail below.

Incorporation of New Bathymetry and New Cross-Sections

Existing cross-section data was based on a combination of LiDAR data and field survey conducted during the FIS model development, which was updated for the 2016 Feasibility Study using Gomez and Sullivan's survey in the vicinity of the Talbot Mills Dam and sediment depth probing transects in the lower impoundment below the Pollard Street Bridge.

The bathymetric survey data collected for the current scope of work as discussed in **Section 2.1** was incorporated into model geometry for 13 existing cross sections within the model in the area between the Route 3A bridge and Talbot Mills Dam. An additional 26 cross sections were added to the model using the new bathymetric survey data for channel geometry and 2010 FEMA LiDAR data for the overbank areas. **Figure 2.4-1** provides an overview of the hydraulic model cross-sections in the study area of interest for the current phase of work. The existing cross sections in the study area were generally between 350 to 900 feet apart (with the exception of closer spacing just upstream of the dam). New cross sections were added between existing cross sections in order to reduce downstream reach lengths to an average of around 200 feet and therefore increase model accuracy in this area.

Note that in the effective FIS model and consequently the existing conditions model from the 2016 Feasibility Study, the downstream reach lengths for a few cross sections were inaccurate and differed from actual measured downstream reach lengths in the area between Talbot Mills Dam and Boston Road (Route 3A) by as much as approximately 300 feet. This was corrected in the process of adding new cross sections and calculating the new downstream reach lengths.

Revision of Bridge Modeling Approach

As noted in the Streamworks review (Streamworks, 2020), the hydraulic model from the 2016 Feasibility Study displayed abrupt steps in water surface elevation at bridges for low flows, which were not observed in the field. This was due to the bridge modeling approach using the Yarnell and Momentum low flow methods for the effective FIS. The bridge modeling approach was adjusted for this study in accordance with Streamworks' comments and updated FEMA guidance, so that only the energy equation was used for low flows at bridges. This change resulted in a smoother and more accurate modeled water surface profiles for low flows at bridges.

Recalibration of Gate Opening Height

The hydraulic model was recalibrated to observed water levels at the dam by adjusting the gate opening heights in the model to account for leakage and seepage at the dam. Leakage flow, while relatively small compared to spillway flows, was determined to be significant enough to affect model results. Flows assessed for this calibration step were from observations made after the July 14, 2021 partial gate failure as described in **Section 2.3** so that the gate settings would be calibrated to current conditions reflecting a higher leakage flow rate.

Water level logger data from seven different dates were used in recalibrating the model along with prorated gage flows for those dates, which ranged from 219 cfs on August 19, 2021 to 2,220 cfs on July 14, 2021. Flow conditions were significantly higher than normal for most of the period from July through September 2021 (typically the lowest flow period of the year) and therefore lower flows were not captured by the water level loggers.

In addition to the water level logger data, two additional water level observations were used in recalibrating the gate opening height. One of these was an observation by Gomez and Sullivan during field data collection for the 2016 Feasibility Study on October 6, 2014. The other observation was made by the Town's consultant, Woodard & Curran, on August 13, 2020, at which point water was observed to be flowing over the dam when flow at the downstream gage was 47.5 cfs [(Streamworks, 2020); (USGS, 2021)]. Since an exact water surface elevation was not reported by Woodard & Curran, this information was used to verify that the prorated flow at Talbot Mills Dam of 44 cfs flowed over the dam and was higher than the spillway elevation of 108.2 in the hydraulic model.

Leakage at Talbot Mills Dam was approximated in the model using different gate opening height settings, where gate opening height varies depending on flow. This relationship was developed using a trial-and-error method, in which the optimal gate opening height setting was found by running the model with different opening heights until the modeled water surface just upstream of the Talbot Mills Dam matched the observed water surface elevation as closely as possible.

The optimized gate setting was determined for nine calibration flows using the trial-and-error method. The resulting gate settings for these calibration flows are listed in **Table 2.4-1**. Optimized gate setting versus flow were plotted and a trendline was fit to the data. A polynomial equation fit the data best, with an R^2 value of 0.98, as shown in **Figure 2.4-2**. This equation was used for flows less than around 2,350 cfs. Flows higher than 2,350 cfs were assigned a maximum gate opening height of 2.7 feet.

Following application of the equation for determining gate opening height from flow, modeled water surface elevations at Talbot Mills Dam were found to be within 0.06 feet of the observed water levels.

Recalibration to Known Water Levels

Following recalibration of the hydraulic model to account for leakage at the dam through adjusting gate opening heights, the model was recalibrated to known water levels upstream and downstream of Talbot Mills Dam. For this calibration step, channel Manning's n values and ineffective areas were adjusted, within justifiable bounds, in an attempt to match modeled water surface elevations as closely to observed water levels as possible. (See below for additional discussion on Manning's n roughness coefficients.)

