Relicensing Study 3.3.17

ASSESS THE IMPACTS OF TURNERS FALLS PROJECT AND NORTHFIELD MOUNTAIN PROJECT OPERATIONS ON TRIBUTARY AND BACKWATER AREA ACCESS AND HABITAT

Study Report

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

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EXECUTIVE SUMMARY

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for the Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018. This report documents the results of Study No. 3.3.17 *Assess the Impact of Project Operations of the Turners Falls Project and Northfield Mountain Project on Tributary and Backwater Area Access and Habitat.*

FirstLight performed systematic surveys in the spring, summer, and fall of 2014 to assess the effects of operations of the Turners Falls and Northfield Mountain Projects on tributary and backwater area habitat and access to that habitat. Habitat within the Turners Falls Impoundment from Vernon Dam to Turners Falls Dam and in the Connecticut River from Turners Falls Dam to the Route 116 Bridge in Sunderland, MA was surveyed. The study goal was to determine if water level fluctuations from the Turners Falls and Northfield Mountain Projects result in reductions of available aquatic habitat due to migration barriers and/or habitat alterations. Per the Revised Study Plan (RSP), the study objectives were to:

- identify potential barriers or constrictions of fish access to tributaries and backwater areas resulting from Project-related water level fluctuations; and
- measure changes in available habitat and water quality in backwater areas and tributaries resulting from Project-related water level fluctuations.

FirstLight evaluated access conditions at the confluence of 19 tributaries in the study area. Of the 19, potential barriers were noted at three: Merriam Brook, Pine Meadow Brook, and Fourmile Brook. The barriers at these three tributaries did not appear to be the result of Project-related water fluctuations. Rather, the barriers were largely a result of natural phenomena including large woody debris accumulation, the size and flow characteristics of the tributary, or sediment deposition. No other tributary barriers or any backwatered habitat were noted in the study area under a range of hydrologic conditions.

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cfs	cubic feet per second
DEM	digital elevation model
DO	dissolved oxygen
DWPC	Massachusetts Division of Water Pollution Control
FERC	Federal Energy Regulatory Commission
ft	feet
fps	feet per second
FirstLight	FirstLight Hydro Generating Company
GIS	geographic information system
ILP	Integrated Licensing Process
µS/cm	micro-Siemens per centimeter
LiDAR	Light Detection and Ranging
mi^2	miles squared or square miles
mg/l	milligrams per liter
MSL	mean sea level
NGVD29	National Geodetic Vertical Datum of 1929
NTU	Nephelometric Turbidity Units
PAD	Pre-Application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
SD1	Scoping Document 1
SD2	Scoping Document 2
SPDL	Study Plan Determination Letter
USGS	United States Geological Service
VY	Vermont Yankee Nuclear Power Plant
°C	Degrees Celsius
°F	Degrees Fahrenheit
WSEL	water surface elevation

1 INTRODUCTION

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission), the process of relicensing the Northfield Mountain Project and Turners Falls Projects using FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018.

As part of the ILP, FERC conducted a public scoping process during which various resource issues were identified. On October 31, 2012, FirstLight filed its Pre-Application Document (PAD) and Notice of Intent with the FERC. The PAD included FirstLight's preliminary list of proposed studies. On December 21, 2012, FERC issued Scoping Document 1 (SD1) and preliminarily identified resource issues and concerns. On January 30 and 31, 2013, FERC held scoping meetings for the two Projects. FERC issued Scoping Document 2 (SD2) on April 15, 2013.

FirstLight filed its Proposed Study Plan (PSP) on April 15, 2013 and, per the Commission regulations, held a PSP meeting at the Northfield Visitors Center on May 14, 2013. Thereafter, FirstLight held 10 resource-specific study plan meetings to allow for more detailed discussions on each PSP and on studies not being proposed. On June 28, 2013, FirstLight filed with the Commission an Updated PSP to reflect further changes to the PSP based on comments received at the meetings. On or before July 15, 2013, stakeholders filed written comments on the Updated PSP. FirstLight filed a Revised Study Plan (RSP) on August 14, 2013, with FERC addressing stakeholder comments.

On August 27, 2013, Entergy Corp. announced that the Vermont Yankee Nuclear Power Plant (VY), located on the downstream end of the Vernon impoundment on the Connecticut River and upstream of the two Projects, would be closing no later than December 29, 2014. With the closure of VY, certain environmental baseline conditions will change during the relicensing study period. On September 13, 2013, FERC issued its first Study Plan Determination Letter (SPDL) in which many of the studies were approved or approved with FERC modification. However, due to the impending closure of VY, FERC did not act on 19 proposed or requested studies pertaining to aquatic resources. RSP Study No. 3.3.17 *Assess the Impact of Project Operations of the Turners Falls Project and Northfield Mountain Project on Tributary and Backwater Area Access and Habitat* was one of the studies that FERC did not act upon in the first SPDL. The SPDL for these 19 studies was deferred until after FERC held a technical meeting with stakeholders on November 25, 2013, regarding any necessary adjustments to the proposed and requested study designs and/or schedules due to the impending VY closure. FERC issued its second SPDL on the remaining 19 studies on February 21, 2014, approving the RSP Study No. 3.3.17 without any modifications.

1.1 Project Location

The Northfield Mountain Project and the Turners Falls Project are located on the Connecticut River in Massachusetts (MA), New Hampshire, (NH) and Vermont (VT) (Figure 1.1-1). A large portion of the Projects, including developed facilities and most of the lands within the Project boundary, is in Franklin County, MA; specifically, in the towns of Erving, Gill, Greenfield, Montague, and Northfield. The northern reaches of the Project boundaries extend into the town of Hinsdale, in Cheshire County, NH, and the town of Vernon, in Windham County, VT. The constructed facilities of the Turners Falls Project are located at approximately river mile 117 on the Connecticut River, at coordinates 42°36'38.77" North, 72°33'05.76"

West, in the towns of Gill and Montague, MA. The tailrace of the Northfield Mountain Project is approximately 5.2 miles upstream of Turners Falls Dam, in the town of Northfield, MA. The Upper Reservoir of the Northfield Mountain Project is located atop Northfield Mountain in Erving, MA. The Turners Falls Impoundment ("Impoundment"), formed by the Turners Falls Dam, extends upstream approximately 20 miles to the base of TransCanada's Vernon Dam in Vernon, VT. Most of the Impoundment lies in MA, however, approximately 5.7 miles of the northern portion of the Impoundment is located in NH and VT.

The geographic scope of this study included the following:

- Turners Falls Impoundment: The Connecticut River from Vernon Dam to Turners Falls Dam.
- Below Turners Falls Dam: The Connecticut River from Turners Falls Dam to the Route 116 Bridge traversing the Connecticut River in Sunderland, MA.

1.2 Study Goals and Objectives

The study goal was to:

- Determine if water level fluctuations at the Turners Falls and Northfield Mountain Projects result in reductions of available aquatic habitat due to movement barriers and/or habitat alterations.

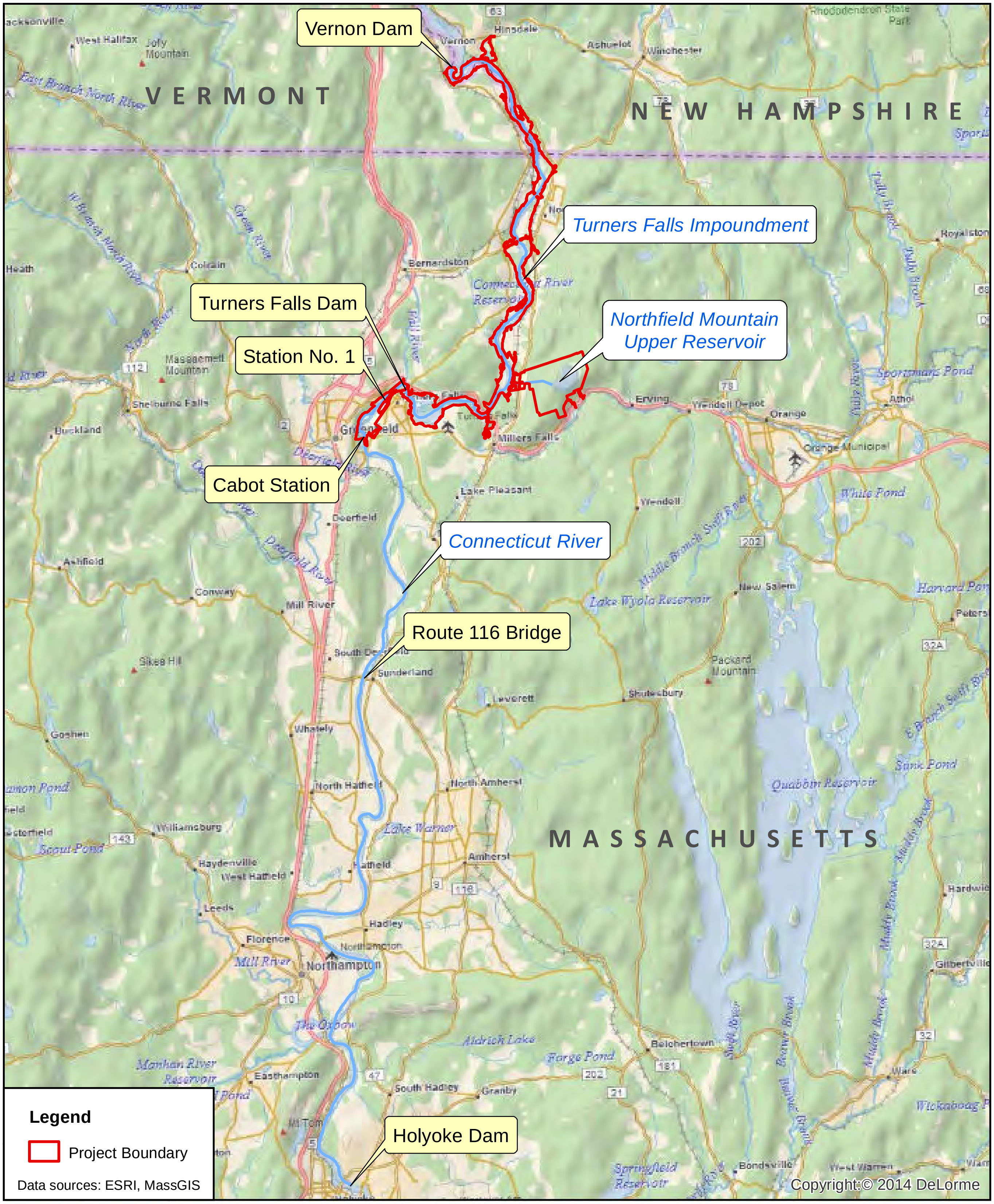
Specific study objectives were to:

- Identify potential barriers or constrictions of fish access to tributaries and backwater areas resulting from Project-related water level fluctuations.
- Measure changes to available habitat and water quality in backwater areas and tributaries resulting from Project-related water level fluctuations.

1.3 Vertical Datum

Note that the datum used in this study is the National Geodetic Vertical Datum of 1929 (NGVD29). Although a more up-to-date datum is available[1], FirstLight has used the NGVD29 datum in reporting dam elevation data, water level data, etc. over numerous years.

[1] NAVD88- North American Vertical Datum of 1988 (NAVD88).



FIRSTLIGHT POWER RESOURCES

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 2.5 5 10 Miles

Figure 1.1-1
Turners Falls Project and
Northfield Mountain Project
Vicinity Map

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2 OVERVIEW OF PROJECT OPERATIONS

The purpose of this section is to provide an overview of water surface elevation (WSEL) fluctuations in the Turners Falls Impoundment and below the Turners Falls Dam within the defined study area due to Project operations and natural flows.

2.1 Turners Falls Impoundment

At the head of Turners Falls Impoundment, TransCanada operates the Vernon Hydroelectric Project (FERC No. 1906). The Vernon Project is operated as a peaking facility when inflows are less than its hydraulic capacity of 17,130 cubic feet per second (cfs). As inflow exceeds its hydraulic capacity, water is typically spilled at Vernon Dam.

The Northfield Mountain Project includes four pump/turbines. Typically, the project pumps water at night and generates during the day when power demand is higher. The approximate hydraulic capacity of the four pump/turbines at the Northfield Mountain Project is 15,200 cfs when pumping and 20,000 cfs when generating.

The FERC license for the Turners Falls Project authorizes the upper and lower limit of the Impoundment to be from elevation 176.0 ft (NGVD29) to elevation 185.0 ft (NGVD29) as measured at the Turners Falls Dam, a nine (9) foot range of operation. Based on hourly data for the period 2000-2009, the median impoundment elevation is 181.3 ft, as measured at the dam. Figure 2.1-1 is an annual WSEL duration curve.

2.2 Hydraulic Modeling Summary

A hydraulic model of the TFI Impoundment was conducted as part of a separate relicensing study entitled Study No. 3.2.2: Hydraulic Study of Turners Falls Impoundment, Bypass Reach and below Cabot Station. A separate report for Study No. 3.2.2 has been completed and was uploaded to the FirstLight northfieldrelicensing.com website on March 31, 2015. The hydraulic model will be used to determine the vertical and horizontal zone of TFI fluctuations due to FirstLight Project operations and Vernon Hydroelectric Project operations. As part of the modelling study, temporary water level loggers were installed in the TFI to record the water surface elevation (WSEL) every 15 minutes. The water level loggers were installed in March or April 2014 and remained in place until November 2014, covering a wide magnitude of flow conditions. The purpose for installing the water level loggers was to collect WSEL data for use in calibrating the hydraulic model. In addition to the WSEL data collected, FirstLight recorded the Vernon discharge, the Northfield Mountain Project pumping and generating flows and the inflows from two major tributaries equipped with United States Geological Survey (USGS) gages (the Ashuelot and Millers Rivers). With observed flow and WSEL data, the TFI hydraulic model was successfully calibrated as described in more detail in Study Report No. 3.2.2.

WSEL fluctuations in the TFI are a function of:

- Vernon Project peaking discharges (maximum hydraulic capacity of 17,130 cfs),
- Northfield Mountain Project operations (maximum hydraulic generating capacity of 20,000 cfs and maximum hydraulic pumping capacity of 15,200 cfs),
- Cabot Station peaking operations (maximum hydraulic capacity of 13,728 cfs),
- naturally high flows, and
- boat wakes.

The hydraulic model showed that when flows start to exceed approximately 20,000 cfs, the French King Gorge, a natural constriction of the river downstream of the Northfield Mountain Project tailrace, starts to control the upstream WSEL. The gorge serves as a pinch point or hydraulic control resulting in water "backing up" upstream of the gorge.

Based on the hydraulic modeling conducted under Study No. 3.2.2, the upstream extent of the TFI varies based on several variables including: the Vernon Project discharge, Northfield Mountain Project operations, tributary inflow to the TFI, and the TFI WSEL elevation at the Turners Falls Dam. Based on the hydraulic modeling study, depending on the above variables, there are times when the TFI does not backwater to the base of the Vernon Dam. In some instances, there is a free-flowing section of the Connecticut River below Vernon Dam. In other instances, particularly under high flows, the French King Gorge backwater extends to the base of the Vernon Dam.

2.3 Below Turners Falls Dam

Water is conveyed from the Impoundment through the gatehouse into a power canal with four hydroelectric facilities, including Station No. 1 and Cabot Station (located at the downstream end of the canal)—Station No. 1 and Cabot Station are collectively referred to as the Turners Falls Hydroelectric Project. The hydraulic capacities of Station No. 1 and Cabot Station are 2,210 cfs and 13,728 cfs, respectively (combined capacity of 15,938 cfs). There are also two other small hydropower facilities owned by Southworth Paper and Turners Falls Hydro LLC, as well as a water withdrawal by the United States Geological Survey (USGS) Conte Lab, that divert flow from the canal. Note that the two small hydropower facilities operate only after Cabot Station and Station No. 1 are operating at full hydraulic capacity.

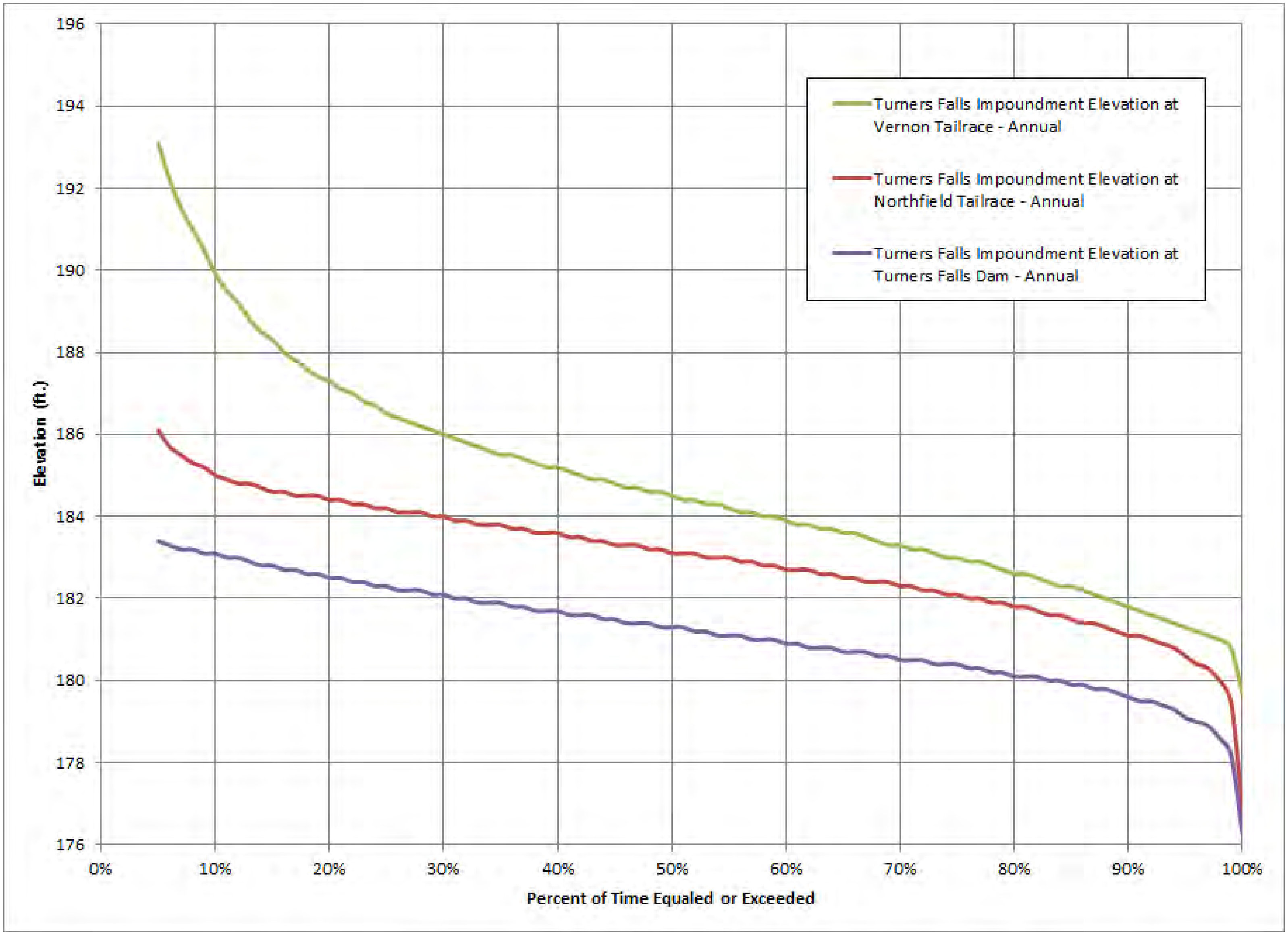
If flows exceed the hydraulic capacity of the canal of roughly 18,000 cfs, water is spilled at Turners Falls Dam. The stretch of the Connecticut River from the base of Turners Falls Dam to the Cabot Station discharge is referred to as the bypass reach. This approximate 2.7 mile long segment receives flow from:

- Turners Falls Dam discharges,
- Spillway fishway,
- Fall River discharge , and
- Discharges from the canal from the following facilities when operating: Station No. 1, Southworth Paper Hydro, Turners Falls Hydro LLC, Conte Lab and Cabot Station.

Per the current FERC license, a continuous minimum flow of 200 cfs is maintained in the bypass reach starting on May 1, and increases to 400 cfs when upstream fish passage starts by releasing flow through the No. 1 bascule gate. The 400 cfs continuous minimum flow is provided until the spillway fishway is closed, typically during the first week in July. In addition, to protect shortnose sturgeon, a continuous minimum flow of 120 cfs is maintained in the bypass reach from spillway fishway closure until the river temperature drops below 7°C, which typically occurs around November 15th.

In the study reach below Cabot Station, water level fluctuations could be caused by Cabot Station operations, bypass reach flows, and Deerfield River flows.

Figure 2.1-1: Turners Falls Impoundment- Annual Elevation Duration Curves, Hourly 2000-2009.



3 STUDY AREA AND SURVEY SITES

The Turners Fall Impoundment includes two major tributaries, the Ashuelot River, which drains into the Impoundment just downstream of Vernon Dam, and the Millers River, which drains into the Impoundment approximately 1.3 miles downstream of the Northfield Mountain Tailrace. The study area also includes 13 smaller tributaries that drain into the Impoundment (Figure 3.0-1). Below the Turners Falls Dam there is one major tributary, the Deerfield River, and three smaller tributaries (Figures 3.0-2). All of these smaller tributaries, with the exception of the Fall River, drain into the Connecticut River below the bypass reach. The Fall River discharges into the bypass reach just below the Turners Falls Dam. The complete list of tributaries surveyed for this study are listed below in upstream to downstream order. The drainage area of the tributary is also shown as measured at its confluence with the Connecticut River (USGS, 2012).

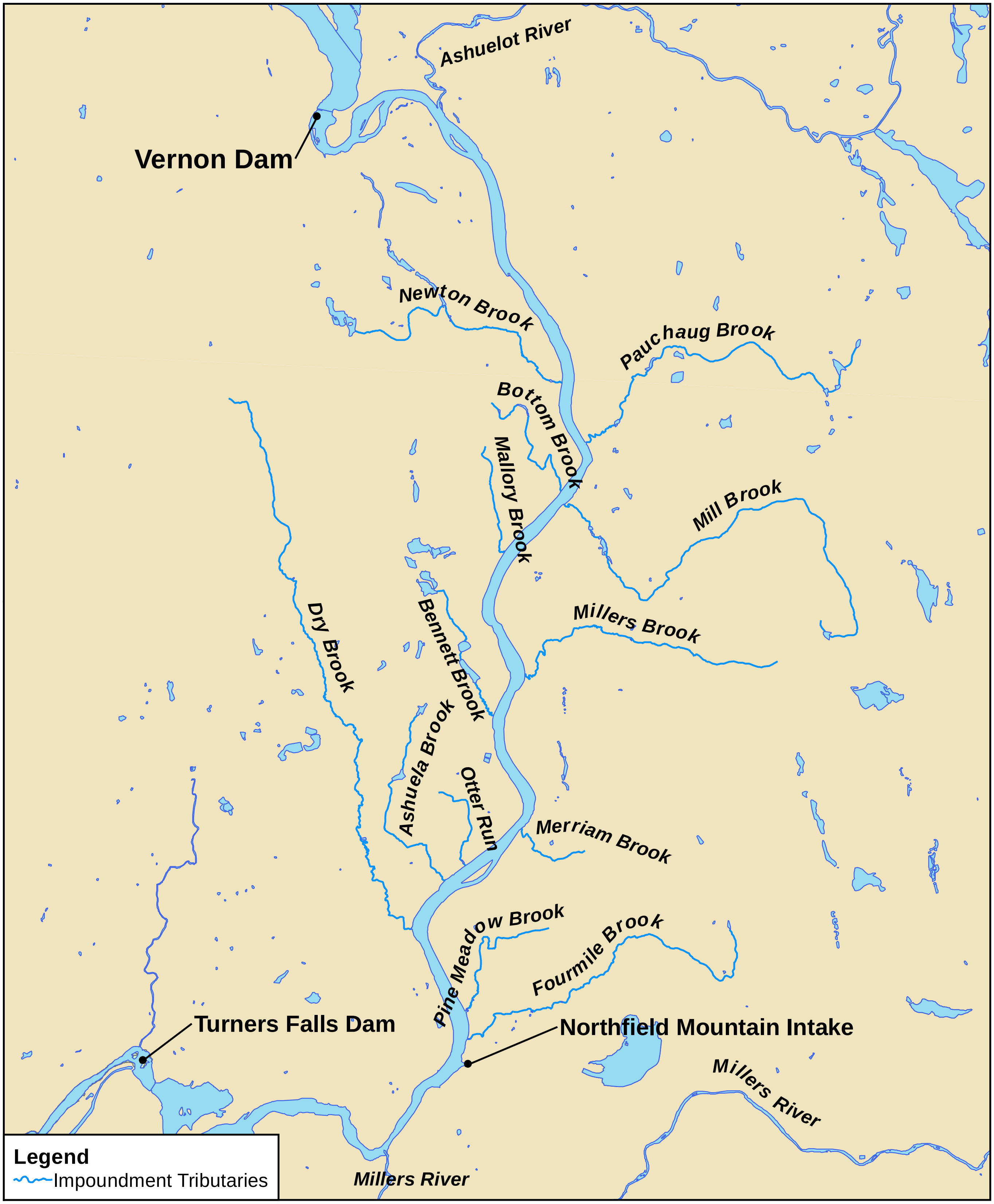
Turners Falls Impoundment (Figure 3.0-1):

- Ashuelot River (422 mi^2)
- Newton Brook (3.66 mi^2)
- Pauchaug Brook (8.65 mi^2)
- Bottom Brook (0.66 mi^2)
- Mill Brook (9.53 mi^2)
- Mallory Brook (0.93 mi^2)
- Millers Brook (5.5 mi^2)
- Bennett Brook (5.57 mi^2)
- Merriam Brook (0.57 mi^2)
- Otter Run (0.31 mi^2)
- Ashuela Brook (1.12 mi^2)
- Dry Brook (9.37 mi^2)
- Pine Meadow Brook (1.31 mi^2)
- Fourmile Brook (5.06 mi^2)
- Millers River (389 mi^2)
- Significant backwater habitats encountered during the survey work (if any).

Below Turners Falls Dam (Figure 3.0-2):

- Fall River (34.2 mi^2)
- Deerfield River (664 mi^2)
- Sawmill River (32 mi^2)
- Gunn Brook (2.15 mi^2)

Limited data are available relative to the potential effects of Turners Falls and Northfield Mountain Projects operations on these tributaries and if, and under what conditions, access to these habitats is restricted for riverine fish species.



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

Figure 3.0-1
Location of Target Tributaries in the Turners Falls Impoundment

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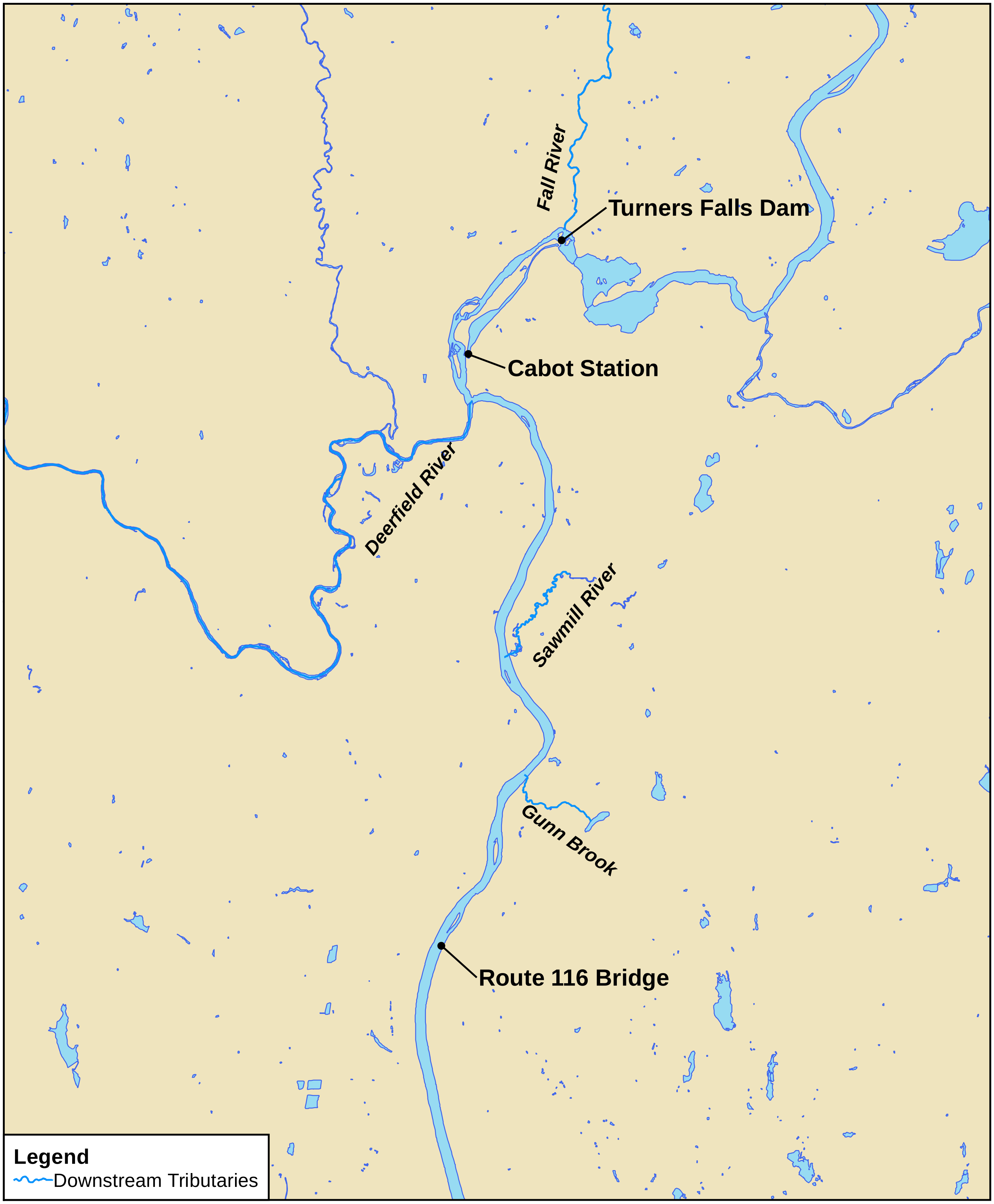

FirstLight Power Resources
GDF SUEZ

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 1 2 4 Miles

Figure 3.0-2
Location of Target Tributaries
Downstream of the Turners Falls Dam

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4 METHODS

As a first step, FirstLight reviewed aerial maps and photographs of the study area to identify access to study locations prior to field work. An assessment was then conducted by boat during high flow and-water level conditions in the spring to locate individual tributaries and backwater areas. Surveyors revisited tributaries in the summer and fall during seasonally lower flow and water level conditions to determine if stream flow intermittency occurred or access to the mouth of the tributaries was affected as a result of Project operations, resulting in restricting fish movement in the tributaries.

FirstLight performed surveys on eight days between May 21 through June 11, 2014 (spring), on five days between August 5 through September 2, 2014 (summer), and on three days from October 13 through October 15, 2014 (fall). During each survey, two observers located and assessed individual tributary confluence areas. Tributaries were accessed either by boat or on foot. FirstLight collected water temperature, dissolved oxygen (DO) concentration, pH, turbidity and WSEL data during each survey. Photographs were taken to document the condition of the tributary during each survey. Water depth, water velocity (feet per second, fps), substrates, access from the river into the tributary, and features that could affect tributary access such as large woody debris in the stream channel were documented during the summer and fall surveys (see Table 4.0-1).

The upstream extent of each tributary confluence was determined in the field based on flow fields (e.g. backwatering or free flowing) and changes in substrate texture (fine sediments vs. coarser substrates associated with free flowing reaches). The upstream extent was delineated in the field using a sub meter accurate Trimble GeoXH 6000 GPS receiver. The perimeter of each tributary confluence was delineated by employing Light Detection and Ranging (LiDAR) elevation data to determine the elevation at the upstream extent and using a geographic information system (GIS) to map the seasonal confluence perimeter.

Longitudinal bathymetric thalweg surveys of the confluence area were conducted at each tributary with depths representing the conditions at the time of the survey. The survey team began at the mouth of the tributary (distance 0 ft) and traversed upstream into each tributary documenting: cumulative distance traveled in feet; changes in substrate composition; flow fields characteristics; changes in thalweg depth; and the location of any possible fish migration barrier. Bed profile, water depths and the length of each tributary confluence varied based on the Connecticut River WSEL, tributary flow, and the depositional characteristics present at the tributary confluences, which are dynamic.

Cross-section or longitudinal profile surveys were conducted at locations that potentially restricted fish movements during the summer and fall survey. For cross-sectional transects, profiles were begun on the left bank and continued across to the right bank.[2] Longitudinal profiles began at the downstream terminus of the confluence and worked upstream within the tributary thalweg. Channel depth and average water velocities were recorded at points along the wetted transect. The number of transect points was based upon changes to tributary bed morphology.

The RSP defined a depth of 1 foot in tributaries as a potential barrier; however given the small size of most of the tributaries surveyed in the study area, and the body depth of the riverine fishes that inhabit the Connecticut River, a shallower criterion was used. The general character of the tributary was considered when determining barriers as many of the tributaries surveyed were small, exhibiting very shallow depths (often less than 0.5 ft) outside of the influence of the Project and therefore shallow depths within the confluence area were not considered barriers but rather a characteristic of the tributary. Bovee (1982) recommends that the minimum clearance requirement should probably be no less than two-thirds of the body depth of the fish. Generally, confluence areas of tributaries with water depths shallower than 0.3 ft in

[2] All references to left bank or right bank are from the perspective of an observer looking downstream.

the thalweg area were considered restrictive to fish movement. Based on this criterion, fishes with a body depth less than or equal to 0.5 ft would not be restricted by depths of 0.3 ft and greater. A list of resident fish species that are found in the Turners Falls Impoundment is presented in Table 4.0-2.

Water quality measurements were collected at each tributary and included: water temperature (°C), dissolved oxygen (mg/l), and pH using a handheld YSI 556 water quality meter; and turbidity (Nephelometric Turbidity Units (NTU)) using a LaMotte 2020 turbidity meter and/or a secchi disk (spring only). For each tributary, measurements were collected at three locations during the summer and fall Surveys: upstream of the confluence in the tributary; inside the confluence; and within the Connecticut River immediately upstream of the confluence area. During the spring survey, water quality parameters were measured within the mainstem Connecticut River and within the confluence only.

Significant backwater areas were defined as those with a notable increase in WSEL caused by a constriction or obstruction in flow, or off-channel habitats created as a result of floodplain (or other habitat features, e.g., oxbow) development and were not associated with the tributary confluences. Observers looked for backwater habitat during spring high-water level conditions and, if applicable, re-surveyed this habitat during summer and fall low-water level conditions to assess connectivity and general conditions. After field data collection, maps were created showing the identification of the upstream-most limit of Connecticut River influence within each tributary during each survey.

As part of other relicensing studies, FirstLight collected WSEL data throughout the Turners Falls Impoundment and bypassed reach in 2014 with either In-Situ Level TROLL Model 500 or Hobo Onset Water Level Logger Model U20. Data were collected on a 15-minute time step from approximately March 25, 2014 to November 7, 2014, covering the period in which the tributary surveys were conducted. All WSEL data are relative to the NGVD29 vertical datum. Figure 4.0-1 shows the water level logger monitoring locations used for this study. The WSEL data from the closest monitoring station were used to determine the WSEL at the time of the specific tributary survey.

For the tributaries located below Cabot Station, water level fluctuations were characterized by stage data collected at the United States Geological Service (USGS) Gage No. 01170500 Connecticut River at Montague City, MA. The gage is located below the Cabot tailrace and includes flow from the Deerfield River. Data were collected at 15 minute intervals and plotted for each seasonal survey period.

For the Fall River, which enters the Turners Falls Project bypass reach, water level fluctuations were characterized by stage data collected with temporary water level loggers installed for another relicensing study, and by FirstLight operations data.

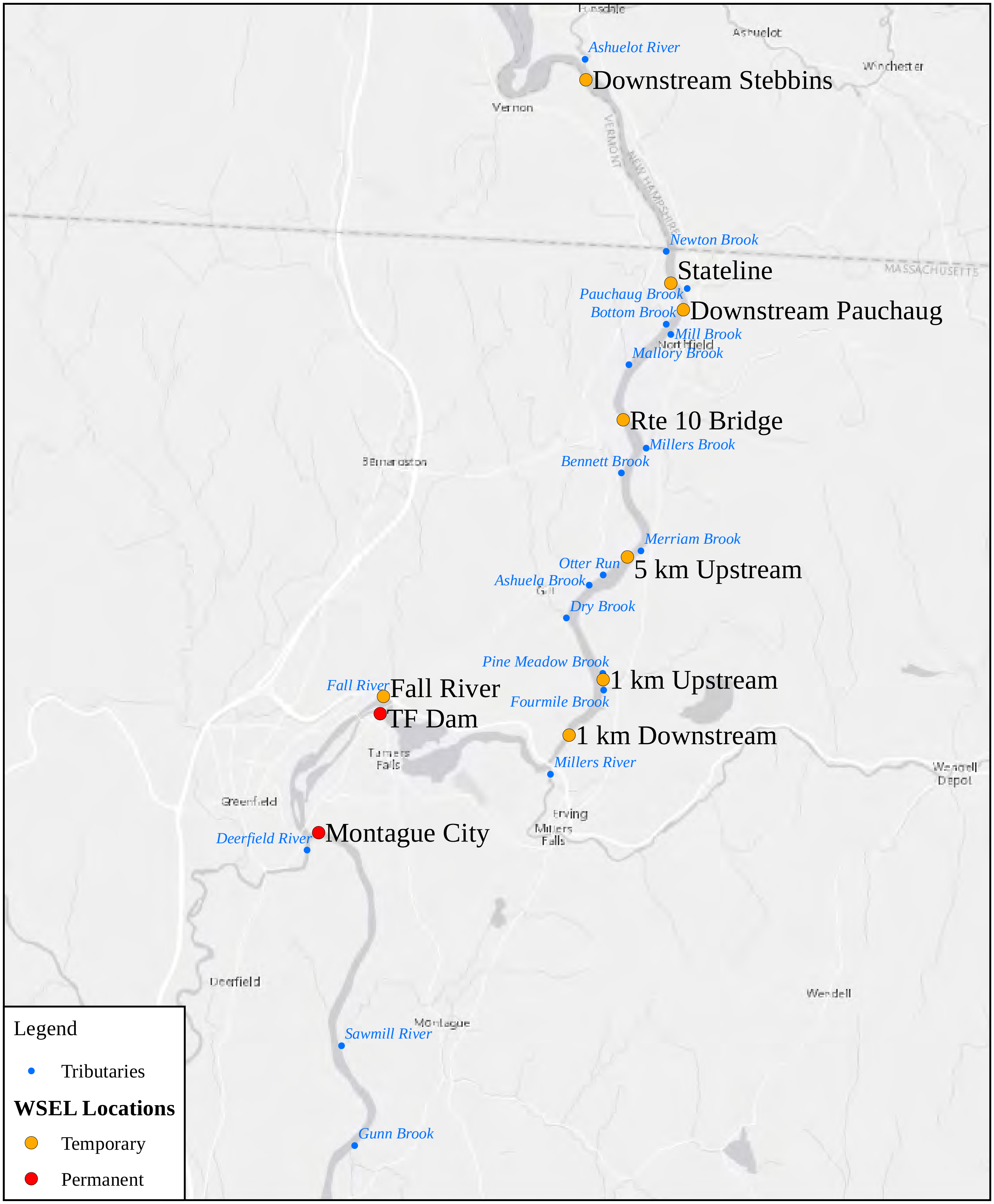
Table 4.0-1. Field Tasks Completed by Season in 2014

Task	Spring	Summer	Fall
Connectivity Survey	X	X	X
Confluence Perimeter Mapping	X	X	X
Longitudinal Thalweg Profile	X	X	X
Longitudinal and/or Cross Section Profile		X	X
Water Quality	X	X	X
WSEL	X	X	X

Table 4.0-2: Relative Abundance of Resident Fish Collected via Electrofishing in the Turners Falls Impoundment in the Early 1970s and 2008

Species		**Relative Abundance (%)**	
Scientific Name	*Common Name*	*1971-1975*	*2008*
Perca flavescens	Yellow perch	25	17
Lepomis gibbosus	Pumpkinseed	16	3
Micropterus dolomieu	Smallmouth bass	15	5
Micropterus salmoides	Largemouth bass	9	6
Lepomis macrochirus	Bluegill	8	3
Notropis hudsonius	Spottail shiner	7	57
Catostomus commersonii	White sucker	5	4
Sander vitreus	Walleye	4	0
Ameiurus nebulosus	Brown bullhead	3	0
Notemigonus crysoleucas	Golden shiner	3	1
Pomoxis nigromaculatus	Black crappie	2	0
Morone americanus	White perch	2	0
Ambloplites rupestris	Rock bass	2	2
Esox niger	Chain pickerel	<1	< 1
Semotilus corporalis	Fallfish	0	1
Cyprinus carpio	Common carp	0	< 1

Note: Relative abundance rounded to nearest whole number.



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study, No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

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Figure 4.0.1. Tributary confluences and the nearest WSEL monitoring stations on the Connecticut River

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5 RESULTS

A total of 19 tributary confluences were surveyed. No significant backwaters associated with floodplain features and/or oxbows were identified in the study area. Backwatering within the highly dynamic tributary confluences was observed in most cases, particularly in the Turners Falls Impoundment during high WSELs and during the spring high flow season. Most tributaries were small with the exception of the Ashuelot, Millers, and Deerfield Rivers. The tributaries exhibited natural seasonal variability in discharge that affected the condition of the confluences with respect to connectivity and habitat. This variability and the resulting effects were most apparent in the small, low order tributaries.

5.1 Flow and Water Surface Elevation Conditions

The summer survey period exhibited the greatest range of impoundment WSELs, with a low elevation of 178.33 ft at the Turners Falls Dam at 1130 on August 12, 2014 and a high of 183.8 ft at 2300 on August 5, 2014. Observations and data collected on August 12, 2014 are representative of an abnormally low impoundment level (178.3 ft at the TF Dam), coupled with a low Vernon discharge of 1,536 cfs; this a condition that was intentionally created in support of TransCanada's Instream Flow Study. Based on the annual elevation duration curve (Figure 2.1-1), an impoundment elevation of 178.3 or less, as measured at the TF Dam, occurs less than 2% of the time.

The Turners Falls Impoundment WSELs during the spring surveys were generally higher given the higher inflow conditions. The fall survey occurred when flows were low. In the Turners Falls Impoundment, Vernon peaking operations and Northfield Mountain Project cycling resulted in Impoundment WSEL fluctuations during the surveys. Figures 5.1-1 through 5.1-5 show: 15-minute WSEL data at the various water level loggers in the Impoundment; Vernon discharge (cfs); and Northfield Mountain pumping and generation (cfs) data for the seasonal tributary surveys. Table 5.1-1 shows the instantaneous WSEL as reported from the nearest monitoring location to each of the tributaries on the date/time of survey.

WSELs below the Turners Falls Project were measured at the Montague City USGS gage. Data were obtained at 15 minute intervals and plotted for each seasonal survey period. Table 5.1-1 shows the instantaneous WSEL as reported from the Montague City gage on the date/time of survey. Downstream tributaries were surveyed during rising WSEL conditions during the spring and fall surveys, but were surveyed under low flow, stable conditions during the summer survey (Figures 5.1-6 through 5.1-8).

For the Fall River, which enters the Turners Falls Project bypass reach, water level fluctuations were characterized by stage data collected with temporary water level loggers installed for another relicensing study, and by FirstLight operations data (Figures 5.1-9 through 5.1-11). The Fall River surveys were conducted under minimum bypass flow conditions (400 cfs in the spring and 120 cfs in the summer and fall).

Table 5.1-1. Nearest water surface elevations to tributary confluence locations during field surveys (elevations are shown in feet, NGVD29)

Tributary	Closest WSEL Logger	Date (Spring)	Instant. WSEL (ft)	Date (Summer)	Instant. WSEL (ft)	Date (Fall)	Instant. WSEL (ft)
Turners Fall Impoundment							
Ashuelot River	Downstream Stebbins	5/21/2014	185.68	8/5/2014	183.00	10/13/2014	182.04
Newton Brook	Stateline	6/4/2014	182.67	8/5/2014	180.98	10/13/2014	181.75
Pauchaug Brook	Downstream Pauchaug	6/4/2014	182.65	8/11/2014	180.99	10/13/2014	181.71
Bottom Brook	Downstream Pauchaug	6/4/2014	182.67	8/11/2014	180.99	10/13/2014	182.01
Mill Brook	Downstream Pauchaug	6/4/2014	182.67	8/11/2014	181.06	10/13/2014	182.03
Mallory Brook	Route 10	6/4/2014	182.01	8/11/2014	181.55	10/13/2014	181.94
Millers Brook	Route 10	6/4/2014	182.04	8/12/2014	179.60	10/13/2014	181.90
Bennett Brook	Route 10	6/5/2014	181.46	8/12/2014	179.50	10/14/2014	180.49
Merriam Brook	5km Upstream of NMPS	6/5/2014	181.47	8/12/2014	179.20	10/14/2014	180.89
Otter Run	5km Upstream of NMPS	6/5/2014	181.37	8/12/2014	178.78	10/14/2014	181.37
Ashuela Brook	5km Upstream of NMPS	6/5/2014	181.19	8/12/2014	178.72	10/14/2014	181.53
Dry Brook	5km Upstream of NMPS	6/5/2014	181.11	9/3/2014	179.76	10/14/2014	181.96
Pine Meadow Brook	1km Upstream of NMPS	6/6/2014	180.53	8/12/2014	179.15	10/14/2014	182.13
Fourmile Brook	1km Upstream of NMPS	6/6/2014	180.22	8/12/2014	178.97	10/14/2014	182.53
Millers River	1km Downstream of NMPS	5/22/2014	183.82	8/12/2014	178.90	10/15/2014	182.38
Downstream of Turners Falls Dam							
Fall River	Bypassed Reach (site 1-3)	6/11/2014	135.53	9/2/2014	135.08	10/15/2014	135.04
Deerfield River	Montague City Gage	6/10/2014	109.48	9/2/2014	105.14	10/15/2014	107.98
Sawmill River	Montague City Gage	6/10/2014	107.88	9/2/2014	105.19	10/15/2014	104.51
Gunn Brook	Montague City Gage	6/10/2014	107.90	9/2/2014	105.18	10/15/2014	107.1

Figure 5.1-1: WSELs in Turners Falls Impoundment during the spring survey period (May 21 – 25, 2014).