Known water levels used for this step of the recalibration included water level logger data collected near the Billerica water supply intake for the same calibration flows as described above, as well as an October 6, 2014 water level observation by Gomez and Sullivan at the Billerica water supply intake.

Additional water level observations were used as checks during the recalibration process, including existing high-water marks as observed by USGS following flooding in March and April 2010 (USGS, 2011). As part of the high-water mark study, USGS visited 14 sites along the Concord River and recorded observed high-water marks as indicated by wrack, staining, sediment, and other visual indicators of the peak flood height for each location. Of the 14 locations on the Concord River, four locations within the study area were used to calibrate the hydraulic model, including locations downstream of Faulkner Street, upstream of Talbot Mills Dam, upstream of Boston Road (Route 3A), and upstream of River Street. The maximum discharge observed at the downstream gage for the March 17, 2010 event was 5,840 cfs. A second peak of 5,660 cfs was observed on April 3, 2010 at the gage (USGS, 2021). It was assumed that the high-water marks were associated with the higher peak on March 17, 2021, but the USGS report is unclear and since their site visits were collected following both events, it is possible that visual evidence from the earlier peak was washed away by rain and the marks are in fact associated with the lower peak or a different flow. However, the modeled difference between these two events was only 0.12 feet, which is within the acceptable limit of error for calibration.

As an additional check during recalibration, water level observations from Billerica resident Ed Reiner were considered. Mr. Reiner has recorded water surface elevations during both high and low flows on a concrete wall with a surveyed benchmark at Pinewood Avenue, located approximately 2.4 miles upstream of the Talbot Mills Dam, since at least 2001 (Reiner, 2016). Additional observations were made by Mr. Reiner during the March-April 2010 floods and other flow events at several locations, including at Pollard Street, Boston Road (Route 3A), River Street, and Route 3. The March-April 2010 observations were recorded by Mr. Reiner by marking the water level with red paint on the bridge abutments or piers. Several of these high-water marks were surveyed by Gomez and Sullivan during the September 2021 field visit as described in **Section 2.3** and used as additional checks in model recalibration.

For this targeted dam removal impact analysis, low flow conditions are of greater importance for the purpose of evaluating impacts to the Town's water supply intake. As such, priority was given during calibration efforts to low and mean flow observations and the water level logger data. However, the model is also calibrated to within 0.5 feet for selected high flow observations. This is in accordance with FEMA guidance, which suggests calibrating hydraulic models to within 0.5 feet of known high-water marks for flood risk analysis and mapping (FEMA, 2020).

Summaries of observed and modeled water surface elevations are provided in **Table 2.4-2** for those observations used for calibration and in **Table 2.4-3** for those observations used only for verification (without making any calibration adjustments). Following recalibration, existing model results indicate water surface elevations at the Billerica water supply intake within 0.16 feet of observed elevations for flows less than 2,000 cfs, and within 0.25 feet of observed elevations for the July 14, 2021 flow of 2,220 cfs.

Revision of Roughness Coefficients

As part of this study, Manning's n roughness coefficients used in the hydraulic model were reviewed for appropriateness based on existing and anticipated proposed conditions. A spreadsheet tool developed by the US Department of Agriculture (USDA) National Stream and Aquatic Ecology Center for determining flow resistance coefficients in natural channels was used to identify a range of appropriate Manning's n values for the model. The spreadsheet tool provides multiple redundant methods of determining flow resistance to improve the accuracy of selecting flow resistance coefficients, since "flow resistance coefficient estimation is approximate, requiring redundancy for confidence in the implemented values" (Yochum, 2018). The spreadsheet tool consists of three steps:

1. Consult tabular guidance
2. Consult photographic guidance
3. Apply a quantitative prediction methodology (quasi-quantitative and/or fully quantitative)

Tabular guidance consists of several different sources, including the table of Manning's n values in the HEC-RAS Hydraulic Reference Manual (USACE, 2016). Photographic guidance consists of photos of streams with verified Manning's n values along with hydraulic data; three different sources were consulted for this step of the analysis [(USGS, 2021); (Barnes, 1967); (USGS, 1998)]. The quantitative prediction step consists of the choice of applying any of nine fully quantitative approaches where applicable given stream parameters, and/or a quasi-quantitative approach. The spreadsheet tool warns that "dependence on quantitative methods alone is not recommended since utilized reaches in the derivations were intentionally selected to have little influence from sinuosity, instream large wood, streambank vegetation, bank irregularities, obstructions, etc.; these types of flow resistance are not lumped into the quantitative estimates" (Yochum, 2018). A quasi-quantitative approach as outlined in USGS Water-Supply Paper 2339 is provided as a means of incorporating the effects of irregularity in the channel, variation in channel cross sections, obstructions, vegetation, and meandering (Schneider, 1989).