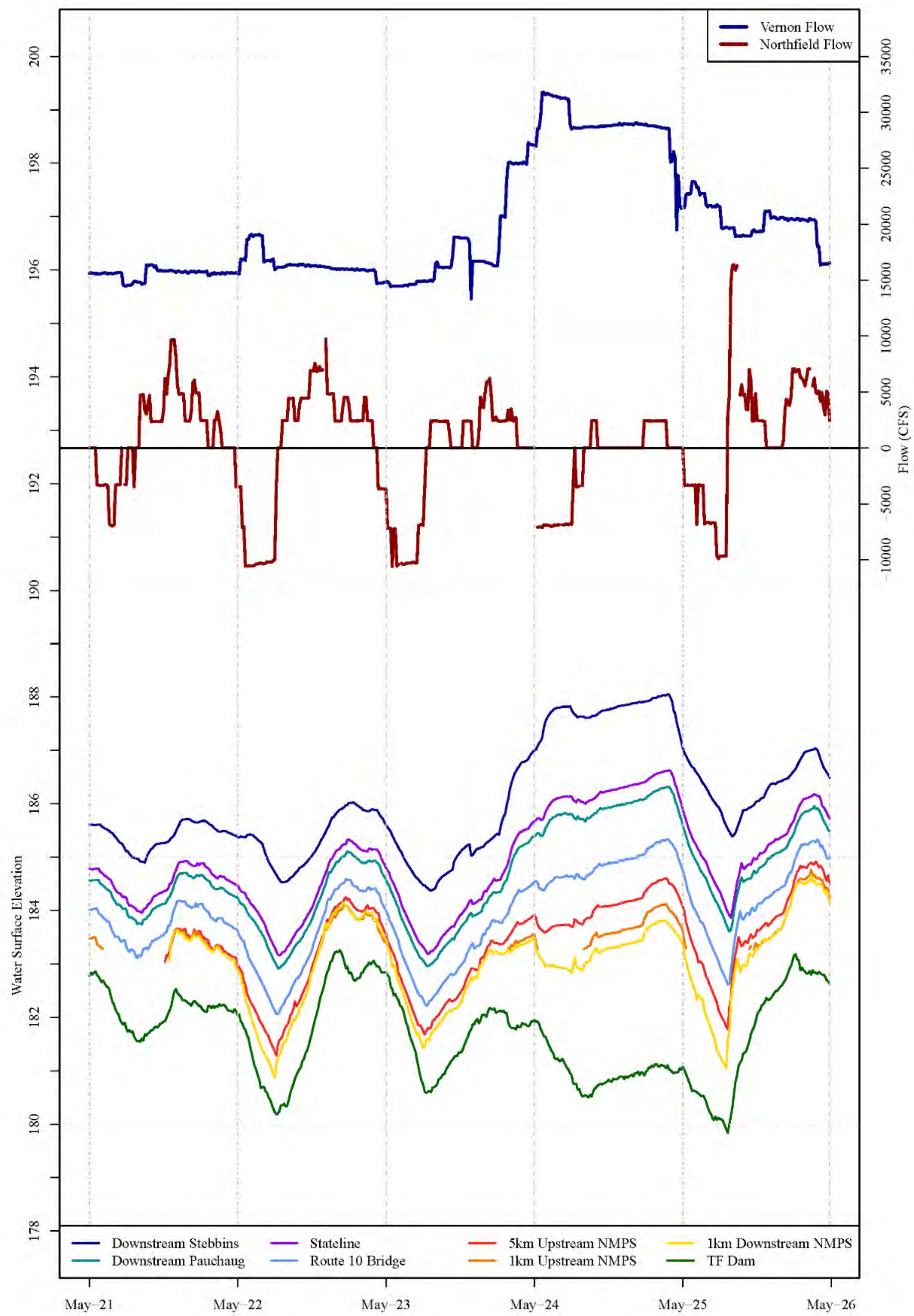


Figure 5.1-2: WSELs in Turners Falls Impoundment during the spring survey period (June 4-8, 2014).

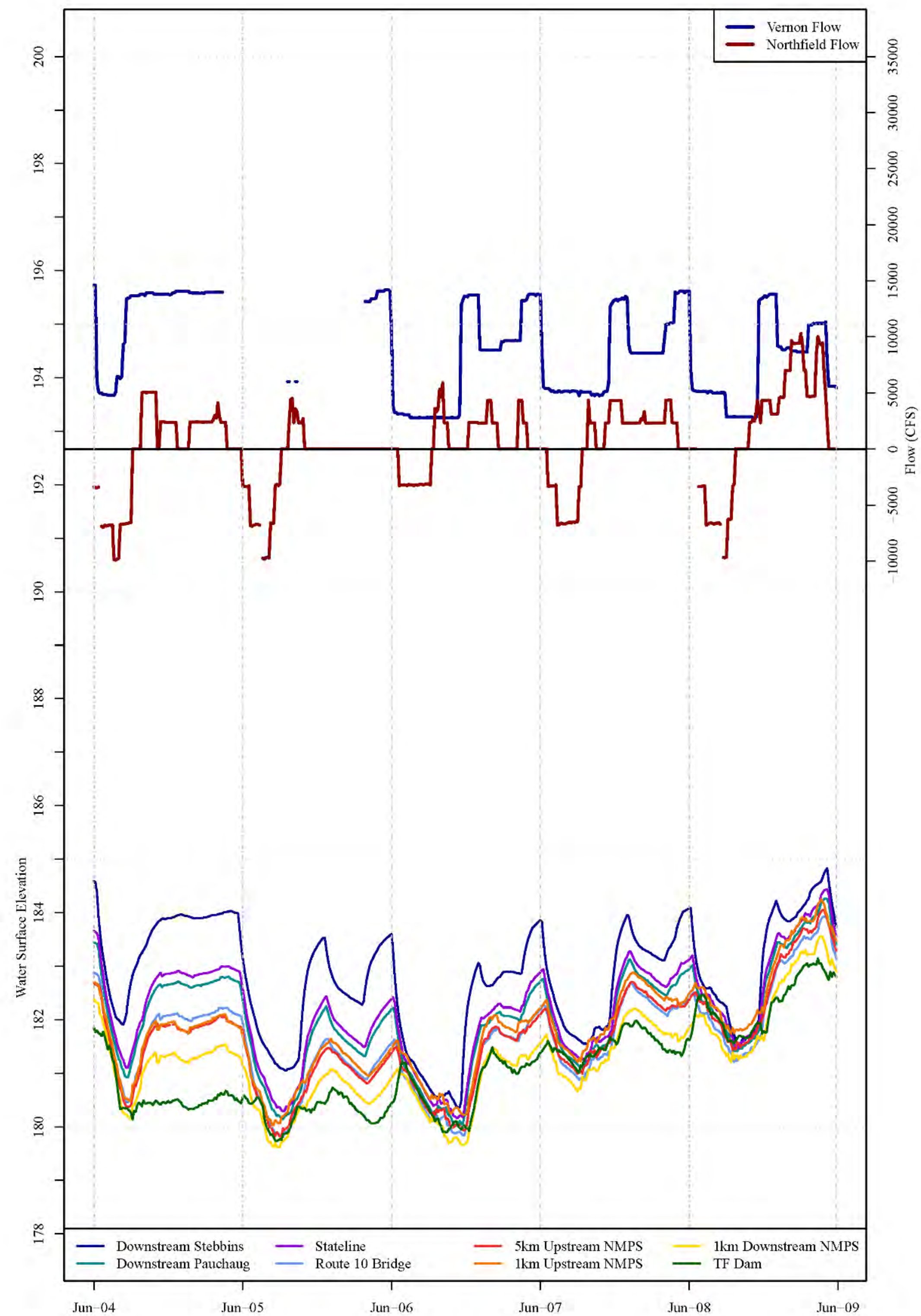


Figure 5.1-3: WSELs in Turners Falls Impoundment during the summer survey period (August 5-9, 2014).

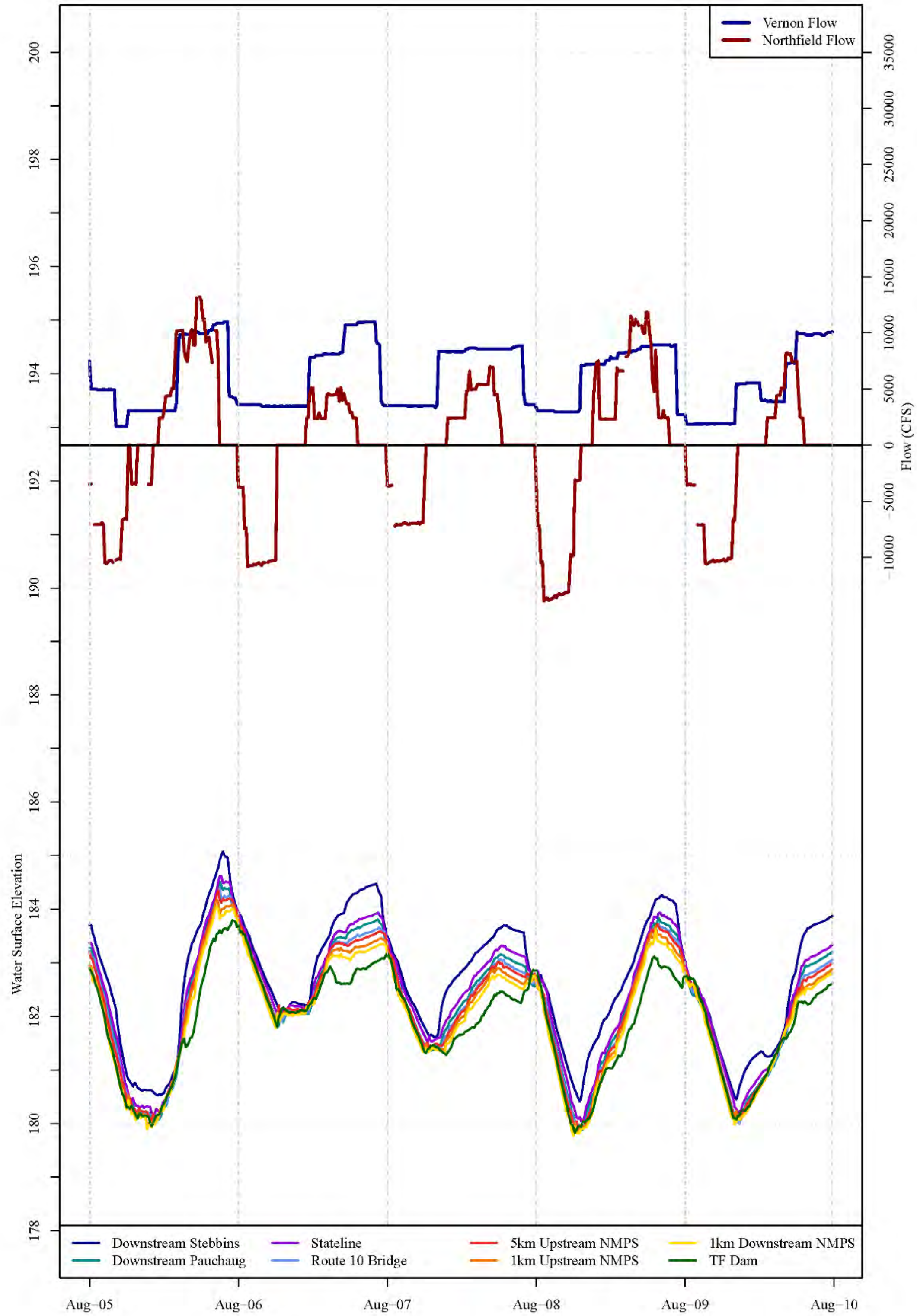


Figure 5.1-4: WSELs in Turners Falls Impoundment during the summer survey period (August 11-15, 2014).

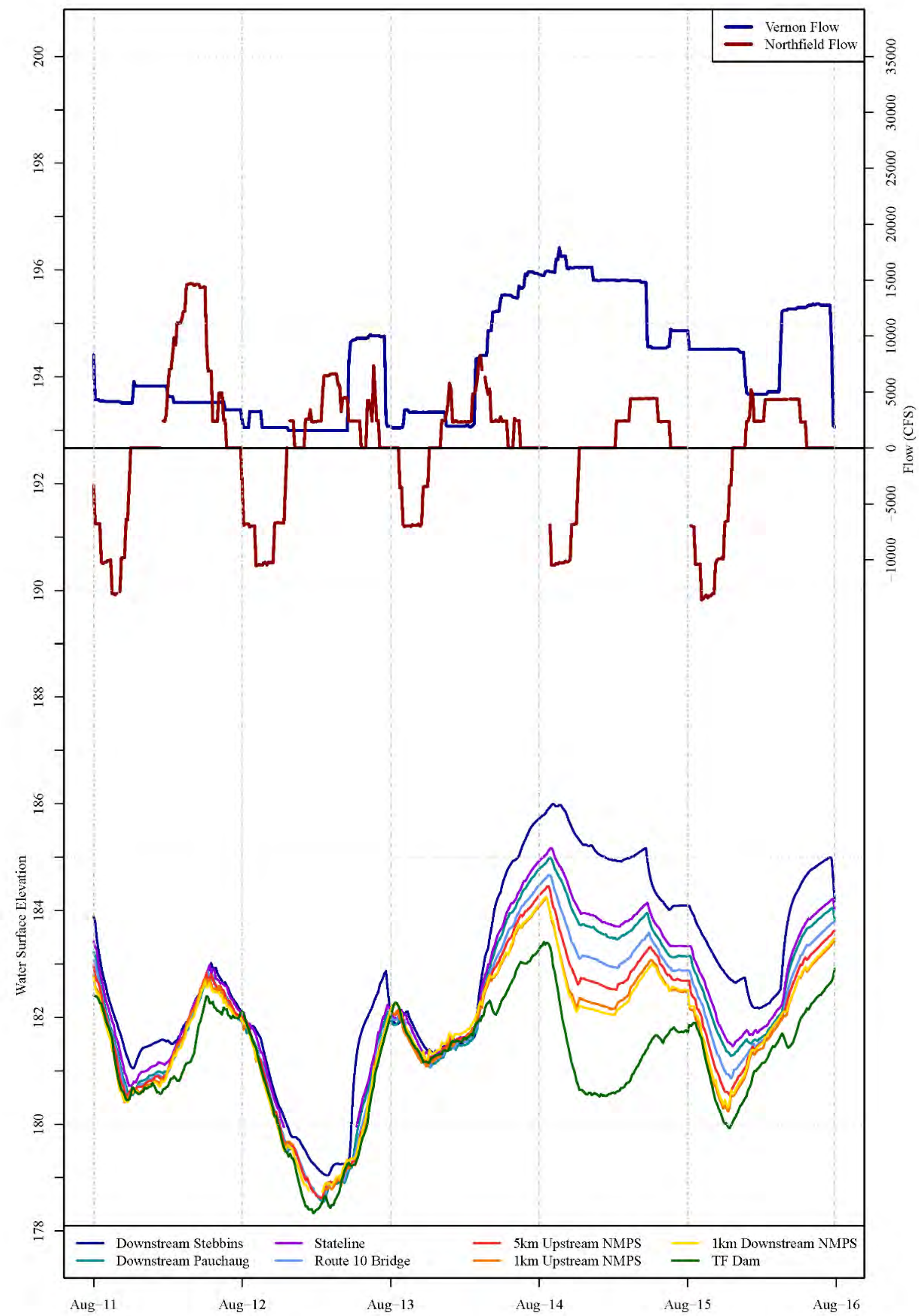


Figure 5.1-5: WSELs in Turners Falls Impoundment during the fall survey period (October 12-16, 2014).

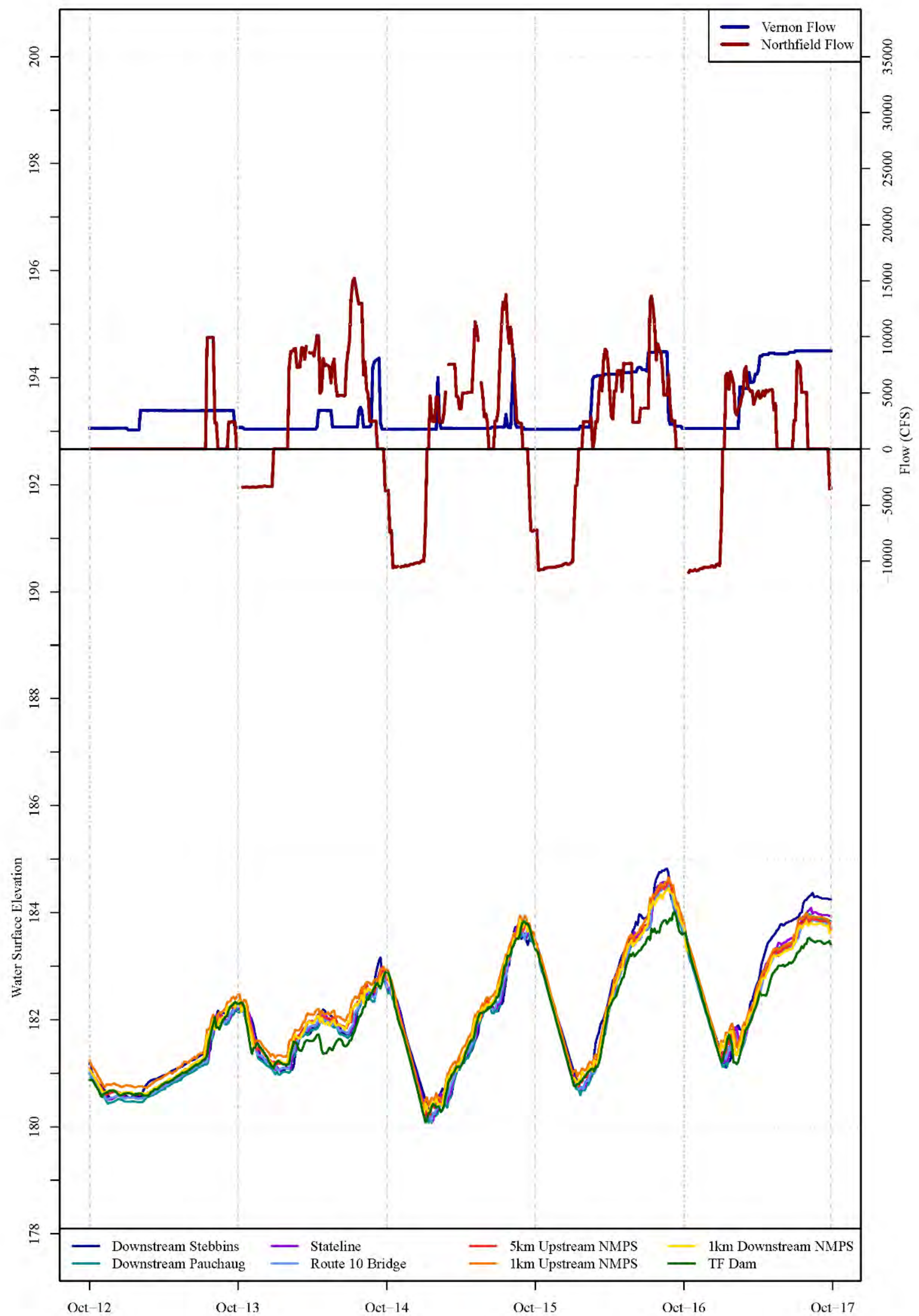


Figure 5.1-6: WSELs at the USGS gage in Montague City, MA during the spring survey period.

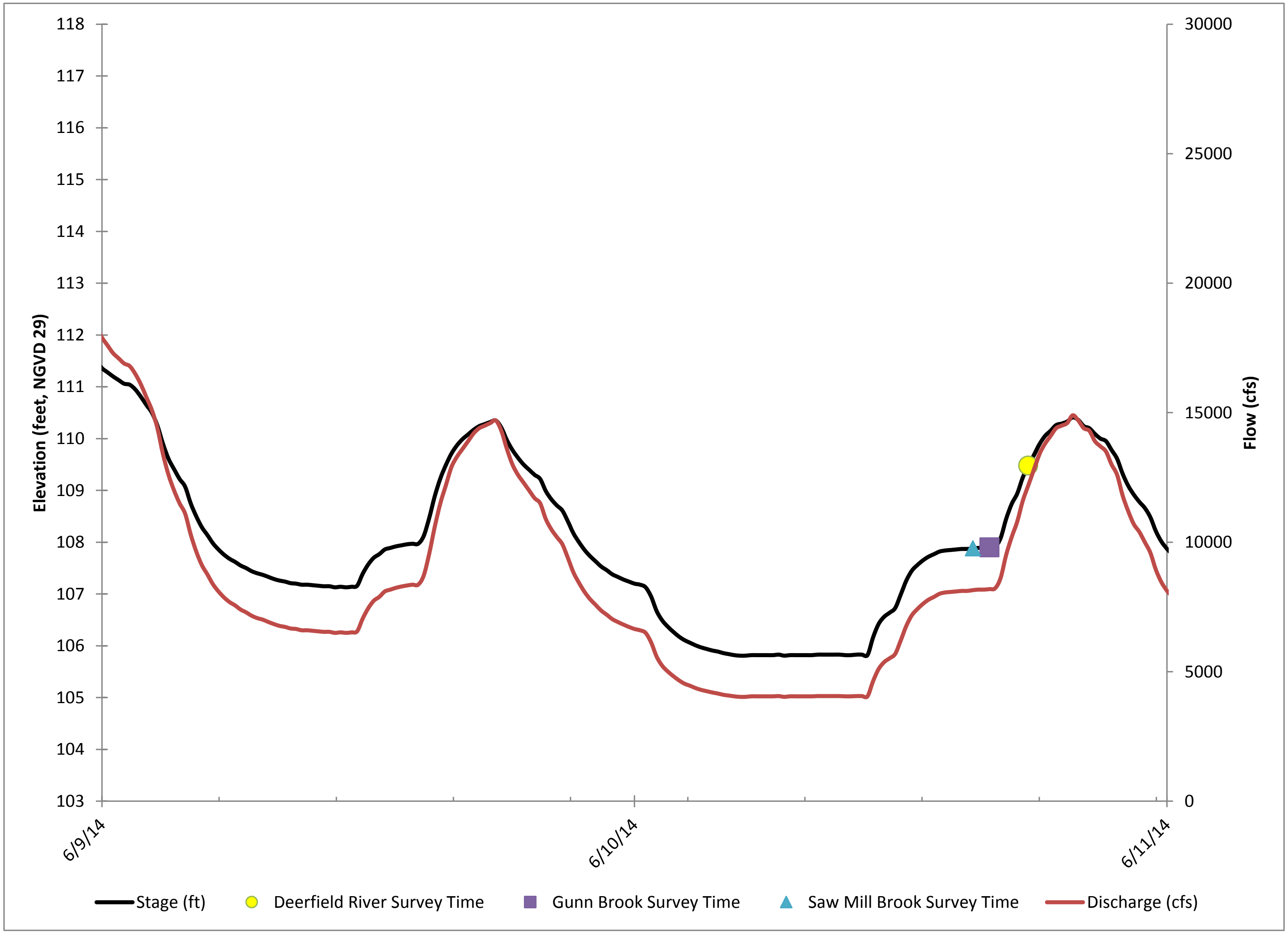


Figure 5.1-7: WSELs at the USGS gage in Montague City, MA during the summer survey period.

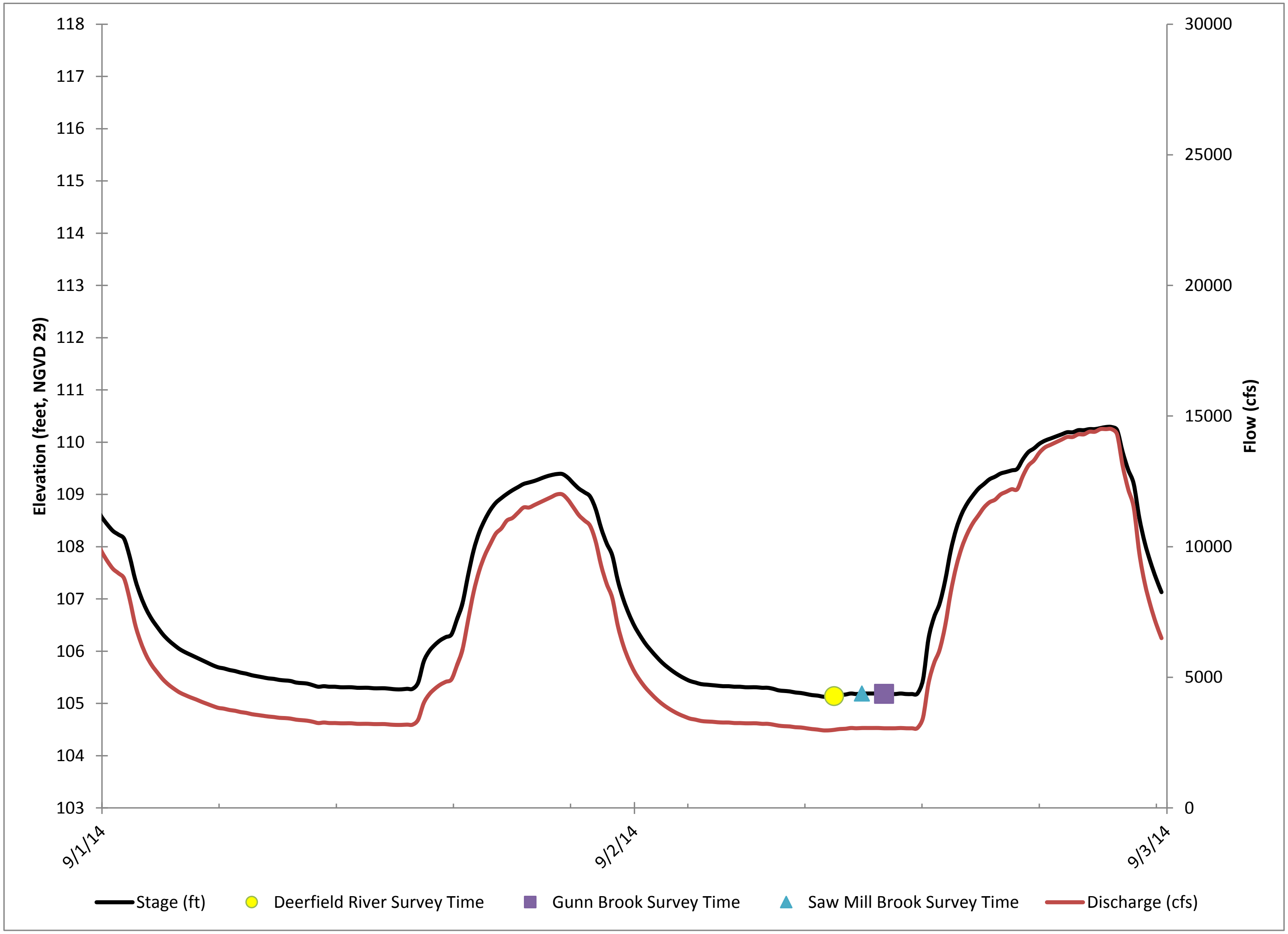


Figure 5.1-8: WSELs at the USGS gage in Montague City, MA during the fall survey.