Each of the three steps was applied where applicable to several locations on the Concord River for both a low flow (215 cfs as observed on August 19, 2021) and a high flow (5402 cfs as observed on March 17, 2010). Both of the flows used for this analysis were associated with known water levels and/or high-water marks. The locations assessed include: upstream of Talbot Mills Dam, at the islands downstream of Pollard Street, at the Town water supply intake, and at the Boston Road (Route 3A) bridge. Overall average Manning's n values as determined through this analysis ranged from 0.038 for high flows at the Boston Road (Route 3A) bridge to 0.056 for low flows at the islands downstream of Pollard Street. The fully quantitative approach was not applicable for calculation of Manning's n values at low flows because the hydraulic parameters (energy grade slope, hydraulic radius, mean flow depth, etc.) were outside the applicable ranges for all the nine available equations. This was primarily due to the nearly flat slope of the

Concord River upstream of the Fordway Bar, which results in an energy grade slope of 0.000002 feet/feet or less under low flow conditions. The fully quantitative approach was utilized for calculation of Manning's n values under high flow conditions [(Rickenmann, 2011); (Limerinos, 1970)].

Following determination of the range of appropriate Manning's n values, these values were refined for use in the model with a preference for values appropriate for low to normal flows, since these flows are of more importance for this study. The values were then further adjusted in order to calibrate the model to known water levels as described above, particularly to known water levels for low to normal flows to conservatively estimate impacts to the Town's water supply intake. The following channel Manning's n values were selected for the revised existing conditions model:

- 0.04 – From upstream model extent to just downstream of Boston Road (Route 3A)
- 0.045 – From downstream of Boston Road (Route 3A) to upstream of Billerica water intake
- 0.05 – From Billerica water supply intake to Pollard Street
- 0.055 – Fordway Bar and downstream islands
- 0.05 – Downstream of Fordway Bar islands to upstream of Interstate 495
- 0.045 – Upstream of Interstate 495 to downstream model extent (mouth of river)

Updated Hydrologic Analysis

As part of this study, the flows used in the hydraulic model were updated to reflect the best available data to date. The flow duration and flood frequency analyses conducted for the 2016 Feasibility Study were updated to include the full period of record at the time of this study (October 1936 through September 2021).

Updated flood frequency results were compared to published FIS flood flows (FEMA, 2016), as shown in **Table 2.4-4** and **Figure 2.4-3**. Peak discharges selected for use in the hydraulic model are highlighted in the table and the figure. As was the case for the 2016 Feasibility Study, because the regulatory FIS 100-year flood flow is within 10% of updated estimates, it was selected for this analysis to maintain consistency with other studies. The FIS 500-year flood flow was also selected, since it is conservatively higher (approximately 9%) than updated estimates. The 2-year flood flow calculated from the post-1970 period was selected because it is conservatively higher (approximately 5%) than that calculated from the full period of record.

Because drought conditions are a concern for the Town's water supply intake, the 7Q10 flow was also calculated using the average daily flows at the gage for the full period of record. The 7Q10 flow is the lowest 7-day average flow which has a 10% chance of occurring each year and represents flow during drought conditions. This flow was determined to be 28 cfs at Talbot Mills Dam and was used to assess potential impacts to the Billerica water supply intake.

A summary of all updated flows selected for use in the hydraulic model is presented for the Talbot Mills Dam location in **Table 2.4-5**. These flows were also developed for the other flow change locations in the model using drainage area ratios.

Revision of Hydraulic Model Scenarios

The revised existing conditions geometry in the hydraulic model incorporates all the model revisions discussed herein. The calibration plan consists of the revised existing conditions geometry with the flows used for recalibration purposes as described above. The existing conditions plan consists of the revised existing conditions geometry with the updated flows of interest as described above.

Following development of the revised calibration and existing conditions scenarios, a new proposed conditions (dam removal) scenario was created. The proposed conditions geometry was based on the revised existing conditions geometry but was adjusted in order to simulate the anticipated conditions following dam removal. This included removal of some sediment within the channel in the lower impoundment to represent projected sediment transport following dam removal. This was accomplished using the sediment depth transects from the 2016 Feasibility Study (**Figures 2.4-4** through **2.4-12**).

As Streamworks noted in their review, the proposed model channel elevations for the 2016 Feasibility Study were higher than might be expected at Talbot Mills Dam based on observations made at the toe of the dam. The geometry used in the model for the 2016 Feasibility Study relied on the sediment probing transect from just upstream of the dam, which may have reflected artificially higher elevations of the submerged former 1798 dam (Gomez and Sullivan, 2016). However, as noted in the 2016 Feasibility Study, "based on the extent of bedrock outcroppings immediately downstream of the dam and historical reports (Ingraham, 1995) that former dams at this site have utilized the ledge as part of their structure, it is likely that a significant grade control exists below the dam or just upstream, and that a falls would develop at the site if it were removed. In fact, 1700 map of Billerica (**Figure 2.1-3**) documents the existence of a series of falls in the Concord River between the present-day Pollard Street and Faulkner Street bridges, which further supports the model results (Ingraham, 1995)."

However, to conservatively estimate potential impacts during low flow conditions at the Billerica water supply intake, the proposed conditions geometry for the cross section at river station 25129 (just upstream of Talbot Mills Dam) was revised so that the channel geometry reflects channel geometry at the toe of the dam. Due to safety concerns due to the high flows during the 2021 field season, neither geophysical nor bathymetric surveys were able to be conducted in the area of the dam. As such, the best available data was used to estimate the elevations at the toe of the dam. These elevations came from survey data collected for the 2016 Feasibility Study as well as data from the 2015 Dam Inspection Report survey (Geotechnical Consultants, 2015). The resulting proposed dam removal cross-section is shown in **Figure 2.4-5**.

For the dam removal scenario, it was assumed that the spillway and river right abutment made of concrete and granite would be removed, and that the historic granite left abutment with low level outlets would remain to preserve some of the history of the site. These assumptions may be refined if the dam removal advances to final design.

As suggested in the Streamworks review, Manning's n values were not adjusted from those used for existing conditions in the lower impoundment for the dam removal scenario.

Revised Hydraulic Model Results

Table 2.4-6 provides a summary of existing versus proposed (dam removal scenario) water surface elevations at the Billerica water supply intake for modeled flows, as well as the water depth above the intake invert (assumed elevation of 102.2 feet NAVD88). The anticipated drop in water surface elevation at the intake ranges from 0.17 feet for the median annual flow (467 cfs) to 0.43 feet for the 100-year flood (5,675 cfs). The anticipated reduction in water surface elevation at the intake during the 7Q10 drought flow (28 cfs) is 0.35 feet. Model results indicate that the change in water surface elevation at the Billerica water supply intake would be less than 0.5 feet for all modeled flows due to the proposed removal of Talbot Mills Dam. The minimum water depth above the intake invert would be 5.8 feet (down from 6.1 feet for existing conditions) for the 7Q10 drought flow. The model supports the assumption that the

Fordway Bar would become the new hydraulic grade control following dam removal, maintaining similar upstream water levels as compared to existing conditions.

Figure 2.4-13 provides selected water surface profiles for the study area from downstream of Faulkner Street to upstream of Boston Road (Route 3A), comparing existing conditions and the proposed dam removal scenario. Additional model output for key locations is provided in **Table 2.4-7** for existing conditions and **2.4-8** for proposed dam removal conditions.

2.5 Intake Pump Performance Analysis

The revised hydraulic model results presented in **Section 2.4** will be used by the Town's consultant to analyze potential impacts on intake pump performance due to changes in water level following dam removal. Once the analysis is complete, results will be incorporated into the final report.

2.6 Superfund Site Preliminary Impact Assessment

The Iron Horse Park Superfund Site is located approximately one mile southeast of the Talbot Mills Dam at Iron Horse Park off High Street in North Billerica. Site remediation is managed by the US Environmental Protection Agency (EPA). The site appears to be hydrologically connected to the dam's impoundment by a wetted section (Segment 24) of the old Middlesex Canal. A map showing the relative locations of the dam, the canal, and the Superfund Site is provided in **Figure 2.6-1**. Schematic maps of Segment 24 of the canal are shown in **Figures 2.6-2** (west) and **2.6-3** (east) (Waterfield Design Group, 2008). A map depicting the extents and features of the Iron Horse Park site is shown in **Figure 2.6-4**.

Site Description

The Iron Horse Park site is a 553-acre industrial complex that includes manufacturing and rail yard maintenance facilities, open storage areas, landfills, and wastewater lagoons. A long history of industrial activities beginning in 1913 resulted in the contamination of the site's soil, groundwater, and surface water (M&E, 2010). Site cleanup, operation and maintenance activities, and environmental monitoring are ongoing.