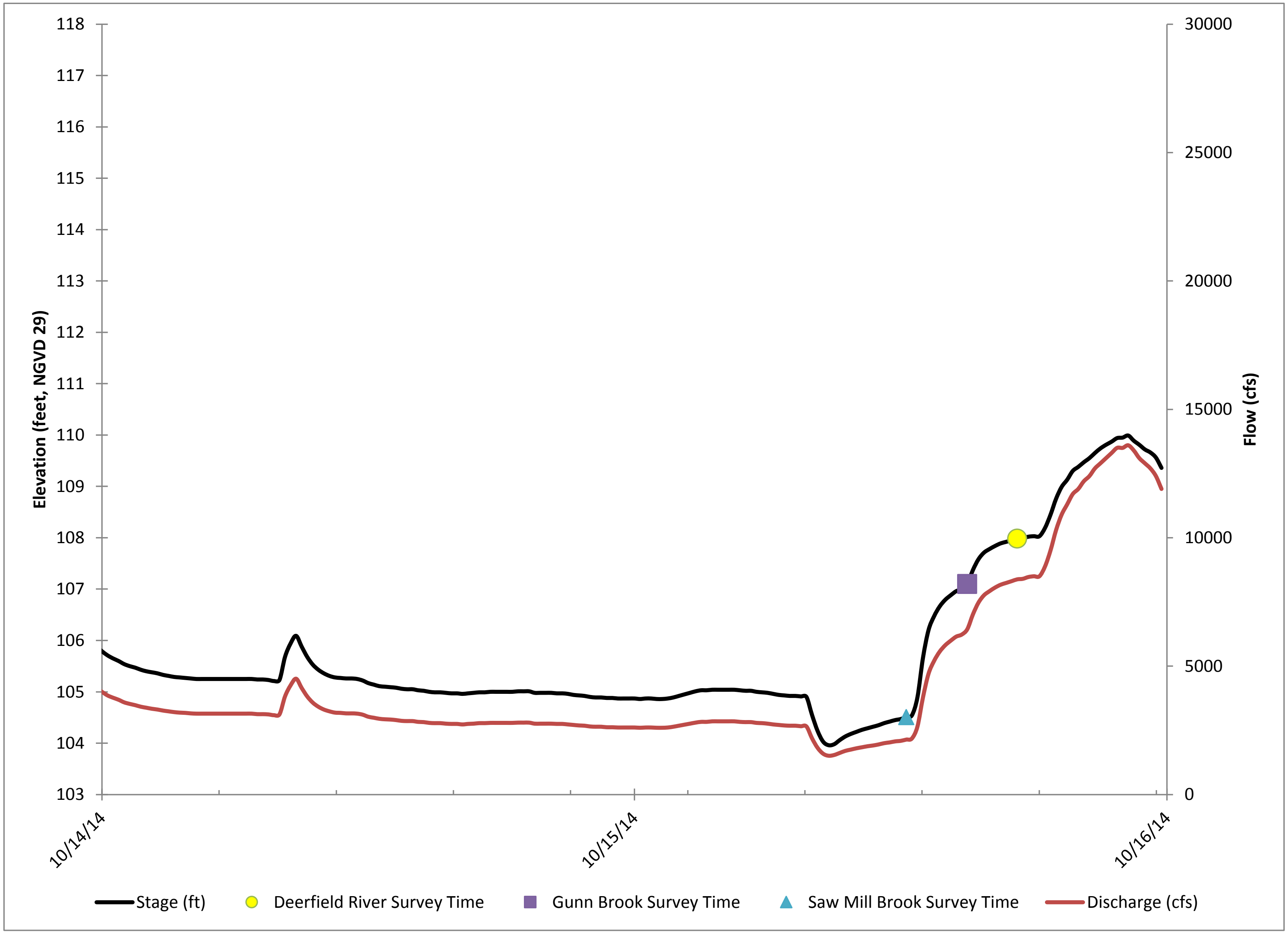


Figure 5.1-9: WSELs at the Turners Falls Bypass Reach near Fall River during the spring survey.

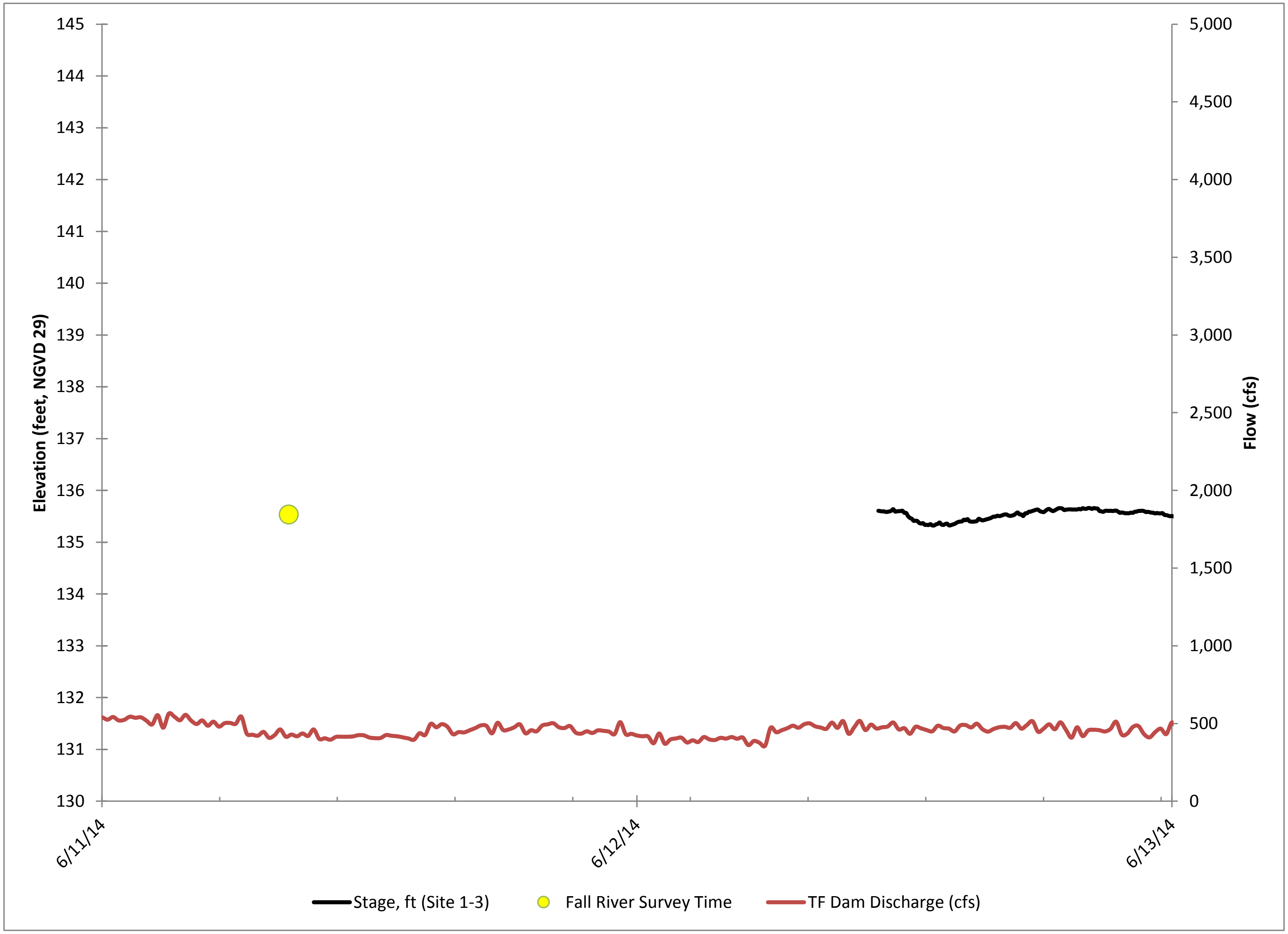


Figure 5.1-10: WSELs at the Turners Falls Bypass Reach near Fall River during the summer survey.

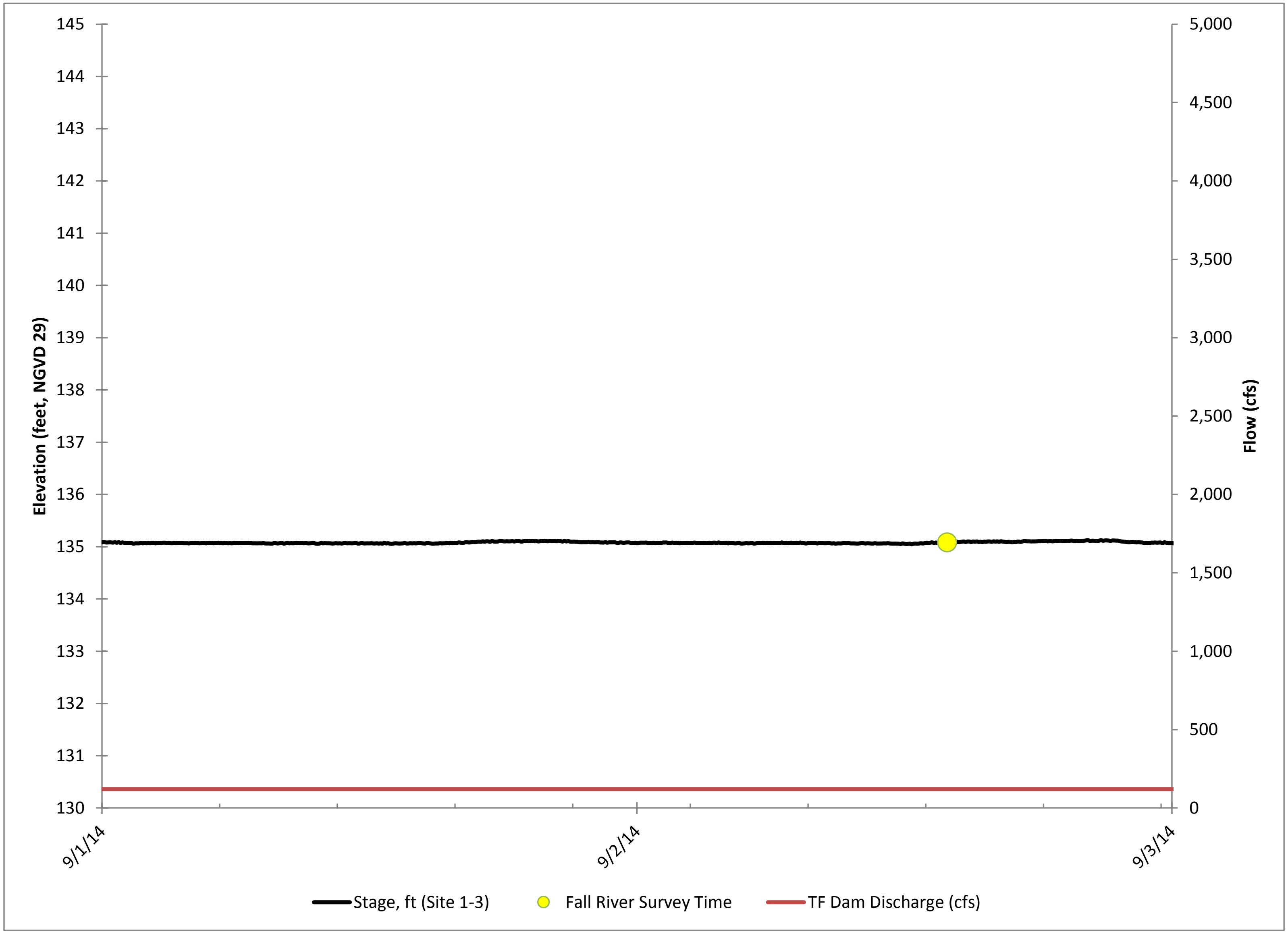
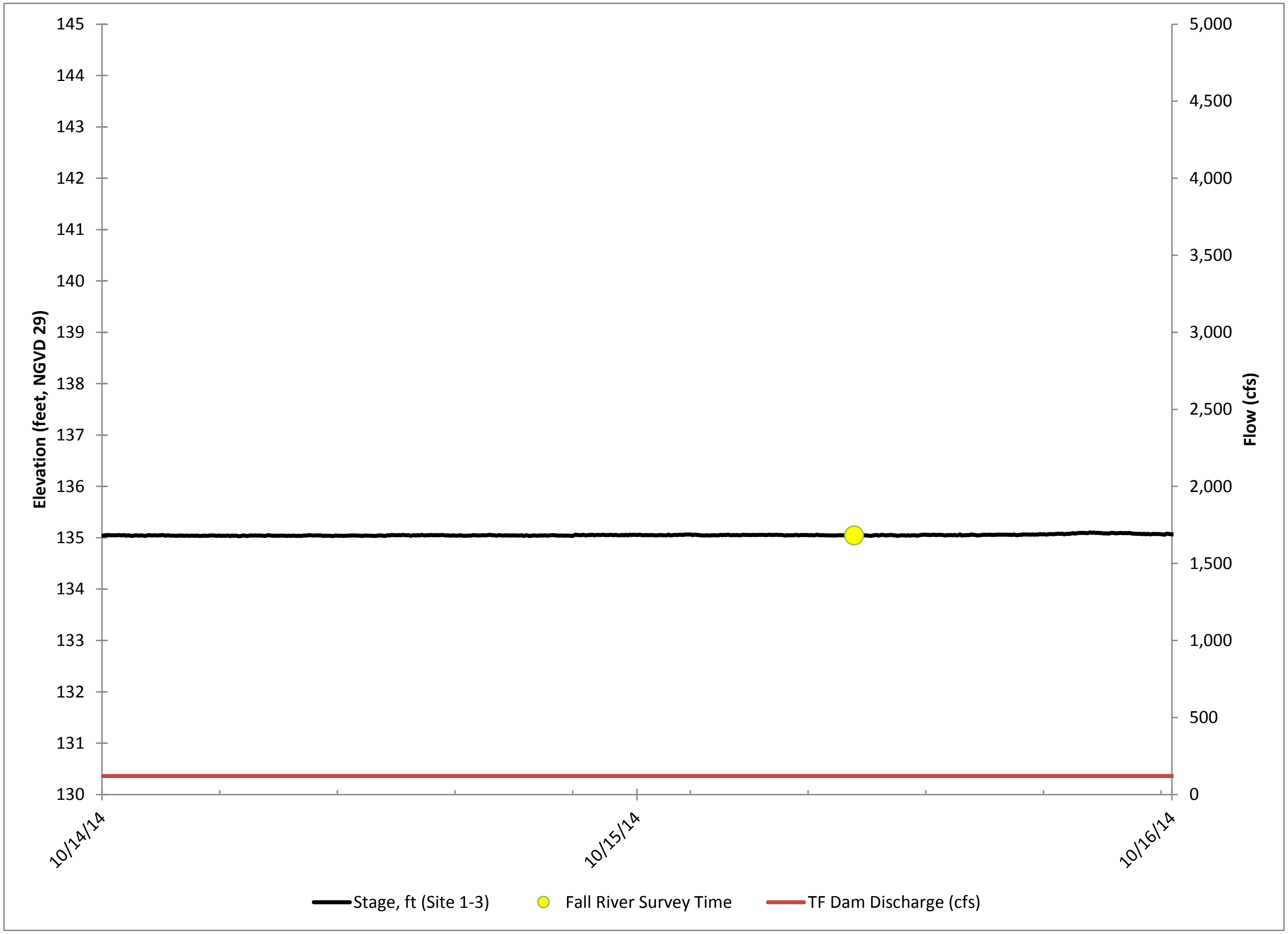


Figure 5.1-11: WSELs at the Turners Falls Bypass Reach near Fall River during the fall survey.



5.2 Water Quality

All tributaries surveyed were located in the state of Massachusetts, with the exception of the Ashuelot River, which is located in New Hampshire. Massachusetts and New Hampshire define surface water quality minimum standards for waters in the states in accordance with the Federal Clean Water Act. The Connecticut River and its tributaries are classified as Inland Water Class B. The Federal Clean Water Act defines Class B water as waters designated as habitat for fish, other aquatic life, and wildlife, including their reproduction, migration, growth and other critical life history functions; for primary and secondary contact recreation; suitable as a source of public water supply, with appropriate treatment and for irrigation and other agricultural uses; and shall have consistently good aesthetic value (DWPC, 2013 and NHDES, 2012). The water quality standards for Class B waters, as they apply to the parameters examined in this report, are listed in Table 5.2-1. All water quality parameters measured in the tributaries during the study met the Massachusetts and New Hampshire water quality standards for Class B waters for warm water fishes.

Table 5.2-1 Federal Clean Water Act Water Quality Standards for Class B Waters

Parameter	Standard
Temperature	Temperature shall not exceed 83 °F (28.3 °C) based on the mean of the daily maximum temperature over a seven day period. The rise in temperature due to discharge shall not exceed 5 °F (2.8 °C) in rivers and streams designated as warm water fisheries.
pH	Between 6.5 and 8.3.
Dissolved Oxygen	Shall not be lower than 5.0 mg/l.
Turbidity	Shall be free from turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class.

Maximum water temperatures measured during the study did not exceed the maximum standard for Class B water quality of 28.3 °C (Table 5.2-2). The highest water temperatures were observed during the summer survey period with a maximum of 24.27°C measured within the Connecticut River near Pine Meadow Brook. Water temperatures were consistently lower and DO concentrations were consistently higher in tributaries when compared to measurements taken in the Connecticut River near the confluence. However, both the Connecticut River and tributaries exhibited levels suitable for fishes and were above the 5.0 mg/l Class B minimum (Table 5.2-3).

In all cases, pH was within the Class B standard within the Connecticut River, but several values outside of the water quality standard for pH were measured in the tributaries (Table 5.2-4). Pauchaug Brook exhibited low pH (acidic) during the spring and summer survey period. Millers Brook, Bennett Brook and Dry Brook (all are tributaries to the impoundment) exhibited high pH (basic) in the fall. However, these impaired pH values were measured within the tributaries upstream of the Project influence and were not associated with Project operation.

In the spring, turbidity was evaluated using a secchi disk with the measurement collected in the immediate vicinity of the tributary confluences. Springtime water clarity ranged from a low of 4 ft near Pauchaug Brook to a high of 9.5 ft near the Deerfield River (Table 5.2-5). Turbidity measured in NTU with a handheld meter during the summer and fall survey periods was generally low in both the Connecticut River and in tributaries. Several elevated values were recorded, but these were generally associated with discrete localized impacts such as boat wakes or by disturbances created by the survey team, despite their best efforts to minimize resuspension of fine sediments.

Table 5.2-2. Summary of Water Temperature (°C) Measurements Taken at 19 Tributaries in 2014

Tributary Name	Water Temperature (°C)							
	Spring		Summer			Fall		
	Conf.	Main.	Conf.	Main.	Up.	Conf.	Main.	Up.
Ashuela Brook	15.79	18.43	18.28	24.22	17.90	13.10	17.50	12.90
Ashuelot River	15.34	14.50	20.88	22.80	N/A	10.08	15.46	10.05
Bennett Brook	16.83	18.19	19.02	24.20	19.00	11.10	14.90	11.10
Bottom Brook	14.08	18.17	14.81	22.90	14.64	9.40	14.70	9.40
Deerfield River	19.29	20.11	21.69	22.69	21.69	13.70	16.50	13.70
Dry Brook	14.96	18.55	16.50	23.32	16.50	13.69	15.90	12.77
Fall River	14.47	19.81	18.78	23.70	18.65	13.90	16.20	13.60
Fourmile Brook	12.49	18.52	17.87	24.20	17.33	13.40	17.00	12.60
Gunn Brook	18.43	20.45	21.58	22.97	19.72	16.00	16.50	15.90
Mallory Brook	15.31	18.47	17.15	23.53	16.61	13.80	15.90	9.70
Merriam Brook	13.25	18.19	15.77	24.21	15.69	11.25	14.80	11.25
Mill Brook	12.57	14.73	17.65	23.34	17.36	8.50	14.70	8.50
Millers Brook	16.59	18.56	16.60	24.15	16.43	9.20	15.30	9.20
Millers River	16.24	14.83	22.77	23.58	22.70	13.80	16.00	13.80
Newton Brook	12.81	14.64	18.48	22.82	18.49	7.60	14.80	8.14
Otter Run	13.31	18.33	21.79	24.15	16.88	14.60	16.90	14.60
Pauchaug Brook	14.81	18.06	16.37	22.97	16.3	8.63	15.20	8.64
Pine Meadow Brook	13.62	18.60	15.54	24.27	15.35	15.60	17.00	13.20
Sawmill River	17.07	20.49	19.00	22.77	18.95	N/A	16.30	14.50

Notes:

Conf.: *Within the confluence*

Main.: *Within the Connecticut River immediately upstream of the confluence area*

Up.: *Upstream of the confluence in the tributary*

N/A: *Measurement not obtained*

Table 5.2-3. Summary of Dissolved Oxygen (mg/l) Measurements Taken at 19 Tributaries in 2014

Tributary Name	Dissolved Oxygen (mg/l)							
	Spring		Summer			Fall		
	Conf.	Main.	Conf.	Main.	Conf.	Conf.	Conf.	Up.
Ashuela Brook	9.59	9.19	8.75	8.32	10.00	10.60	10.00	10.60
Ashuelot River	10.08	10.70	9.48	8.90	N/A	12.45	10.26	12.00
Bennett Brook	8.45	9.21	8.01	8.29	8.98	9.80	8.90	10.50
Bottom Brook	9.95	9.63	10.00	8.35	10.23	11.10	9.80	11.50
Deerfield River	9.22	9.28	8.75	8.55	9.54	10.70	9.50	10.90
Dry Brook	10.24	9.10	9.98	8.17	9.81	11.40	9.90	11.30
Fall River	9.92	9.03	9.98	8.24	10.20	11.40	10.30	11.10
Fourmile Brook	10.40	9.10	9.24	8.54	9.44	10.50	9.80	10.40
Gunn Brook	9.33	9.04	8.79	8.33	9.29	9.50	9.60	9.70
Mallory Brook	9.34	6.58	9.04	8.41	9.23	10.40	9.30	9.90
Merriam Brook	10.53	9.16	10.06	8.38	10.14	14.30	9.60	14.30
Mill Brook	10.68	10.47	9.01	8.40	9.71	12.10	9.80	13.00
Millers Brook	9.47	9.43	9.46	8.39	9.72	11.10	10.00	11.6
Millers River	9.73	10.28	9.13	8.25	9.10	10.50	9.10	10.8
Newton Brook	10.46	10.28	10.06	8.70	9.70	12.70	9.20	13.00
Otter Run	9.74	9.18	8.74	8.13	9.41	10.27	10.30	10.30
Pauchaug Brook	9.35	9.59	10.30	8.20	10.33	11.70	9.50	12.10
Pine Meadow Brook	10.08	9.02	8.93	8.64	9.92	10.10	9.80	10.60
Sawmill River	9.73	9.04	9.41	8.48	9.40	N/A	9.60	10.20

Notes:

Conf.: *Within the confluence*

Main.: *Within the Connecticut River immediately upstream of the confluence area*

Up.: *Upstream of the confluence in the tributary*

N/A: *Measurement not obtained*

Table 5.2-4. Summary of pH Measurements Taken at 19 Tributaries in 2014

Tributary Name	pH							
	Spring		Summer			Fall		
	Conf.	Main.	Conf.	Main.	Up.	Conf.	Main.	Up.
Ashuela Brook	7.31	7.17	7.06	7.37	7.44	7.70	8.10	7.50
Ashuelot River	6.99	7.18	7.03	7.26	N/A	6.98	7.30	7.20
Bennett Brook	6.81	7.10	6.77	7.44	6.81	8.40	8.25	7.90
Bottom Brook	7.34	7.23	7.23	7.41	7.15	7.35	7.16	7.45
Deerfield River	7.15	7.27	7.21	7.29	7.19	6.70	6.50	8.30
Dry Brook	7.28	7.14	7.37	7.35	7.31	8.70	7.70	8.50
Fall River	7.50	7.73	8.33	8.02	8.33	8.10	7.85	8.16
Fourmile Brook	6.55	7.11	6.78	7.43	6.67	8.00	8.00	7.30
Gunn Brook	7.49	7.23	7.35	7.28	7.44	7.20	7.20	7.50
Mallory Brook	7.25	7.19	7.34	7.38	7.22	7.70	7.60	7.50
Merriam Brook	7.08	7.22	7.38	7.47	7.55	7.76	7.59	7.60
Mill Brook	6.84	7.12	7.17	7.41	7.11	7.07	7.16	7.23
Millers Brook	7.08	7.25	7.12	7.39	7.24	7.15	8.40	7.53
Millers River	6.87	7.06	7.41	7.32	7.64	7.36	7.25	7.43
Newton Brook	7.16	7.16	7.44	7.15	7.37	7.30	7.50	7.50
Otter Run	6.88	7.18	7.19	7.51	7.70	7.80	7.40	7.20
Pauchaug Brook	5.58	7.21	5.86	7.35	6.01	7.22	7.40	7.33
Pine Meadow Brook	7.04	7.22	6.66	7.29	6.76	7.80	8.00	7.20
Sawmill River	6.92	7.26	6.79	7.20	6.81	N/A	7.60	7.90

Notes:

Conf.: *Within the confluence*

Main.: *Within the Connecticut River immediately upstream of the confluence area*

Up.: *Upstream of the confluence in the tributary*

N/A: *Measurement not obtained*

Table 5.2-5. Summary of Water Clarity Measurements Taken at 19 Tributaries in 2014

Tributary Name	Secchi Depth (ft)	Turbidity (NTU)					
	Spring	Summer			Fall		
	Conf.	Conf.	Main.	Up.	Conf.	Main.	Up.
Ashuela Brook	6.0	24.10	1.02	3.56	1.33	0.74	1.82
Ashuelot River	6.75	N/A	N/A	N/A	0.82	1.09	0.92
Bennett Brook	6.0	12.80	0.38	5.15	4.54	2.35	2.79
Bottom Brook	5.0	1.00	0.81	1.12	1.39	0.83	2.13
Deerfield River	9.5	0.37	0.71	0.57	0.60	0.80	0.70
Dry Brook	6.5	11.40	2.05	8.34	N/A	N/A	N/A
Fall River	5.0	0.00	0.69	0.25	2.25	1.80	0.40
Fourmile Brook	7.0	0.05	1.75	0.00	0.43	N/A	0.69
Gunn Brook	7.0	3.27	0.46	2.20	2.04	0.28	6.49
Mallory Brook	5.0	1.11	0.53	0.81	1.53	0.83	0.39
Merriam Brook	6.0	0.55	N/A	0.54	1.19	0.69	0.87
Mill Brook	5.0	1.69	0.70	0.81	0.77	0.83	0.65
Millers Brook	5.0	3.66	0.59	3.32	2.07	0.80	1.36
Millers River	5.5	0.77	N/A	0.96	0.75	0.50	0.89
Newton Brook	5.0	1.94	2.73	1.91	1.43	0.93	1.93
Otter Run	6.0	19.60	0.93	11.80	3.42	0.92	3.01
Pauchaug Brook	4.0	2.45	0.85	2.20	2.28	0.87	3.51
Pine Meadow Brook	6.0	19.80	1.27	16.00	1.64	0.66	0.72
Sawmill River	7.5	0.68	0.28	1.10	N/A	0.30	1.90

Notes:

Conf.: *Within the confluence*

Main.: *Within the Connecticut River immediately upstream of the confluence area*

Up.: *Upstream of the confluence in the tributary*

N/A: *Measurement not obtained*

5.3 Tributary Thalweg Surveys

Each tributary was surveyed during the spring, summer and fall. WSEL data at the time of each seasonal survey are presented in Table 5.1-1. A description of each tributaries is provided below including the barriers identified, seasonal longitudinal thalweg profiles, and other supporting information. Observations and data collected on August 12, 2014 are representative of an abnormally low impoundment level (178.3 ft) coupled with a low Vernon discharge of 1,536 cfs, a condition intentionally created in support of TransCanada's Instream Flow Study. There is no backwater habitat in the study area.

Features that may restrict fish movements into tributary habitat were identified in three tributaries: Merriam Brook, Pine Meadow Brook, and Fourmile Brook, all of which drain into the Turners Falls Impoundment. No barriers or restrictions to access were observed at the other 16 tributaries. See Appendix A for photos illustrating the seasonal condition of the mouth of the confluence.

5.3.1 Turners Falls Impoundment

5.3.1.1 Ashuelot River

The Ashuelot River is one of three major tributaries that flow into the Connecticut River within the Project area. It is located in New Hampshire and was the most upriver tributary surveyed. The Ashuelot River is hydraulically controlled at a dam located approximately 1.6 miles upstream of its confluence with the impoundment. The upstream extent of the impoundment backwater effect on the Ashuelot River confluence was documented during each seasonal survey (Appendix B). In the spring a combination of high impoundment WSEL and high tributary flows resulted in the largest zone of influence in the confluence area. The springtime confluence extended approximately 2,500 feet upstream and ended at a riffle where the tributary exhibited a noticeable change in elevation. The substrates at the upstream extent of the confluence were courser, dominated by cobble and gravel. The lower confluence was backwatered due to influence from the impoundment, and exhibited finer substrates. The confluence extent during summer and fall conditions was shorter, extending approximately 550 ft and 1,000 ft upstream, respectively. Water depths were generally 1 foot or more in the confluence; no barriers to fish movement were documented (Figure 5.3.1.1-1). See Appendix A for photos illustrating the seasonal condition of the mouth of the confluence.

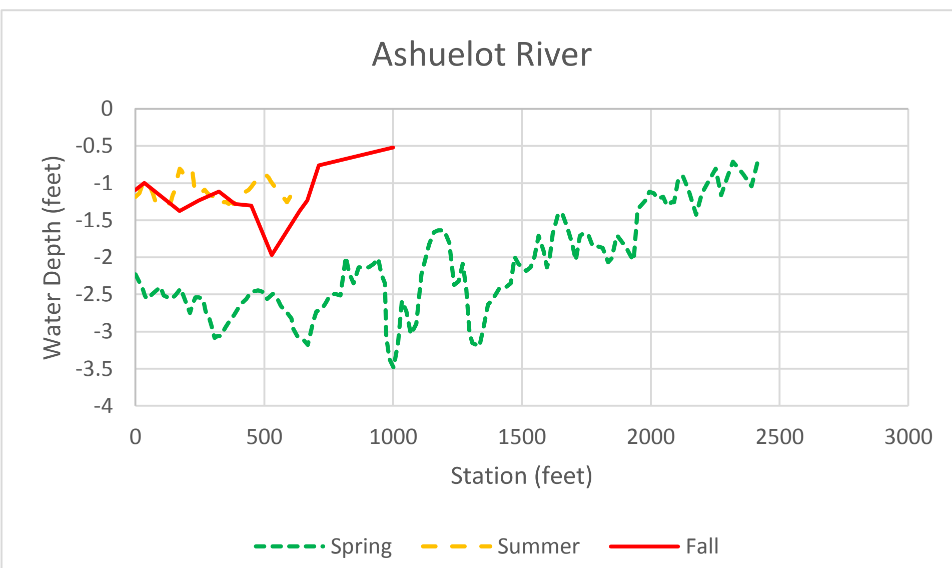


Figure 5.3.1.1-1. Longitudinal thalweg profiles Ashuelot River during spring, summer, and fall conditions

5.3.1.2 Newton Brook

Newton Brook is a small tributary (drainage area = 3.66 mi^2) located on the west bank of the Connecticut River near the Massachusetts - New Hampshire state line (Figure 3.0-1). Substrate in Newton Brook consists of mud transitioning to sand in the upper reaches. The upstream end of the confluence is delineated by a change in elevation and flow characteristics as low gradient conditions give rise to increased gradient further upstream in the tributary. The upstream extent of the impoundment backwater effect on Newton Brook was documented during each seasonal survey (Appendix B). The maximum zone of influence was recorded during the spring, where the upstream extent was measured approximately 250 ft from the confluence with the Connecticut River. The fall survey recorded similar conditions with the zone of influence reaching approximately 225 ft upstream. Summer impoundment influences were less extensive, with an upstream hydraulic control measured near the mouth of Newton Brook. Depth profiles surveyed in the confluence revealed no barriers to fish movement (Figure 5.3.1.2-1). Appendix A contains photos that illustrate the seasonal conditions at the Newton Brook confluence.

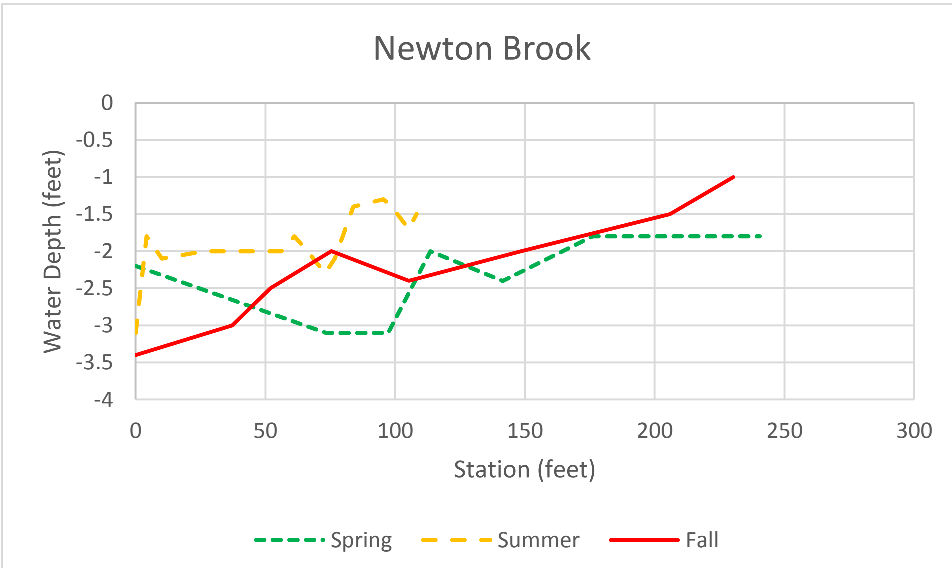


Figure 5.3.1.2-1. Longitudinal thalweg profiles Newton Brook during spring, summer, and fall conditions

5.3.1.3 Pauchaug Brook

Pauchaug Brook is located on the east bank of the Connecticut River south of the state line (Figure 3.0-1). Pauchaug Brook is a low gradient sinuous stream associated with silver maple floodplain habitat, and is influenced by the impoundment WSEL. Upstream hydraulics are influenced by Louisiana Brook and an abandoned stone dam at Route 63. Substrate throughout the stream channel is characteristically fine sediments consisting of silt and mud, transitioning to muddy-sand to coarse sands at the upper survey extent. Seasonal fluctuation in the size and extent of the confluence were documented during 2014 field surveys. The largest zone of backwater influence was measured during the spring survey where the upstream extent was approximately 1,500 ft upstream from the confluence with the Connecticut River, (Appendix B). The spring measurements were influenced by high tributary flows. The backwater extent during the summer and fall surveys was shorter, extending approximately 475 ft and 1,200 ft upstream, respectively. Depth profiles surveyed in the confluence revealed no barriers to fish movement (Figure 5.3.1.3-1). Appendix A contains photos that illustrate the seasonal conditions at the Pauchaug Brook confluence.

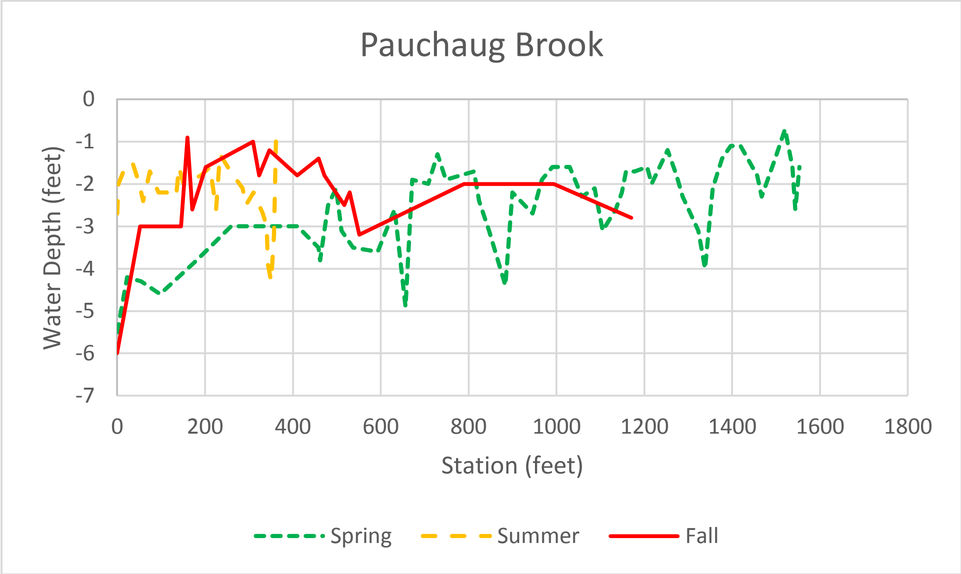


Figure 5.3.1.3-1. Longitudinal thalweg profiles Pauchaug Brook during spring, summer, and fall conditions

5.3.1.4 Bottom Brook

Bottom Brook is a small (drainage area < 1 mi^2), narrow tributary located on the west bank of the Connecticut River (Figure 3.0-1). Within the zone of influence, Bottom Brook is characteristically a shallow, low gradient tributary with a soft bottom comprised of silts and fine sand. During the spring and fall surveys, upstream influence extended approximately 150 ft upstream from the mouth. The summer survey recorded impoundment backwater influence to approximately 50 ft upstream of the confluence with the Connecticut River (Figure 5.3.1.4-1). Appendix A contains photos that depict the seasonal conditions at the Bottom Brook confluence.

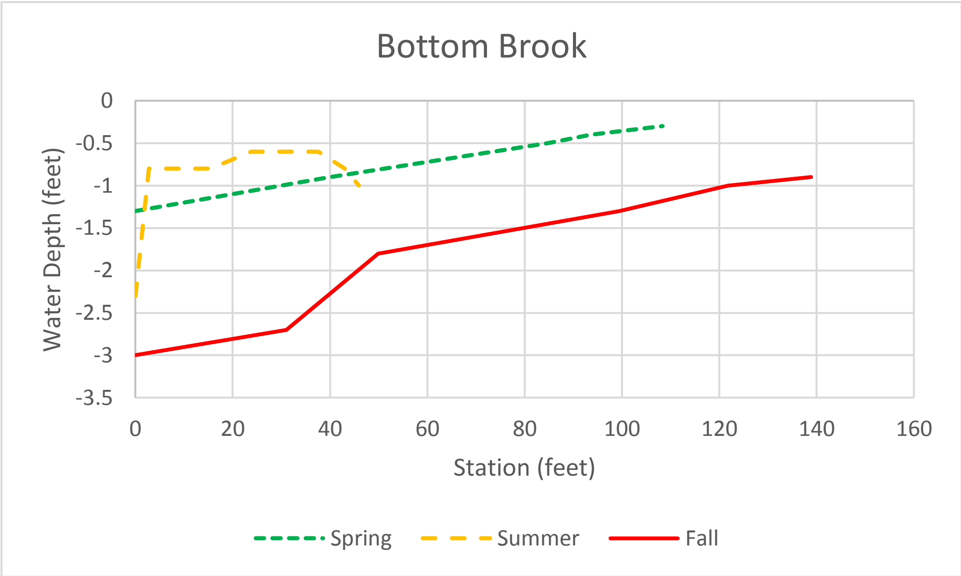


Figure 5.3.1.4-1. Longitudinal thalweg profiles Bottom Brook during spring, summer, and fall conditions

5.3.1.5 Mill Brook

Mill Brook flows into the Connecticut River from the east (Figure 3.0-1). The upstream end of the confluence was delineated by a change in flow characteristics as low gradient conditions gave rise to increased velocities and riffle habitat marked by a change in elevation and substrate, as sands and mud in the lower confluence transitioned to gravel and sands. The maximum zone of backwater influence was recorded during the spring, where the upstream extent was measured approximately 700 ft upstream from the confluence with the Connecticut River (Appendix B). The fall survey recorded similar conditions with the zone of influence reaching approximately 700 ft upstream. Summer influence was not as pronounced, with an upstream extent of approximately 600 ft. Depth profiles surveyed in the confluence revealed no barriers to fish movement (Figure 5.3.1.5-1). Appendix A contains photos illustrating the seasonal conditions at the Mill Brook confluence.

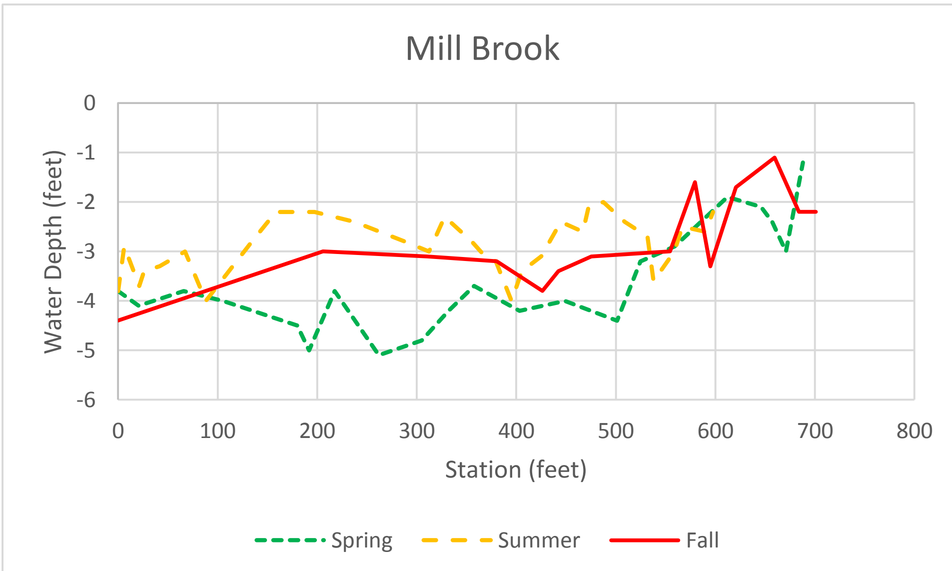


Figure 5.3.1.5-1. Longitudinal thalweg profiles Mill Brook during spring, summer, and fall conditions

5.3.1.6 Mallory Brook

Mallory Brook is a small tributary (drainage area < 1 mi^2) that flows into the Connecticut River from the west and has a small confluence area. The lower confluence is low gradient but gains elevation quickly upstream. Depths in the tributary confluence were shallow in the spring despite the impoundment level being at the highest level when compared to the summer and fall surveys (Figure 5.3.1.6-1). High flows in the spring freshet laid down substantial sediments within the tributary confluence elevating the bed. Subsequent surveys in the summer and fall revealed that the tributary had eroded much of the fine sediments and altered the elevation of the stream bed. Figure 5.3.1.6-2 illustrates this observation: in the photo, landmarks present during all three seasonal surveys reveal the change in the bed elevation. The elevated bed resulted in a reduced influence by the impoundment WSEL. Substrates in Mallory Brook are composed of silt, mud and sand. Appendix A contains photos illustrating the seasonal conditions at the mouth of Mallory Brook.

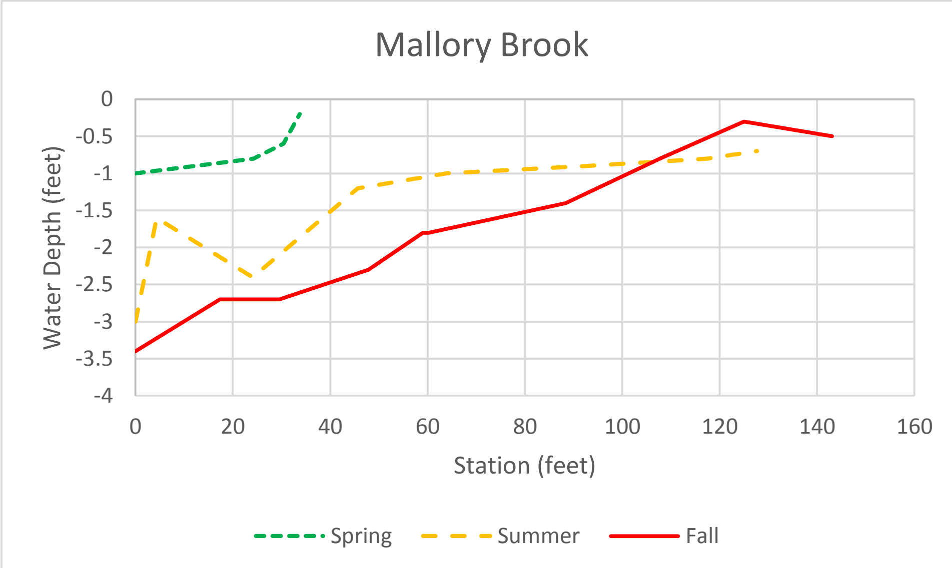


Figure 5.3.1.6-1. Longitudinal thalweg profiles Mallory Brook during spring, summer, and fall conditions

Figure 5.3.1.6-2. Seasonal photos of a location upstream of the of Mallory Brook confluence, but still within the zone of influence under spring freshet flows and impoundment levels

Note the seasonal change in bed elevation (spring, summer and fall from left to right).

5.3.1.7 Millers Brook

Millers Brook flows into the Connecticut River from the east, south of the Route 10 Bridge (Figure 3.0-1). Millers Brook has a shallow meandering thalweg with substrates comprised of fine sediments. The backwater extent of the confluence was greatest in the spring and fall extending upstream approximately 850 and 1,100 ft, respectively. The summertime extent of the confluence was shorter, extending approximately 95 ft upstream and was largely contained to the mouth of Millers Brook. Generally, seasonal changes in the volume of the wetted perimeter were minimal. Depth profiles surveyed in the confluence revealed no barriers to fish movement (Figure 5.3.1.7-1). Appendix A contains photos illustrate the seasonal conditions at the Millers Brook confluence.

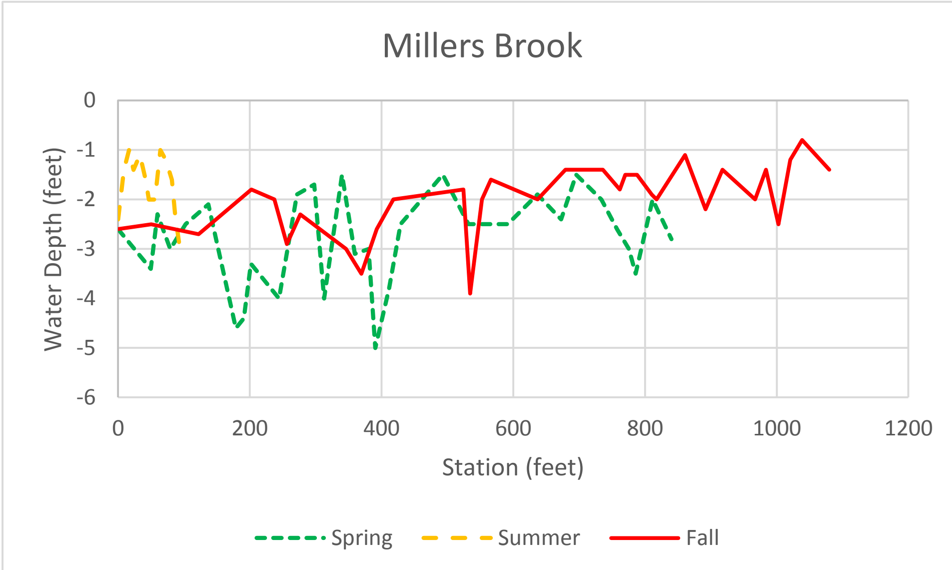


Figure 5.3.1.7-1. Longitudinal thalweg profiles Millers Brook during spring, summer, and fall conditions

5.3.1.8 Bennett Brook

Bennett Brook flows into the Connecticut River from the northwest (Figure 3.0-1). Seasonal changes in the backwater influence were documented during the 2014 surveys. No backwatering was observed during summer, when the WSEL of the impoundment was 179.5 ft. At the fall WSEL of 180.49 ft, the confluence extended approximately 300 ft upstream and at the spring WSEL of 181.46 ft, the confluence extended 500 ft upstream (Figure 5.3.1.8-1). In spring, the upper confluence was defined by a change in sediment from silt/sand to cobble. The banks of the lower confluence area were silted and large woody debris was observed within the channel of the confluence area during the spring and fall surveys; evidence of beaver activity was also noted. Although the width of the lower confluence changed seasonally, from a maximum of 20 ft in the spring to less than 5 ft in fall, depth profiles revealed no barriers to fish movement into the brook and debris did not appear to restrict fish movement. Appendix A contains photos illustrating the seasonal conditions of the mouth of the confluence.