<u>Geographic Setting</u>

The topography of the site is generally flat with gradual slopes associated with each of the landfill or disposal areas. The topographic relief of the site is approximately 50 feet, with the highest elevation of approximately 150 feet on the eastern side of the site and the lowest of approximately 100 feet on the northeast side near the B&M Pond. The site is surrounded by upland areas on the southeast side and low-lying wetland areas on the western, northern, and eastern sides of the site. Approximately 17 percent of the site is covered by wetlands. Soils on and in the immediate vicinity of the site are classified as predominantly urban land (M&E, 2010).

<u>Geology</u>

Bedrock underlying the site is comprised of granite, schist, and diorite. Bedrock surface elevations suggest the presence of a trough in the bedrock surface trending northeast from the Old B&M Oil/Sludge Recycling Area to the Unnamed Brook, then northwest toward the Asbestos Lagoons. Bedrock fractures were found trending north-northeast and east-west (M&E, 2010).

The overburden primarily consists of glacial drift deposits including basal and ablation till and glacial outwash deposits. Basal till was found primarily on the southwestern portion of the site, and ablation till was found primarily in the western and southern portions of the site overlying basal till. Glacial outwash deposits were encountered throughout the site. Peat deposits were encountered underlying fill materials near streams, ponds, and wetlands at the site (M&E, 2010).

Also of note for this study is the presence of a natural geologic watershed divide located between the Concord River and Iron Horse Park. The former railroad that crosses the canal between Rogers Street and High Street is a topographical high point (elevation 126 feet NAVD88) with significant underlying granite bedrock that forms the boundary between the Concord River basin to the west and the Shawsheen River basin to the east. During the time of canal construction in the early 1800s, it was reported that in this area referred to as the "deep cut," "the canal passed through half a mile of deep cutting, 800 feet of which was through hard granite which had to be blasted. Some places had to be blasted 7 feet deep, and 14 to 20 feet wide. The cut for this half mile was from 12 to 20 feet deep." **Figure 2.6-5** shows an elevation profile of the former canal path prior to blasting in the area east of Rogers Street (Breen, 2015).

Hydrogeology

Groundwater in both the overburden and bedrock aquifers generally enters the site from the southwest and flows to the northeast (M&E, 2010). Groundwater contours are shown in **Figure 2.6-6** (shallow overburden) and **Figure 2.6-7** (bedrock) (M&E, 2006).

Similarly, surface water flows onto the site from the south and flows to the northeast, where it converges with B&M Pond and associated wetlands. Surface water flows offsite by way of a series of wetlands that has developed over time around an Unnamed Brook and its confluence with the eastern portion of the Middlesex Canal. Based on seepage meter, staff gauge, and mini-piezometer results, the potential for groundwater to discharge to surface water was evident throughout most of the site (M&E, 2010). Overland drainage and surface water flow directions are shown in **Figure 2.6-8** (ERM, 2021).

Investigative & Remediation Activities

The site is divided into four operable units (OUs). OU-1 is the Boston & Maine (B&M) Wastewater Lagoons, OU-2 is the Shaffer Landfill, and OU-3 was originally the remainder of the site. During the feasibility study for OU-3 completed in 2004, it was decided that site-wide surface water, sediment, and groundwater required additional investigation and OU-3 was then limited to site source areas. Consequently, OU-4 includes residual groundwater, surface water, and sediment contamination following the source control measures implemented for OU-3 (M&E, 2010). OU-4 is most relevant to the Talbot Mills Dam removal project.

Various investigations have been performed for OU-4. An Ecological Risk Assessment/Wetlands Remedial Investigation Addendum (ERA/WRIA; M&E, 2006a) was performed to more accurately determine the risk to ecological receptors exposed to contaminants in surface water and sediment throughout the site. A Groundwater Data Evaluation report (M&E, 2006b) was generated in 2006 to provide a summary of groundwater sampling performed in the winter of 2005-06. A Supplemental Human Health Risk Assessment (M&E, 2008) was performed to determine risk drivers associated with future groundwater use, which include miscellaneous organics and metals. A focused Feasibility Study was completed in 2010 (M&E, 2010).

For OU-4, the Feasibility Study identified no significant risk due to migration of vapors from groundwater and indicated that the only potential risk to human health from groundwater is associated with the scenario of a potential future on-site resident using groundwater. No human health risk was identified for exposure to either sediment or surface water. Moderate ecological risk was identified for benthic invertebrates (bottom-dwelling organisms) exposed to contaminated sediments, but those sediments were confined to a small pond and unnamed brook on the site (USEPA, 2010).