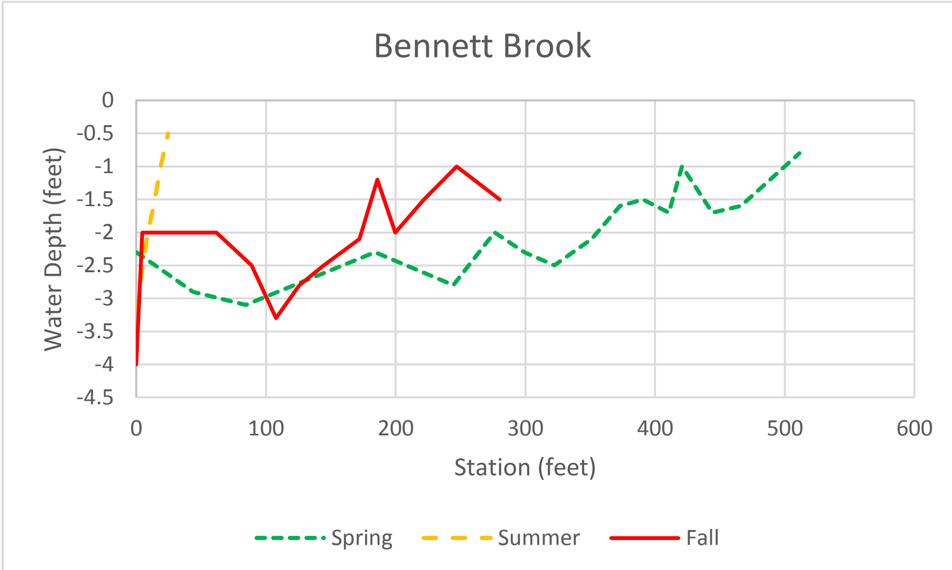


Figure 5.3.1.8-1. Longitudinal thalweg profiles Bennett Brook during spring, summer, and fall conditions

5.3.1.9 Merriam Brook

Merriam Brook is a small (drainage area < 1 mi^2), steep gradient tributary to the Turners Falls Impoundment (Figure 3.0-1). It contains a limited confluence area with a seasonal upstream extent ranging from as little as 6 ft as documented in the summer survey to approximately 25 ft in the spring. Seasonal variation in wetted aquatic habitat was minimal at Merriam Brook.

Depth profiles within the confluence area vary seasonally (Figure 5.3.1.9-1 and Appendix B) resulting from a combination of factors including impoundment WSEL and tributary flow. The cobble and small boulder substrate characteristic of higher gradient streams result in a pool and weir type flow under low flow conditions and such barriers are a common characteristic of Merriam Brook and extend well upstream of Project influence as is evident in Figure 5.3.1.9-2.

In the lower confluence, where the bed elevation of the tributary begins to transition into the impoundment, WSEL of the impoundment is the major driving factor in depth of the confluence; however backwatering of tributary flows also affects depths in the lower confluence. The effect of tributary backwater is largely attributable to the magnitude of flow such that the greater the tributary flow the greater effect backwatering has on confluence depth. In the upper reach of the confluence, where effects of impoundment WSEL fluctuation and backwatering are less pronounced, the tributary flow itself is the dominant factor affecting depth.

Connectivity to the impoundment was not affected in the spring when tributary flow was seasonally high (Figure 5.3.1.9-3) but was limited during low-flow tributary conditions during the summer and fall (Figures 5.3.1.9-4 and 5.3.1.9-5). Water depths collected along a transect (Figure 5.3.1.9-6) within the upper extent of the tributary confluence were less than 0.25 feet with water velocities ranging from 0.33 to 1.25 fps in the fall (Table 5.3.1.9-1). The tributary water velocities during the fall low flow season, when these data were collected, are not a barrier to most fishes but the shallow depth is likely a barrier. However, these conditions are characteristic of the stream itself and not due to impoundment fluctuation. Impoundment WSEL does affect the depth of the confluence and its extent such that the higher the impoundment level, the deeper the lower confluence and the further backwatering occurs up into the tributary. This effect results in an increase in lentic habitat and a decrease in riverine habitat within the confluence but does not provide better access to the tributary because upstream reaches outside of the Project influence were shallow and generally unpassable to fishes. Therefore, higher impoundment levels result in an increase in impounded habitat, a decrease in riverine habitat and provide no net gain in access to habitats within Merriam Brook.

Table 5.3.1.9-1. Stream Cross Section Characteristics of Merriam Brook in Fall

Profile Characteristic	Merriam Brook
Dominant substrate	cobble/gravel
Avg. water depth (ft)	0.15
Maximum water depth (ft)	0.25
Avg. water velocity(fps)	0.73
Max. water velocity (fps)	1.25

Substrates at the confluence were composed primarily of cobble, gravel and fines including sand and silt. The coarse substrates were overlain and embedded in fine sediments presumably deposited during the spring freshet when high flows in the river move large volumes of sediment. This conclusion was supported by field observation of a reduction in fine sediments in the confluence area as the seasonal surveys progressed and is evident when comparing Figures 5.3.1.9-4 through 5.3.1.9-6.

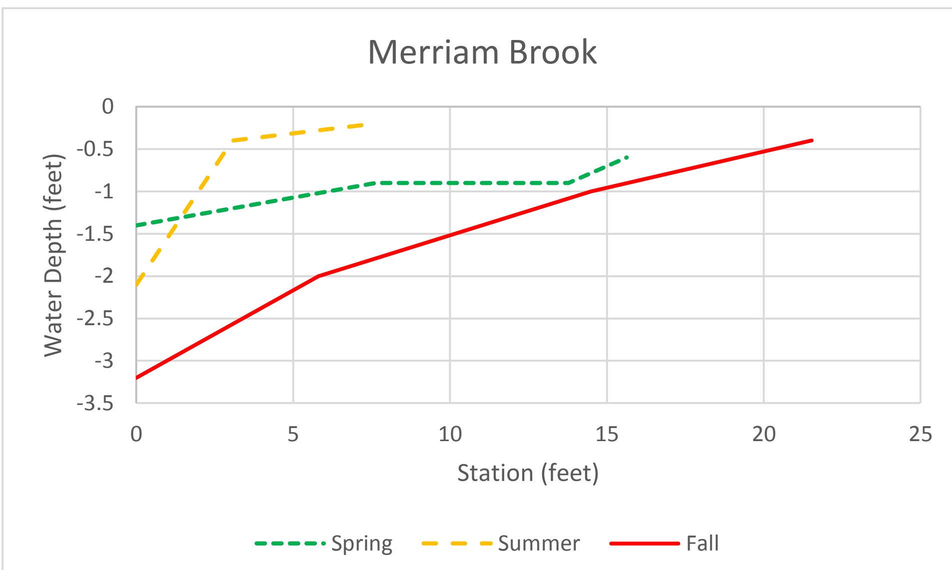


Figure 5.3.1.9-1. Longitudinal thalweg profiles of Merriam Brook during spring, summer, and fall conditions

Figure 5.3.1.9-2. High-gradient reach of Merriam Brook located immediately upstream of the confluence area.

The photo was taken during the summer survey period on August 12, 2014.

Figure 5.3.1.9-3. Conditions at Merriam Brook Confluence during the spring survey period

The photo was taken on June 5, 2014. Note the fine substrates overlaying the cobble; this is particularly evident on the banks of the tributary.

Figure 5.3.1.9-4. Conditions at Merriam Brook Confluence during the summer survey period

The photo was taken on August 12, 2014.

Figure 5.3.1.9-5. Conditions at Merriam Brook Confluence during the fall survey period

Photo was taken on October 14, 2014. Note the cross-section transect at a potential barrier and the lack of fine substrates along the tributary banks when compared to the spring survey.

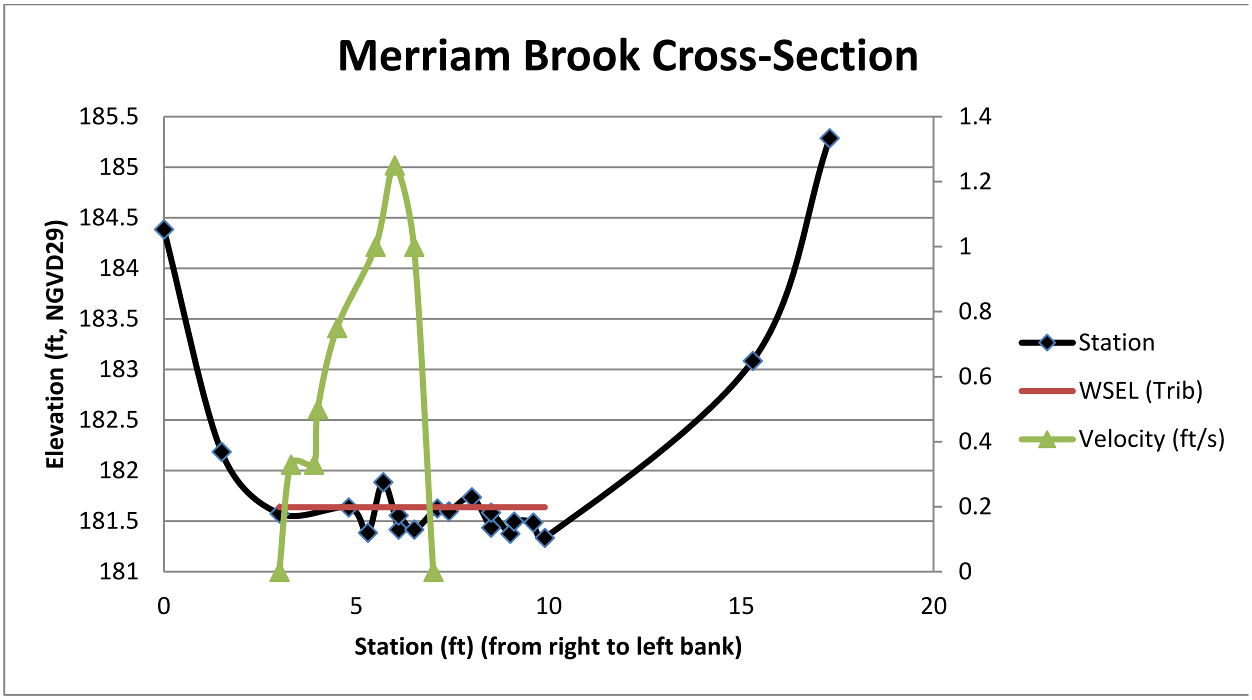


Figure 5.3.1.9-6. Cross-section bed profile and water velocities as measured at a potential barrier
Data collected on October 14, 2014.

5.3.1.10 Otter Run

Otter Run is a very small tributary (drainage area < 1 mi^2) that flows into the Connecticut River from the north (Figure 3.0-1) and meanders through low wetlands in a gently sloped floodplain area. Seasonal changes in the impoundment backwater effect were documented during the 2014 surveys, such that at higher impoundment elevations and river flows typical of spring, much of the floodplain becomes inundated, although a well-defined thalweg remains. The zone of influence was greatest in spring, when the confluence extended nearly 400 ft upstream (impoundment WSEL 181.37 ft), and no backwatering effects were observed during the summer survey when the impoundment WSEL was 178.78 ft (Appendix B). Although the impoundment WSEL was similar during the fall survey, at 181.37 ft, the confluence was 100 ft shorter than the spring survey. The confluence area appeared to be susceptible to change due to the presence of a large amount of deep, fine substrate, into which a shallow thalweg was formed, although depth appeared sufficient to allow fish movement (Figure 5.3.1.10-1). In addition, no barriers were observed during spring or fall surveys. Appendix A contains photos illustrating the seasonal conditions of the mouth of the confluence.

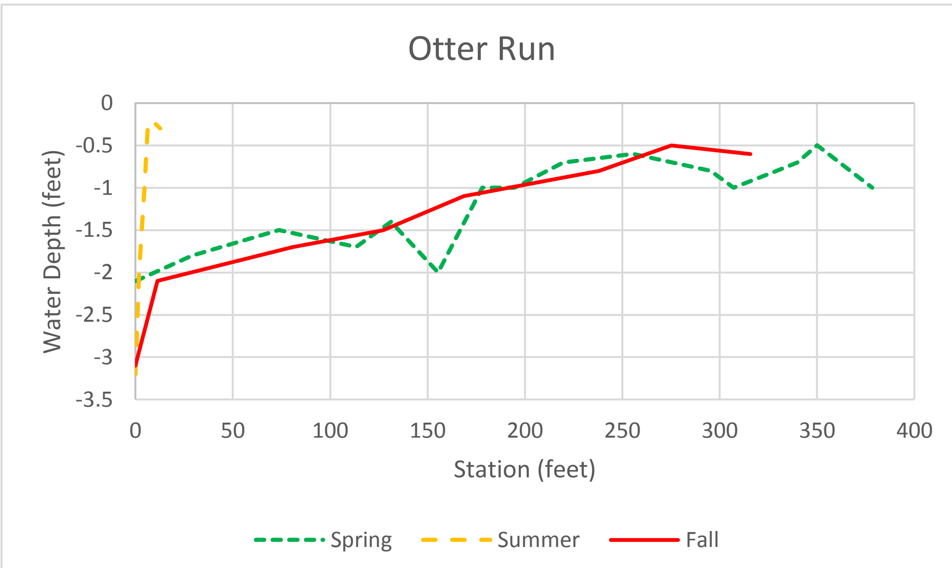


Figure 5.3.1.10-1. Longitudinal thalweg profiles Otter Run during spring, summer, and fall conditions

5.3.1.11 Ashuela Brook

Ashuela Brook is a small tributary (drainage area = 1.1 mi^2) that flows into the Connecticut River from the north (Figure 3.0-1). Seasonal changes in the impoundment backwater effect were documented during the 2014 surveys. The impoundment WSEL was slightly higher (0.3 ft) during the fall survey as compared to spring and the upstream extent of the confluence was similar at approximately 300 ft (Appendix B). Substrate in the thalweg was comprised of mud and silt. No backwater effects were observed during the summer survey, when the impoundment WSEL was 178.72 ft. The confluence area appeared to be susceptible to change due to the presence of a large amount of deep, fine substrate, into which a shallow thalweg was formed, although depth appeared sufficient to allow fish movement (Figure 5.3.1.11-1). In addition, no barriers were observed during spring or fall surveys. Appendix A contains photos illustrating the seasonal conditions of the mouth of the confluence.

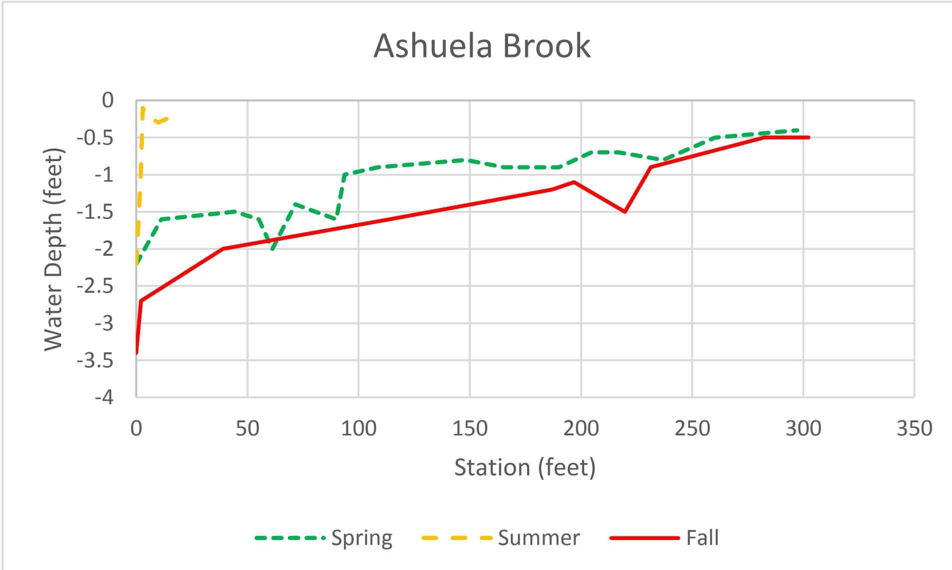


Figure 5.3.1.11-1. Longitudinal thalweg profiles Ashuela Brook during spring, summer, and fall conditions

5.3.1.12 Dry Brook

Dry Brook (drainage area = 9.4 mi^2) flows into the Connecticut River from the northwest (Figure 3.0-1). The zone of influence appeared greatest during the fall survey, when the impoundment WSEL was 181.96 ft and the confluence extended approximately 300 ft upstream (Appendix B). The substrate in the lower confluence area was predominantly silt, with cobble and boulders embedded. The confluence extent was shorter in the spring and summer, extending approximately 210 and 25 ft upstream, respectively, due to the lower impoundment levels. Depth profiles indicate no barriers to movement within the confluence area (Figure 5.3.1.12-1); however, a rapid change in elevation, approximately 150 ft upstream of the spring confluence area, causes the formation of falls and presents a natural velocity barrier to fish movement further up in the brook (Figure 5.3.1.12-2). Appendix A contains photos illustrating the seasonal conditions of the mouth of the confluence.

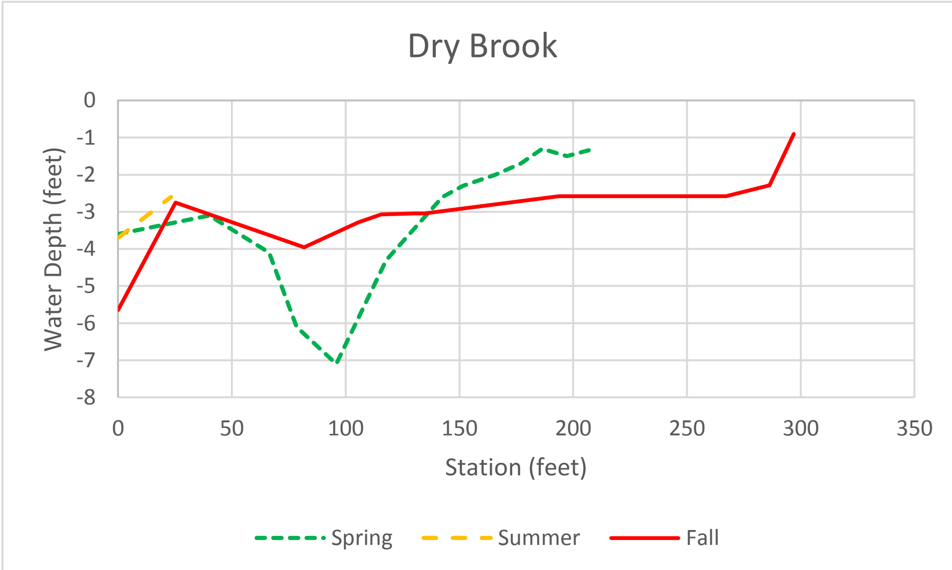


Figure 5.3.1.12-1. Longitudinal thalweg profiles Dry Brook during spring, summer, and fall conditions

Figure 5.3.1.12-2. A potential barrier to fish movement in Dry Brook located approximately 150ft upstream of the Spring confluence.

5.3.1.13 Pine Meadow Brook

Pine Meadow Brook is a small tributary (drainage area = 1.31 mi^2) that discharges into the Impoundment approximately 0.6 mile upriver of the Northfield tailrace (Figure 3.0-1). The measured thalweg depth profiles are shown in Figure 5.3.1.13-1. Its confluence area is generally low gradient and thus subject to influence from the Impoundment WSEL, which affects the area of wetted habitat within the confluence

(Appendix B and Figure 5.3.1.13-2). In the lower confluence, where the bed elevation of the tributary transitions into the Impoundment, the gradient becomes steeper.

No barriers were observed at the mouth of the confluence during any of the seasonal surveys; however, the flow in the lower confluence becomes channelized and shallow during low pond and low tributary flow periods (Figure 5.3.1.13-3). A woody debris jam was present approximately 183 ft upstream from the impoundment that restricts access to the rest of the tributary under low-flow conditions (Figure 5.3.1.13-4). The top of the debris jam is at an elevation of 180 ft (Figure 5.3.1.13-5). Figure 5.3.1.13-6 is a representative photo of the confluence at higher impoundment elevation (182.13 ft) at which elevation the debris jam is not a barrier. Removal of the small debris jam would likely facilitate fish access to upstream portions of Pine Meadow Brook.

Substrates in Pine Meadow confluence are dominated by sand, silt, and mud. The water depth and velocity varies with tributary flow and impoundment level, but the water depth was 0.70 feet with a maximum water velocity of 1.63 fps at an impoundment level of 179.15 ft at the time of data collection (Table 5.3.1.13-1).

Table 5.3.1.13-1. Stream Characteristics of Pine Meadow Brook in Summer

Profile Characteristic	Pine Meadow Brook
Dominant substrate	silt/mud
Avg. water depth (ft)	0.70
Maximum water depth (ft)	2.00
Avg. water velocity(fps)	0.94
Max. water velocity (fps)	1.63

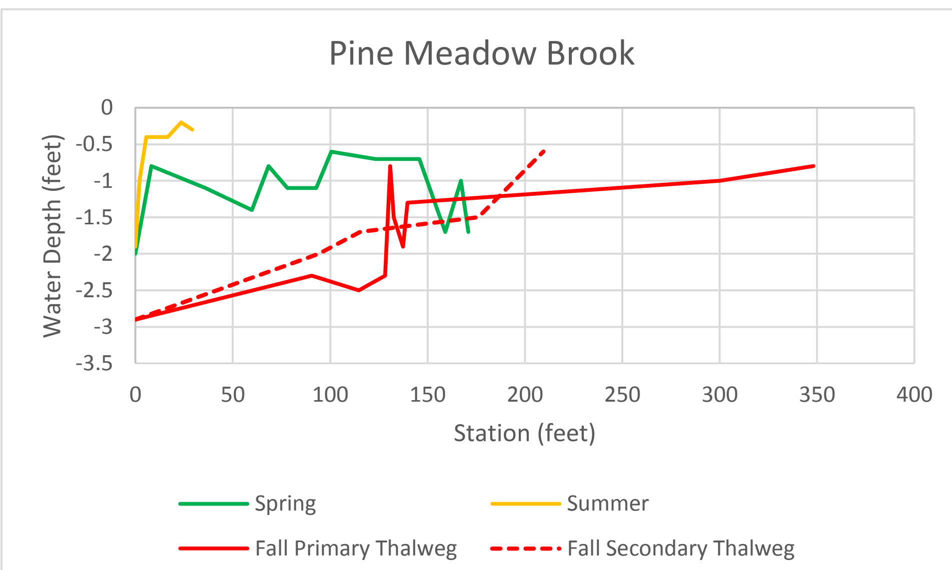


Figure 5.3.1.13-1. Longitudinal thalweg profiles Pine Meadow Brook during spring, summer, and fall conditions

Figure 5.3.1.13-2. Conditions at Pine Meadow Brook Confluence during the spring survey period, impoundment WSEL of 180.53 ft (NGVD29)

The photo was taken on June 6, 2014.

Figure 5.3.1.13-3. Conditions at Pine Meadow Brook Confluence on August 12, 2014

Impoundment WSEL 179.15 ft (NGVD29) as measured downstream at the nearest water level gage.