In 2011, a Record of Decision (ROD) was issued, which prescribed excavation and disposal of contaminated sediment from B&M Pond, Monitored Natural Recovery (MNR) for other sediment exceeding cleanup levels, implementation of storm water runoff controls, long-term groundwater monitoring, and institutional controls to prevent use of groundwater (USEPA, 2018). Implementation of these remedial actions was completed in 2021, as summarized in the OU4 Remedial Action Construction Completion

Report (ERM, 2021). Remedial activities relevant to the Talbot Mills Dam removal project (involving groundwater, surface water, and/or sediments) include:

- Implementation of stormwater runoff controls to prevent recontamination of sediments by runoff draining directly into B&M Pond and the Unnamed Brook (shown in **Figure 2.6-8**)
- Groundwater monitoring to confirm that impacts do not migrate beyond the compliance boundary for the site (including the installation of new wells to supplement the existing monitoring well network – shown in **Figure 2.6-9**)
- Prevention of contaminant exposure to groundwater within the groundwater compliance boundary
- Prevention of groundwater exceeding performance standards from migrating beyond the groundwater compliance boundary
- Monitored Natural Recovery in the Unnamed Brook and other unexcavated sediments that exceed sediment cleanup levels (shown in **Figure 2.6-10**)

Field Reconnaissance

Field reconnaissance was conducted on March 7, 2021 by project partners to observe drainage patterns and flow directions in the Middlesex Canal Segment 24 between the Concord River and Iron Horse Park. The observations indicated the following:

- Moving east from the Talbot Mills Dam impoundment, the canal passes through a culvert under Rogers Street. The invert of the culvert appears to barely align with the impoundment water level, resulting in little to no flow through the culvert.
- East of Rogers Street, the canal appears to be more of a stagnant pond than a flowing stream. This section has no culvert connectivity to other canal sections.
- The canal then intersects a former railroad track. No culvert opening was observed under the railroad, and it is assumed that any former crossing is either blocked or filled in. Similarly, the schematic map of the Middlesex Canal (**Figure 2.6-2**) shows no bridge crossing at this structure. Note that this former railroad crossing is the location of the geologic divide between the Concord and Shawsheen watersheds as described above and shown in **Figure 2.6-5**.
- There is no detectable flow between the railroad and High Street.
- East of the High Street crossing, water in the canal distinctively flows east toward the Superfund Site.
- East of High Street, water is diverted from the canal through a manmade ditch that flows in a northeasterly direction toward Content Brook.
- Segment 25 of the former canal is buried through the Superfund Site.
- Segment 26 of the canal flows in an easterly direction toward Pond Street and beyond.

Consultation

Gomez and Sullivan met with the EPA on September 24, 2021 to identify potential impacts that the proposed dam removal could have on the migration of contaminated groundwater, surface water, or sediments away from the Superfund Site. The EPA was consulted to collect existing information, confirm flow directions and pathways, evaluate potential impacts due to the proposed project, and identify next steps for follow-up impact analysis. The EPA concurred with the findings described above and agreed that the proposed Talbot Mills Dam removal project is unlikely to result in the migration of contaminated groundwater, surface water, or sediments away from the Superfund Site. The EPA indicated that an updated groundwater and surface water sampling event was conducted in May 2021, and groundwater was still generally found to flow toward the northeast and east. The semi-annual sampling report is forthcoming and the updated groundwater contour maps will be available on the EPA's website for the Superfund Site[10] once finalized. The EPA indicated no further concerns, data needs, or study requests at this time, but asked to be kept apprised of the proposed dam removal project.

Summary

In summary, the proposed Talbot Mills Dam removal project is unlikely to result in the migration of contaminated groundwater, surface water, or sediments away from the Iron Horse Park Superfund Site based on the following justifications:

- Segment 24 of the Middlesex Canal between the Talbot Mills Dam impoundment and Iron Horse Park is either stagnant or flowing to the east, toward the Superfund Site.
- Groundwater and surface water within the Superfund Site flow predominantly toward the east and northeast, away from Segment 24 of the Middlesex Canal and the Concord River.
- A geologic divide that forms the boundary between the Concord and Shawsheen River basins crosses the Middlesex Canal along a former railroad between the dam impoundment and the Superfund Site. This area is characterized by a significant bedrock deposit, making it unlikely that any potential increased water velocities due to dam removal and subsequent lowering of the canal water surface would result in scouring of the canal bottom or reversing of the canal flow direction.
- Remedial actions have been largely completed for the Superfund Site, including measures to contain contaminated groundwater onsite and prevent recontamination of sediments through stormwater runoff.
- No significant pumping of surface or groundwater, which could potentially result in a change in the direction of groundwater flow patterns, would be proposed for the purpose of dewatering during dam removal construction. Initial dewatering of the impoundment and bypassing of flow through the construction site would occur by passive methods.