Figure 5.3.1.13-4. Conditions at Pine Meadow Brook Confluence on August 12, 2014

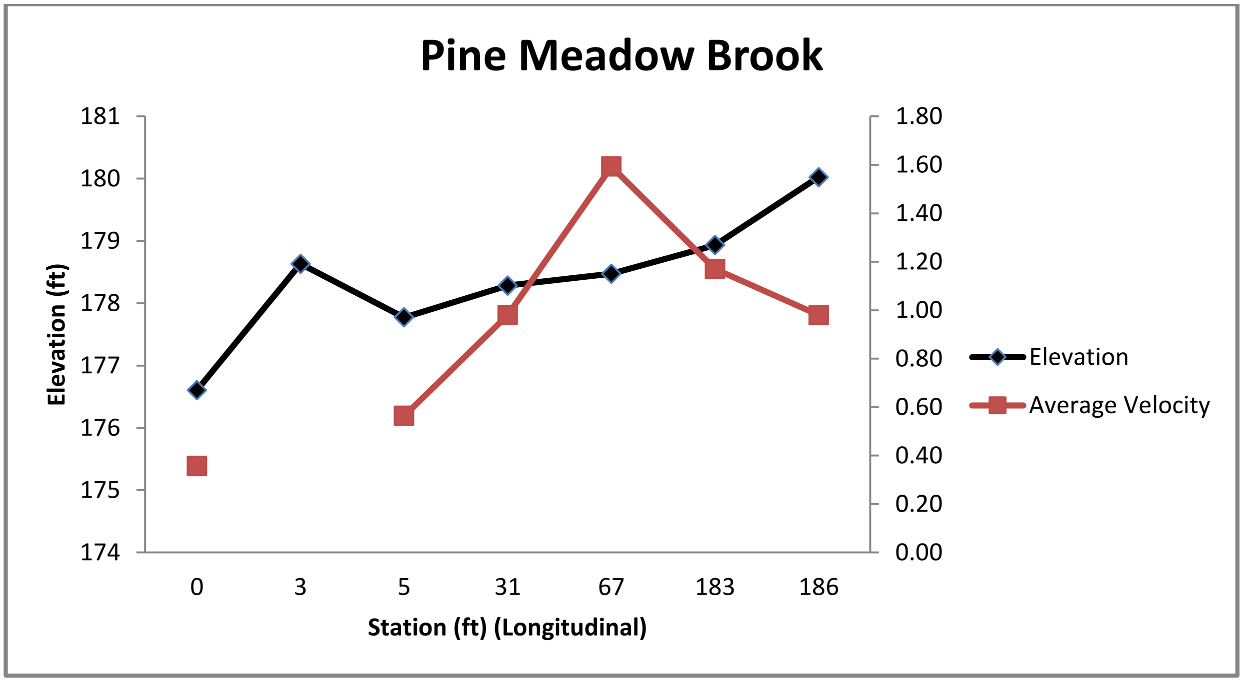


Figure 5.3.1.13-5. The longitudinal bed profile of Pine Meadow Brookon August 12, 2014

Stations 183 and 186 represent the base and top of the woody debris jam, respectively.

Figure 5.3.1.13-6. Conditions at Pine Meadow Brook confluence on October 14, 2014

The impoundment level at the time of the photo was 182.13 ft (NGVD29).

5.3.1.14 Fourmile Brook

Fourmile Brook is a tributary (drainage area = 5.1 mi^2) to the Connecticut River that enters the Impoundment approximately 1,500 ft upstream of the Northfield Mountain tailrace. The tributary confluence has a moderate gradient and is subject to influence by the impoundment WSEL. Unlike most other tributaries surveyed, the Fourmile Brook confluence area is characterized by an alluvial fan that extends approximately 150 ft into the impoundment. Cobble and gravel deposits from the tributary have created a bar that is exposed at lower impoundment levels (Figure 5.3.1.14-1), which reduces the access to tributary habitat during low impoundment WSEL (Figure 5.3.1.14-2 and Appendix B). When the bar is exposed the tributary flows from a pool that bifurcates into shallow thalwegs and discharges into the Impoundment (Figure 5.3.1.14-3). When exposed, the thalweg depth is somewhat dependent on the magnitude of flow from the tributary but the thalweg is not well defined and increased flow would tend to spread out across the cobble bar and not necessarily provide access to the tributary. Figure 5.3.1.14-4 illustrates the contours of the confluence and cobble bar. The confluence is inundated at an impoundment WSEL of 180 ft.

During the low-flow/impoundment conditions in summer (impoundment elevation 178.97 ft) the average water depth along the tributary confluence was 0.64 ft with an average water velocity of 0.72 fps (Table 5.3.1.14-1). Substrates at the Fourmile Brook confluence are composed primarily of cobble-gravel with some fines (e.g., sand and silt) that form the perched cobble bar at the tributary mouth.

Table 5.3.1.14-1. Stream Characteristics of Fourmile Brook in Summer

Profile Characteristic	Fourmile Brook
Dominant substrate	cobble/sand
Avg. water depth (ft)	0.64
Maximum water depth (ft)	2.20
Avg. water velocity(fps)	0.72
Max. water velocity (fps)	1.52

While the restriction of access to the tributary is affected by low impoundment levels, Project operation was not the only factor. An undersized culvert located in the upper confluence (Figure 5.3.1.14-5) acts to concentrate flows during high flow events, creating high water velocities and scouring the stream bed, depositing materials at the mouth of the tributary. These deposits have contributed to shallow depths in the confluence.

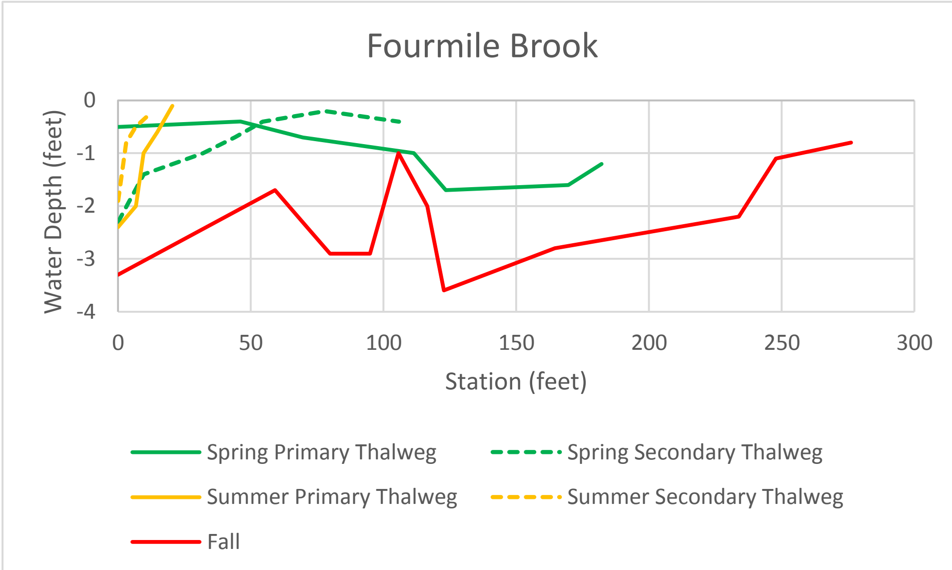


Figure 5.3.1.14-1. Longitudinal thalweg profiles of Fourmile Brook during spring, summer, and fall conditions

Figure 5.3.1.14-2. Condition at Fourmile Brook confluence on August 12, 2014
The impoundment level was 178.97 ft at the time of the photo.

Figure 5.3.1.14-3. Condition at Fourmile Brook confluence on August 12, 2014
The impoundment level was 178.97 ft at the time of the photo.

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

FirstLight GDF SUEZ

N

0 10 20 40 Feet

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

Figure 5.3.1.14-4. Four Mile Brook Confluence 1 ft Contour

Path: W:\gis\studies\3_3_17\maps\figure_5_3_1_14_4.mxd

Figure 5.3.1.14-5. Conditions at Fourmile Brook on October 14, 2014

5.3.1.15 Millers River

The Millers River is one of three major tributaries (drainage area = 389 mi^2) that flow into the Connecticut River within the Project area. The Millers River drains into the Connecticut River from the east, downstream of the French King Bridge (Figure 3.0-1). Surface water fluctuation in the Millers River confluence is affected by a combination of impoundment WSEL and flow from the tributary. The lower confluence contains sand substrate with some cobble and boulder. The upper confluence substrate is comprised primarily of cobble and gravel with some boulders. The upstream end of the confluence is delineated by a change in flow characteristics. As low gradient conditions transition to higher gradient conditions above the influence of Project operation, flow velocities and riffle habitat is increased. During the spring the Impoundment backwatered upstream approximately 1,150 ft. upstream from the confluence with the Connecticut River, to a high gradient riffle in the Millers River. The fall survey recorded similar conditions. Low flow summer conditions resulted in the Impoundment backwatering upstream approximately 800 feet. Depth profiles surveyed in the confluence revealed no barriers to fish movement as water depths were generally greater than 1 foot until the stream gradient increased further upstream (Figure 5.3.1.15-1). Appendix A contains photos illustrating the seasonal conditions at the Millers River confluence.

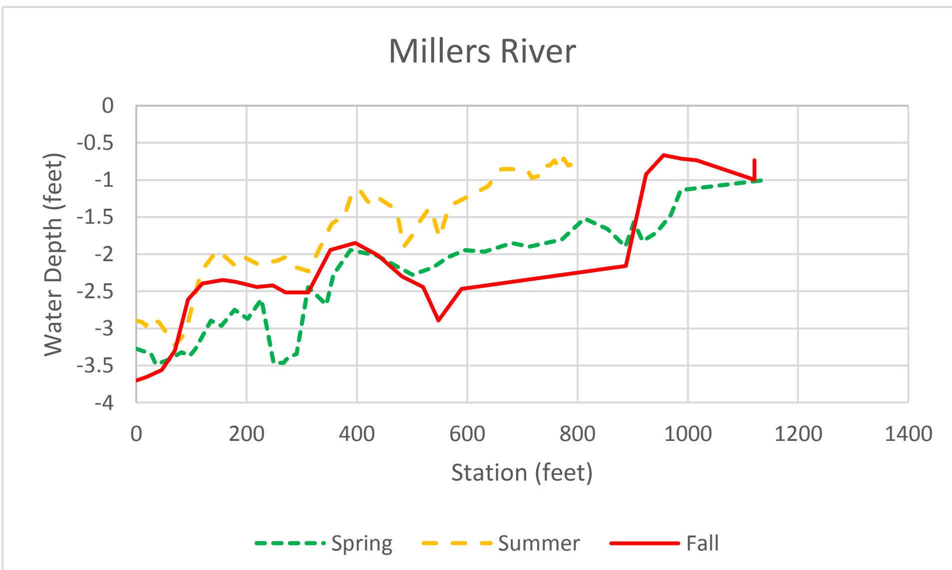


Figure 5.3.1.15-1. Longitudinal thalweg profiles Millers River during spring, summer, and fall conditions

5.3.2 Below Turners Falls Dam

5.3.2.1 Fall River

The Fall River is the first tributary located downstream of the Turners Falls Dam (Figure 3.0-2) and drains into the bypass reach; its drainage area is 34.2 mi^2. As the area below the dam is not affected by fluctuating impoundment levels, WSEL remained relatively stable during seasonal surveys. The surveys were conducted under minimum bypass flow conditions (400 cfs in the spring and 120 cfs in the summer and fall). However, spill events at the dam have a significant effect on WSEL in the bypass reach and the Fall River confluence, and the extent of the confluence is affected by the amount of spill. Seasonal fluctuations in the size and extent of the confluence were documented, such that the zone of influence was greatest in spring, extending approximately 250-300 ft upstream (Appendix B). A gravel bar in the center of the lower confluence area that created a pool between the upstream riffle and the gravel bar was observed during the spring survey. Substrate in the pool was comprised of sand, gravel and cobble. The gravel bar was not exposed during the summer and fall surveys. The confluence extent during summer and fall extended approximately 25 and 100 ft upstream, respectively. Depth profiles of the confluence areas revealed no barriers to fish passage under the conditions surveyed (Figure 5.3.2.1-1). Appendix A contains photos illustrating the seasonal condition of the mouth of the confluence.

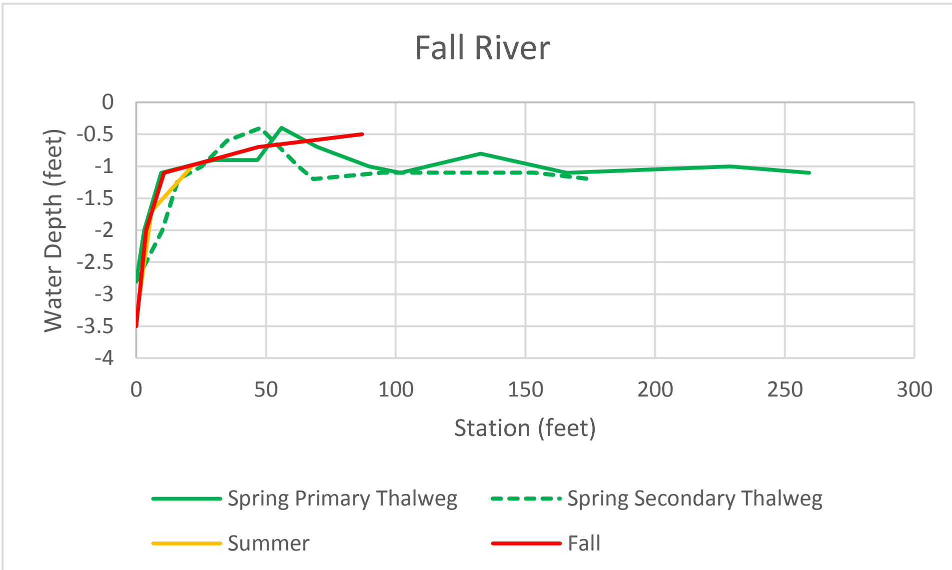


Figure 5.3.2.1-1. Longitudinal thalweg profiles Fall River during spring, summer, and fall conditions

5.3.2.2 Deerfield River

The Deerfield River is located downstream from Cabot Station and is one of the three major tributaries (drainage area = 664 mi^2) that flow into the Connecticut River within the Project area (Figure 3.0-2). The river originates in southern Vermont and flows approximately 76 miles before discharging to the Connecticut River in Greenfield, Massachusetts. The river is highly regulated as ten dams (several peaking hydroelectric projects and two seasonally operated reservoirs) are located on the Deerfield River, with the most downstream dam located approximately 13.5 miles upstream from the Connecticut River confluence. Seasonal changes in the size and extent of the confluence were documented during the 2014 surveys. The largest zone of influence was documented in the spring, when the WSEL was 109.48 ft and confluence extended approximately 2,300 ft upstream (Appendix B). Substrate at the upper confluence area was predominantly bedrock and boulder with gravel and sand, while the lower confluence was dominated by silt and sand. The confluence extent during fall conditions was shorter (approximately 630 ft) and minimal during summer conditions. Low Connecticut River levels (WSEL 105.14) in the summer resulted in a small confluence area with flow at the lower end of the confluence area bifurcated due to an exposed sand bar. Depth profiles of the confluence area indicate no barriers to fish movement during any of the conditions surveyed, as water depths were generally greater than 1 foot until the stream gradient increased further upstream (Figure 5.3.2.2-1). Appendix A contains photos illustrating the seasonal condition of the mouth of the confluence.

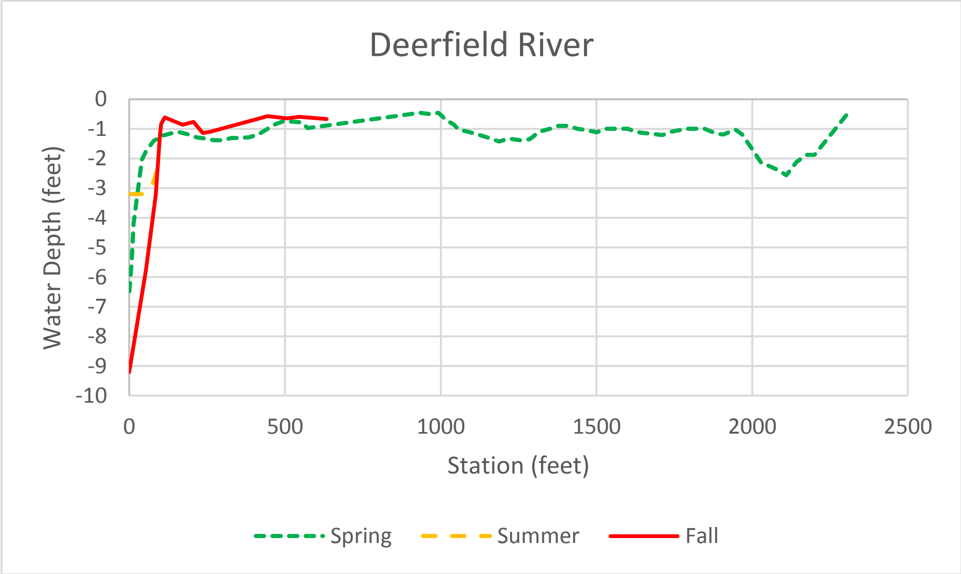


Figure 5.3.2.2-1. Longitudinal thalweg profiles Deerfield River during spring, summer, and fall conditions

5.3.2.3 Sawmill River

The Sawmill River is a tributary (drainage area = 32 mi²) located approximately 7.5 miles downstream of the Turners Falls Dam (Figure 3.0-2). The confluence extended approximately 200 ft upstream in spring when the WSEL was the highest (WSEL 107.88 ft), while the extent of the confluence was reduced to 125-140 ft upstream in summer and fall, respectively, when the WSEL was lower (Appendix B). The substrate at the upstream extent of the confluence in spring was primarily sand/gravel, whereas finer substrates dominated the lower confluence area. Woody debris was present in the confluence area; however, no restrictions to fish movement were identified, which is also confirmed by depth profiles of the confluence area (Figure 5.3.2.3-1). Appendix A contains photos illustrating the seasonal condition of the mouth of the confluence.

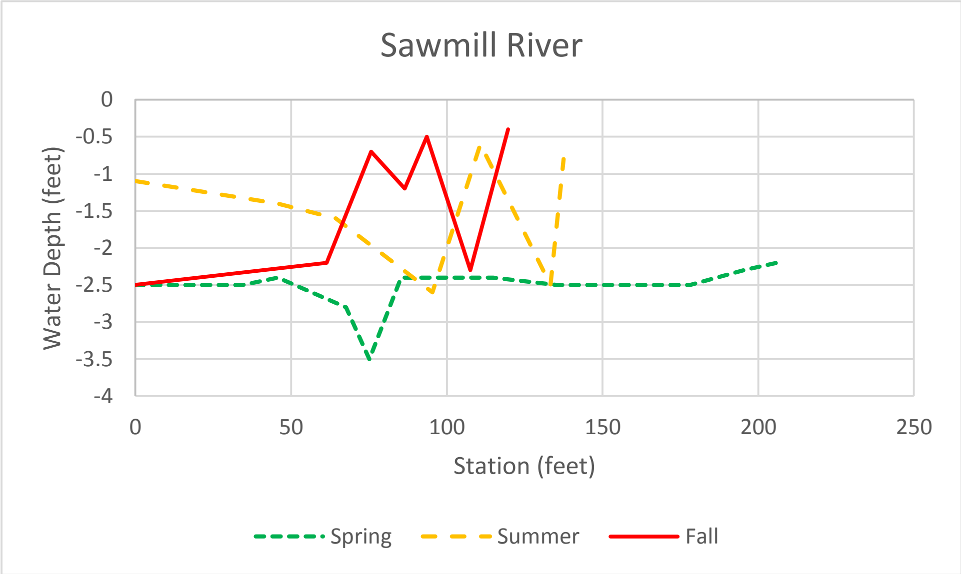


Figure 5.3.2.3-1. Longitudinal thalweg profiles Sawmill River during spring, summer, and fall conditions

5.3.2.4 Gunn Brook

Gunn Brook is a very small (drainage area = 2.15 mi^2), high-gradient tributary located approximately 8 miles downstream of the Turners Falls Dam (Figure 3.0-2). Seasonal changes in the size and extent of the confluence were documented during the 2014 surveys. The furthest upstream extent of the confluence was documented during the summer survey and extended approximately 100 ft upstream. The lower confluence substrate was predominantly sand, but transitioned to gravel/cobble at the upstream extent. Both the confluence and tributary itself were shallow, but the depth of the confluence did not appear to prevent fish movement (Figure 5.3.2.4-1). Non-project-related barriers to fish movement further upstream from the confluence were documented, such as woody debris formations and a road crossing culvert. Appendix A contains photos illustrating the seasonal conditions of the mouth of the confluence.

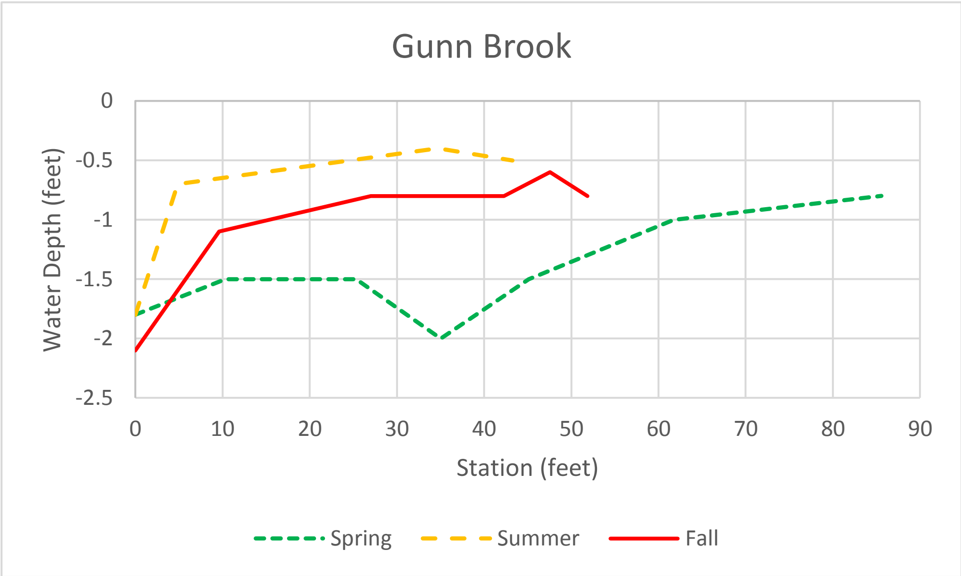


Figure 5.3.2.4-1. Longitudinal thalweg profiles Gunn Brook during spring, summer, and fall conditions

6 DISCUSSION

Most of the 19 tributaries to the Connecticut River located within the study area are small, low order streams. The exceptions are the Ashuelot, Millers and Deerfield Rivers which are hydraulically controlled at upstream dams. The remaining 16 tributaries exhibit natural seasonal flow variability, which affects the character (depth, flow, water velocities, substrate, sediment deposition, erosion, scour, etc.) of the streams and their confluences. These natural stream factors combined with influences of the Project operation and changing impoundment surface elevations result in dynamic conditions at the confluences. The surveys captured a seasonal snapshot of the confluence areas. Most confluences were determined to provide suitable access for riverine fishes. In the case of the three tributaries with observed access restrictions (Merriam Brook, Pine Meadow Brook and Fourmile Brook), surveys revealed that barriers were localized and temporary resulting from factors such as sediment deposition and woody debris accumulation. The effects of these potential barriers on tributary access are most pronounced during seasonal low flow periods when low water levels create breaks in connectivity, and not necessarily the result of the impoundment level.

When the study was developed, it was thought that the seasonal timing of the surveys; spring, summer and fall would be representative of high, low and medium impoundment levels and flow from the tributaries. This was the case relative to tributary flows, which were observed at their highest levels in the spring. However, impoundment levels did not necessarily follow this trend and some of the highest impoundment levels were recorded in the summer and fall periods. In most cases however, the tributary confluence area was largest in the spring, followed by fall and summer at the time the surveys were conducted. This result was an artifact of the survey design and fluctuations within the impoundment and their effects on tributary access occurs on a much smaller temporal scale, sometimes daily. Therefore, barriers such as those at Merriam Brook, Pine Meadow Brook and Fourmile Brook are inundated regularly, no longer presenting barriers to access while inundated.

Generally, small fish such as fluvial minnows may utilize the riverine habitat within these shallow, flowing tributary confluences. Other species may seek predatory refugia (Stephen *et al*., 2008) in the shallow flowing areas, whereas larger predatory species including basses and sunfish may feed in these areas where accessible. Cool water species are known to use these types of confluences as thermal refuge in the warmer months (Stephen *et al*., 2008).