Therefore, no impact to the quality of the Town's water supply in the Concord River is expected.

[10] https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.docdata&id=0100524

3 Summary and Next Steps

Summary

In summary, the following data collection efforts and analyses were conducted for this targeted impact analysis of the proposed Talbot Mills Dam removal as it relates to the Town's water intake and other concerns:

- Bathymetric Survey
- Subsurface Assessment
- Water Level Monitoring
- 1D Hydraulic Model Revisions
- Intake Pump Performance Analysis *(pending, by Town)*
- Superfund Site Preliminary Impact Assessment

The revised hydraulic model produced existing versus proposed (dam removal scenario) water surface elevations at the Billerica water supply intake for a range of flows, as well as the water depth above the intake invert (assumed elevation of 102.2 feet NAVD88). The anticipated drop in water surface elevation at the intake ranges from 0.17 feet for the median annual flow (467 cfs) to 0.43 feet for the 100-year flood (5,675 cfs). The anticipated reduction in water surface elevation at the intake during the 7Q10 drought flow (28 cfs) is 0.35 feet. Model results indicate that the change in water surface elevation at the Billerica water supply intake would be less than 0.5 feet for all modeled flows due to the proposed removal of Talbot Mills Dam. The minimum water depth above the intake invert would be 5.8 feet (down from 6.1 feet for existing conditions) for the 7Q10 drought flow.

It should be noted that even though the anticipated reduction in water surface elevations is relatively small, it is expected to result in significant beneficial impacts in reducing upstream flooding of properties and infrastructure.

Considering the available information, including boring data and historical and recent observations, it was determined that the Fordway Bar is a natural geomorphic feature that is resistant to erosion and would likely serve as the new hydraulic grade controlling upstream water surface elevations at or near its current elevation following a dam removal scenario. The hydraulic model indicates that proposed water surface elevations upstream of the Fordway Bar would be similar to (within 0.5 feet of) existing water levels. Therefore, no significant impact to the Town's raw water intake is anticipated.

Additionally, a review of background information on the nearby Iron Horse Superfund Site and consultation with the EPA led to a determination that the proposed Talbot Mills Dam removal project is unlikely to result in the migration of contaminated groundwater, surface water, or sediments away from the Superfund Site. Therefore, no impact to the quality of the Town's water supply in the Concord River is expected.

Next Steps

The revised hydraulic model results presented in this draft report will be used by the Town's consultant to analyze potential impacts on intake pump performance due to changes in water level following dam removal. Once the analysis is complete, results will be incorporated into the final report.

Pending any unmitigable impacts to the Town's water supply intake, which are not expected, or any additional concerns raised by the Town, it is recommended that the proposed Talbot Mills Dam removal project proceed to the preliminary design and permitting phase. During this phase, the following additional recommendations identified in the 2016 Feasibility Study and 2020 Streamworks review can be addressed as appropriate:

- Upstream Extension of Hydraulic Model (Upstream Impact Analysis)
- 2D Hydraulic Modeling
- Unsteady Hydraulic Modeling (Downstream Impact Analysis)
- Additional Sediment Probing & Sampling
- Sediment Mobility Assessment
- Sediment Management Planning
- Bridge Scour Analysis
- Retaining Wall Stability Analysis
- Fish Passage Contingency Estimate
- Cultural Resources Mitigation Planning
- Recreational/Aesthetic Study
- Resource Delineation

4 References

Alvord, D., Storrow, C., & Shedd, J. (1862). *Report of Experiments and Observations on the Concord and Sudbury Rivers in the Year 1861.* Boston: William White. Retrieved from https://archive.org/details/1861EngineersReport

Avery, Jr., J. (1859). *Plan II to Accompany Report of Hearing on Concord & Sudbury Meadows: Survey at Billerica Mills.*

Barnes, H. H. (1967). *Roughness Characteristics of Natural Channels; USGS Water Supply Paper 1849.* Washington: United States Geological Survey.

Breen, J. J. (2015, March). Deep Cut at Bedford & Billerica Railroad. *Middlesex Canal Association: Towpath Topics, 53*(3). Retrieved from http://www.middlesexcanal.org/towpath/towpathtopicsMar2015.htm

DEP. (2010). *Final Modified Water Withdrawal Permit MGL C 21G [for the Town of Billerica].* Boston: DEP.

ERM. (2021). *OU4 Remedial Action Construction Completion Report, Iron Horse Park Superfund Site (Doc ID 100019488).* Retrieved from https://semspub.epa.gov/src/document/01/100019488

FEMA. (2016). *Flood Insurance Study; Middlesex County, Massachusetts; Revised July 6, 2016.*

FEMA. (2020). *Guidance for Flood Risk Analysis and Mapping: General Hydraulics Considerations.* Washington, DC: United States Department of Homeland Security, Federal Emergency Management Agency.

Geotechnical Consultants. (2015). *Talbot Mills Dam Phase I Inspection / Evaluation Report.* Geotechnical Consultants, Inc.

Gomez and Sullivan. (2016). *Concord River Diadromous Fish Restoration Feasibility Study.* Henniker: Gomez and Sullivan Engineers, DPC.

Ingraham, A. (1995). *A short history of the milldam at North Billerica, 1653-1995. Billerica, MA: The Billerica Historical Society.* Retrieved from https://archive.org/details/TheMilldamAtNorthBillerica

Limerinos, J. (1970). *Determination of the Manning Coefficient From Measured Bed Roughness in Natural Channels; USGS Water-Supply Paper 1898-B.* United States Geological Survey.

M&E. (2006). *Groundwater Data Evaluation Report, Iron Horse Park Superfund Site, Operable Unit 4, North Billerica, MA (DocID 472620).* Retrieved from https://semspub.epa.gov/work/01/472620.pdf

M&E. (2010). *Draft Final Feasibility Study, Iron Horse Park Superfund Site, Operable Unit 4, North Billerica, MA (DocID 472622).* M&E. Retrieved from https://semspub.epa.gov/work/01/472622.pdf

NOAA. (2010, December). *2010 FEMA Lidar: Concord River (MA) Point Cloud files with Orthometric Vertical Datum North American Vertical Datum of 1988 (NAVD88) using GEOID18*. Retrieved from LiDAR Datasets at NOAA Digital Coast: https://chs.coast.noaa.gov/htdata/lidar1_z/geoid18/data/2549/

NOAA. (2021, July 9). *Storm Summary Number 6 for Heavy Rainfall and Wind Associated with Post-Tropical Storm Elsa*. Retrieved from The Weather Prediction Center: https://www.wpc.ncep.noaa.gov/storm_summaries/storm10/stormsum_6.html

Reiner, E. (2016, February 8). Concord River Water Level Recordings.

Rickenmann, D. R. (2011). *Evaluation of flow resistance in gravel-bed rivers through a large field data set.* Water Resources Research, 47, W07538, doi: 10.1029/2010WR009793.

Schneider, A. (1989). *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains; USGS Water-Supply Paper 2339.* Denver, CO: United States Geological Survey.

Streamworks. (2020). *Review of Talbot Mills Dam Removal Feasibility Study.* Streamworks, PLLC.

Thorson, R. M. (2017). The Boatman: Henry David Thoreau's River Years. Cambridge, MA: Harvard University Press.

USACE. (2016). *HEC-RAS Hydraulic Reference Manual Version 5.0.* Davis, CA: USACE Hydrologic Engineering Center.

USEPA. (2010). *Proposed Plan: Iron Horse Park - North Billerica, MA (DocID 469099).* Boston: USEPA Region 1. Retrieved from https://semspub.epa.gov/work/01/469099.pdf

USGS. (1998). *Estimation of Roughness Coefficients for Natural Stream Channels with Vegetated Banks; Water-Supply Paper 2441; prepared in cooperation with the New York State Department of Transportation.* Denver, CO: United States Geological Survey.

USGS. (2011). *Elevation of the March-April 2010 Flood High Water in Selected River Reaches in Central and Eastern Massachusetts.* Reston, Virginia: US Geological Survey.

USGS. (2021, July 8). *USGS 01099500 Concord River below R Meadow Brook, at Lowell, MA*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/uv?site_no=01099500

USGS. (2021, September 24). *Verified Roughness Characteristics of Natural Channels*. Retrieved from Surface-Water Field Techniques: https://wwwrcamnl.wr.usgs.gov/sws/fieldmethods/Indirects/nvalues/index.htm

Waterfield Design Group. (2008). *Middlesex Canal National Register Historic District Assessor's Plan Map Book.* Prepared for the Middlesex Canal Commission in association with the Northern Middlesex Council of Governments and the Massachusetts Historic Commission. Winchester, MA: The Waterfield Design Group, Inc. Retrieved from http://middlesexcanal.org/commission/MCmapbook.pdf

Yochum, S. E. (2018). *Flow Resistance Coefficient Selection in Natural Channels: A Spreadsheet Tool.* National Stream and Aquatic Ecology Center: USDA.

Appendix A – Figures & Tables

Appendix B – Photographs