Water depth and water velocity are two important factors affecting fish passage over natural barriers (Bovee, 1982). In Merriam Brook, water depths were shallow, as low as 0.15 ft, and water velocities were recorded at less than 0.5 feet per second. These areas had slow, flowing water that small fishes could pass. The RSP identified depths less than 1 foot in the thalweg to be a potential barrier to fishes. However, Bovee (1982) states that the minimum recommended clearance requirement should probably be no less than two-thirds of the body depth of the fish. For example, a white sucker with a 3 inch body depth would migrate over a stream feature with a water depth of at least 2 inches (0.17 ft) and an average sized spottail shiner would pass a barrier with 1 inch (0.08 ft) of water. Given that no riverine species with a body depth of 1.5 ft (18 inches) are present in the study area and that most tributaries within the study area are small order streams and characteristically shallow, a depth criteria of 1 ft was inappropriate. Further, these criteria may be tempered based upon the number and length of crossings that fish must make; fish that encounter very few passage barriers can likely negotiate fairly shallow water (Bovee, 1982).

Overall, the study results indicate that the effects of Project-related water fluctuations on tributary access and aquatic habitat conditions are minimal. Potential channel restrictions and barriers to fish in Merriam Brook, Fourmile Brook, and Pine Meadow Brook were localized and temporary, and the result from natural low-flow hydrologic conditions and geomorphic characteristics or processes.

7 LITERATURE CITED

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APPENDIX A - SEASONAL COMPARISON PHOTOS

Ashuelot River during the spring survey, photo was taken on 5/21/2014 with an impoundment WSEL of 185.68 ft (NGVD 29) as measured from the nearest monitoring station.

Ashuelot River during the summer survey, photo was taken on 8/5/2014 with an impoundment WSEL of 183.00 ft (NGVD 29) as measured from the nearest monitoring station.

Ashuelot River during the fall survey, photo was taken on 10/13/2014 with an impoundment WSEL of 182.04 ft (NGVD 29) as measured from the nearest monitoring station.

Newton Brook during the spring survey, photo was taken on 6/4/2014 with an impoundment WSEL of 182.67 ft (NGVD 29) as measured from the nearest monitoring station.

Newton Brook during the summer survey, photo was taken on 8/5/2014 with an impoundment WSEL of 180.98 ft (NGVD 29) as measured from the nearest monitoring station.

Newton Brook during the fall survey, photo was taken on 10/13/2014, with an impoundment WSEL of 181.75 ft (NGVD 29) as measured from the nearest monitoring station.

Pauchaug Brook during the spring survey, photo was taken on 6/4/2014, with an impoundment WSEL of 182.65 ft (NGVD 29) as measured from the nearest monitoring station.

Pauchaug Brook during the summer survey, photo was taken on 8/11/2014 with an impoundment WSEL of 180.99 ft (NGVD 29) as measured from the nearest station.

Pauchaug Brook during the fall survey, photo was taken on 10/13/2014 with an impoundment WSEL of 181.71 ft (NGVD 29) as measured from the nearest station.

Bottom Brook during the spring survey, photo was taken on 6/4/2014 with an impoundment WSEL of 182.67 ft (NGVD 29) as measured from the nearest station.

Bottom Brook during the summer survey, photo was taken on 8/11/2014 with an impoundment WSEL of 180.99 ft (NGVD 29) as measured from the nearest station.

Bottom Brook during the fall survey, photo was taken on 10/13/2014 with an impoundment WSEL of 182.01 ft (NGVD 29) as measured from the nearest station.

Mill Brook during the spring survey, photo was taken on 6/4/2014 with an impoundment WSEL of 182.67 ft (NGVD 29) as measured from the nearest station.

Mill Brook during the summer survey, photo was taken on 8/11/2014 with an impoundment WSEL of 181.06 ft (NGVD 29) as measured from the nearest station.

Mill Brook during the fall survey, photo was taken on 10/13/2014 with an impoundment WSEL of 182.03 ft (NGVD 29) as measured from the nearest station.

Mallory Brook during the spring survey, photo was taken on 6/4/2014 with an impoundment WSEL of 182.01 ft (NGDV 29) as measured from the nearest station.

Mallory Brook during the summer survey, photo was taken on 8/11/2014 with an impoundment WSEL of 181.55 ft (NGVD 29) as measured from the nearest station.

Mallory Brook during the fall survey, photo was taken on 10/13/2014 with an impoundment WSEL of 181.94 ft (NGVD 29) as measured from the nearest station.

Millers Brook during the spring survey, photo was taken on 6/4/2014 with an impoundment WSEL of 182.04 ft (NGVD 29) as measured from the nearest station.

Millers Brook during the summer survey, photo was taken on 8/12/2014 with an impoundment WSEL of 179.60 ft (NGVD 29) as measured from the nearest station.

Millers Brook during the fall survey, photo was taken on 10/13/2014 with an impoundment WSEL of 181.90 ft (NGVD 29) as measured from the nearest station.

Bennett Brook during the spring survey, photo was taken on 6/5/2014 with an impoundment WSEL of 181.46 ft (NGVD 29) as measured from the nearest station.

Bennett Brook during the summer survey, photo was taken on 8/12/2014 with an impoundment WSEL of 179.50 ft (NGVD 29) as measured from the nearest station.

Bennett Brook during the fall survey, photo was taken on 10/14/2014 with an impoundment WSEL of 180.49 ft (NGVD 29) as measured from the nearest station.

Merriam Brook during the spring survey, photo was taken on 6/5/2014 with an impoundment WSEL of 181.47 ft (NGVD 29) as measured from the nearest station.

Merriam Brook during the summer survey, photo was taken on 8/12/2014 with an impoundment WSEL of 179.20 ft (NGVD 29) as measured from the nearest station.

Merriam Brook during the fall survey, photo was taken on 10/14/2014 with an impoundment WSEL of 180.89 ft (NGVD 29) as measured from the nearest station.

Otter Run during the spring survey, photo was taken on 6/5/2014 with an impoundment WSEL of 181.37 ft (NGVD 29) as measured from the nearest station.

Otter Run during the summer survey, photo was taken on 8/12/2014 with an impoundment WSEL of 178.78 ft (NGVD 29) as measured form the nearest station.

Otter Run during the fall survey, photo was taken on 10/14/2014 with an impoundment WSEL of 181.37 ft (NGVD 29) as measured from the nearest station.

Ashuela Brook during the spring survey, photo was taken on 6/5/2014 with an impoundment WSEL of 181.19 ft (NGVD 29) as measured from the nearest station.

Ashuela Brook during the summer survey, photo was taken on 8/12/2014 with an impoundment WSEL of 178.72 ft (NGVD 29) as measured from the nearest station.

Ashuela Brook during the fall survey, photo was taken on 10/14/2014 with an impoundment WSEL of 181.53 ft (NGVD 29) as measured from the nearest station.

Dry Brook during the spring survey, photo was taken on 6/5/2014 with an impoundment WSEL of 181.11 ft (NGVD 29) as measured from the nearest station.

Dry Brook during the summer survey, photo was taken on 9/3/2014 with an impoundment WSEL of 179.76 ft (NGVD 29) as measured from the nearest station.

Dry Brook during the fall survey, photo was taken on 10/14/2014 with an impoundment WSEL of 181.96 ft (NGVD 29) as measured from the nearest station.

Pine Meadow Brook during the spring survey, photo was taken on 6/6/2014 with an impoundment WSEL of 180.53 ft (NGVD 29) as measured from the nearest station.

Pine Meadow Brook during the summer survey, photo was taken on 8/12/2014 with an impoundment WSEL of 179.15 ft (NGVD 29) as measured from the nearest station.

Pine Meadow Brook during the fall survey, photo was taken on 10/14/2014 with an impoundment WSEL of 182.13 ft (NGVD 29) as measured from the nearest station.

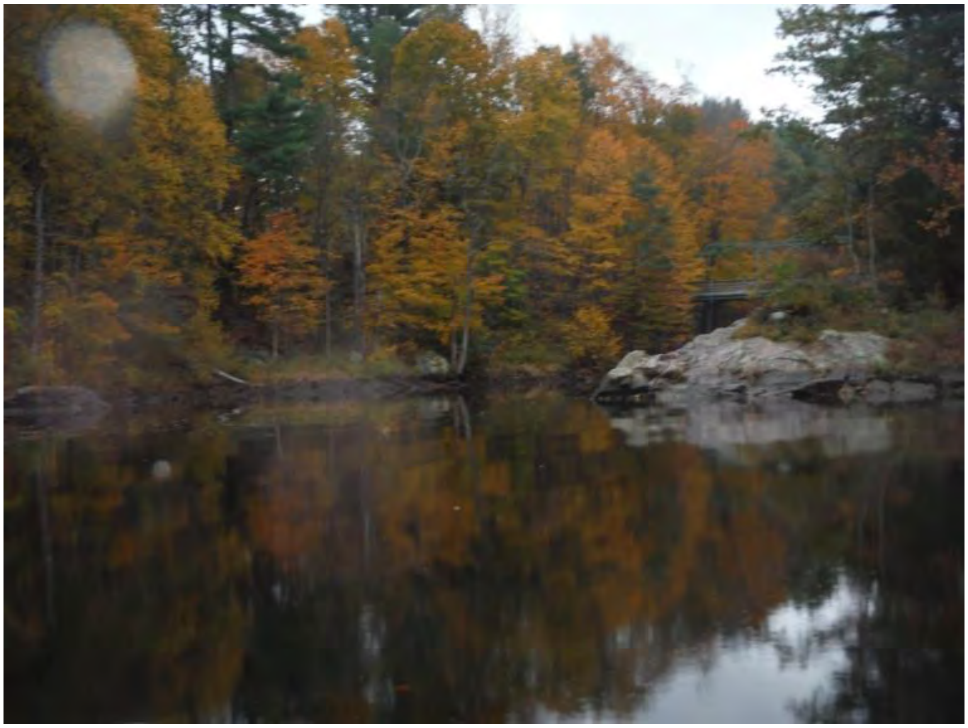
Fourmile Brook during the spring survey, photo was taken on 6/6/2014 with an impoundment WSEL of 180.22 ft (NGVD 29) as measured from the nearest station.

Fourmile Brook during the summer survey, photo was taken on 8/12/2014 with an impoundment WSEL of 178.97 ft (NGVD 29) as measured from the nearest station.

Fourmile Brook during the fall survey, photo was taken on 10/14/2014 with an impoundment WSEL of 182.53 ft (NGVD 29) as measured from the nearest station.

Millers River during the spring survey, photo was taken on 5/22/2014 with an impoundment WSEL of 183.82 ft (NGVD 29) as measured from the nearest station.

Millers River during the summer survey, photo was taken on 8/12/2014 with an impoundment WSEL of 178.90 ft (NGVD 29) as measured from the nearest station.



Millers Rivers during the fall survey, photo was taken on 10/15/2014 with an impoundment WSEL of 182.38 ft (NGVD 29) as measured from the nearest station.

Fall River during the spring survey, photo was taken on 6/11/2014 with a WSEL of 135.53 ft (NGVD 29) as measured from the nearest station.

Fall River during the summer survey, photo was taken on 9/2/2014 with a WSEL of 135.08 ft (NGVD 29) as measured from the nearest station.

Fall River during the fall survey, photo was taken on 10/15/2014 with a WSEL of 135.04 ft (NGVD 29) as measured from the nearest station.

Deerfield River during the spring survey, photo was taken on 6/10/2014 with a WSEL of 109.48 ft (NGVD 29) as measured from the nearest station.

Deerfield River during the summer survey, photos were taken on 9/2/2014 with a WSEL of 105.14 ft (NGVD 29) as measured from the nearest station.

Deerfield River during the fall survey, photos were taken on 10/15/2014 with a WSEL of 107.98 ft (NGVD 29) as measured from the nearest station.

Sawmill River during the spring survey, photo was taken on 6/10/2014 with a WSEL of 107.88 ft (NGVD 29) as measured from the nearest station.

Sawmill River during the summer survey, photo was taken on 9/2/2014 with a WSEL of 105.19 ft (NGVD 29) as measured form the nearest station.

Sawmill River during the fall survey, photo was taken on 10/15/2014 with a WSEL of 104.51 ft (NGVD 29) as measured from the nearest station.

Gunn Brook during the spring survey, photo was taken on 6/10/2014 with a WSEL of 107.90 ft (NGVD 29) as measured from the nearest station.

Gunn Brook during the summer survey, photo was taken on 9/2/2014 with a WSEL of 105.18 ft (NGVD 29) as measured from the nearest station.

Gunn Brook during the fall survey, photo was taken on 10/15/2014 with a WSEL of 107.10 ft (NGVD 29) as measured from the nearest station.

APPENDIX B – THALWEG PROFILE MAPS

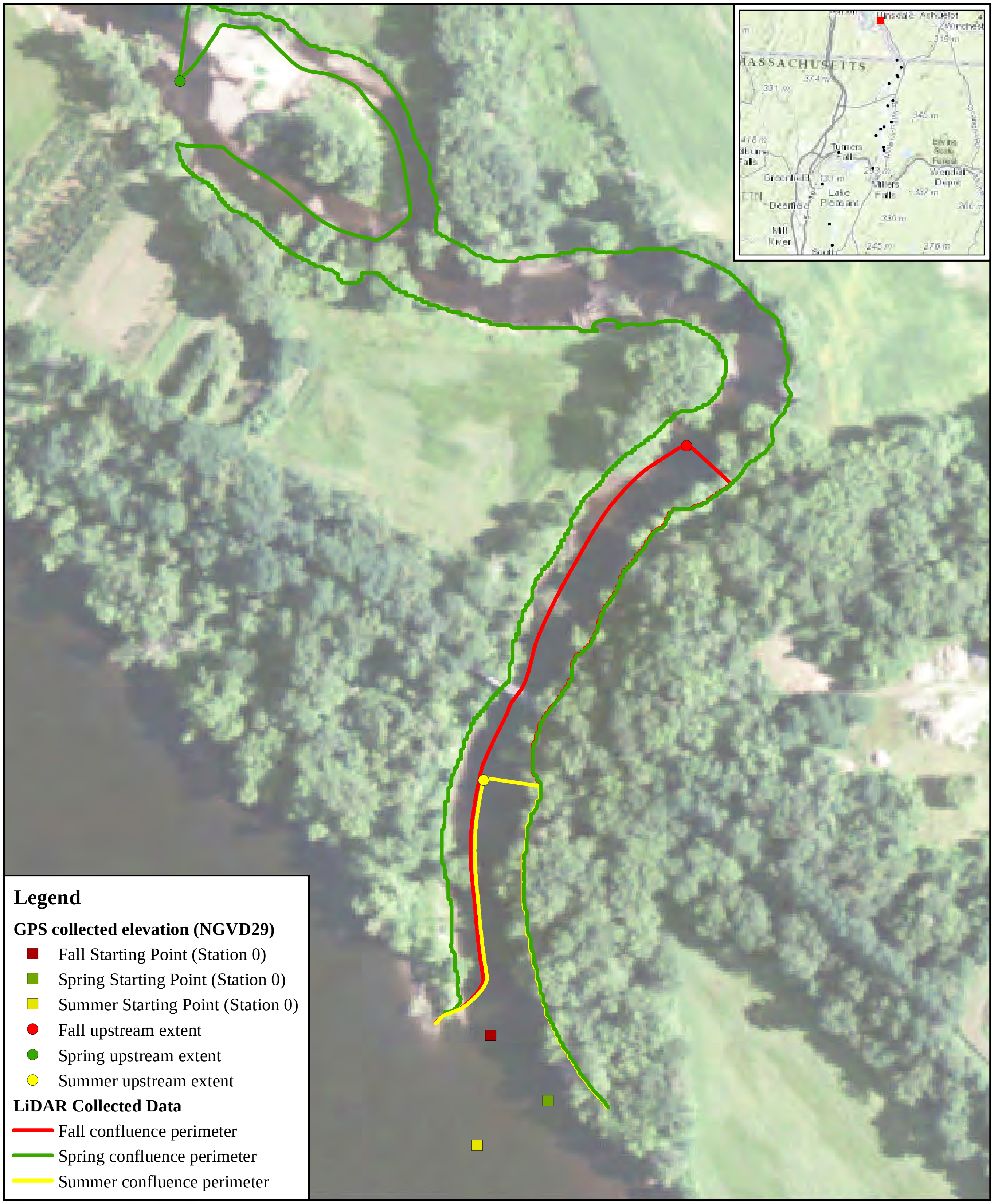
Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 50 100 200
Feet

Appendix B Figure.
Ashuela Brook
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



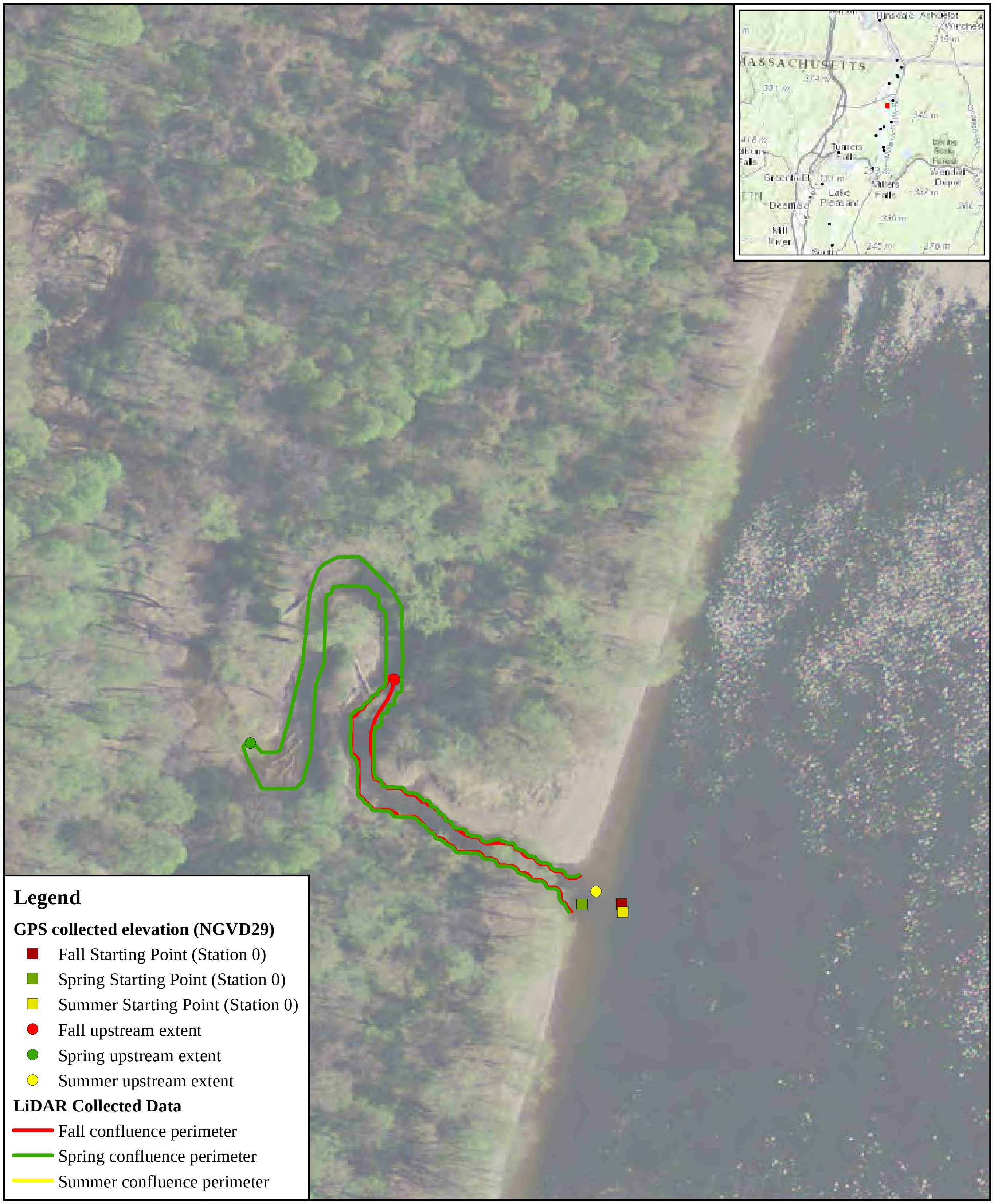
FirstLight GDF SUEZ

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

Appendix B Figure.
Ashuelot River
spring, summer, and fall thalweg survey start and end points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

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Appendix B Figure.
Bennett Brook
spring, summer, and fall thalweg survey start and end points

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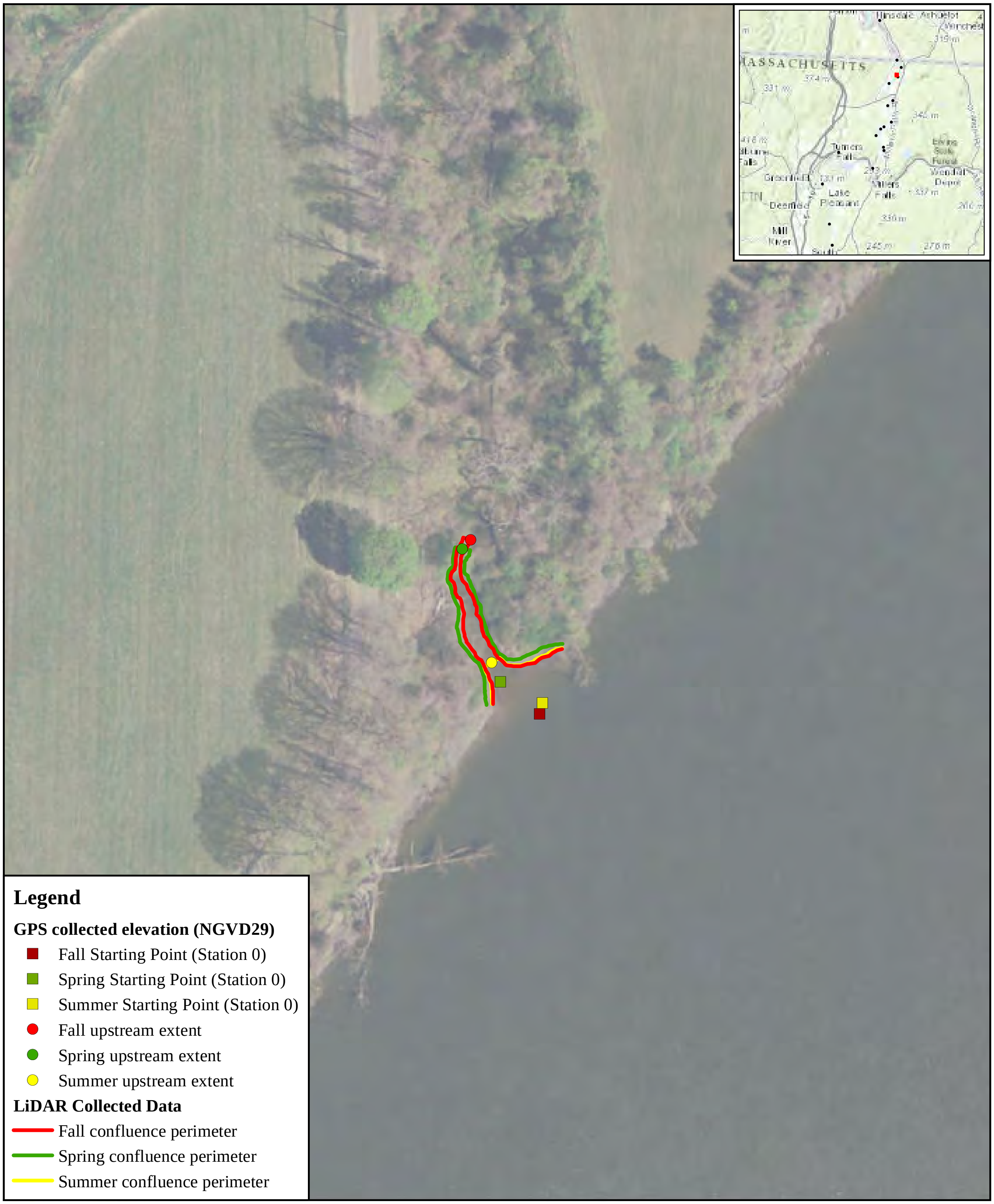
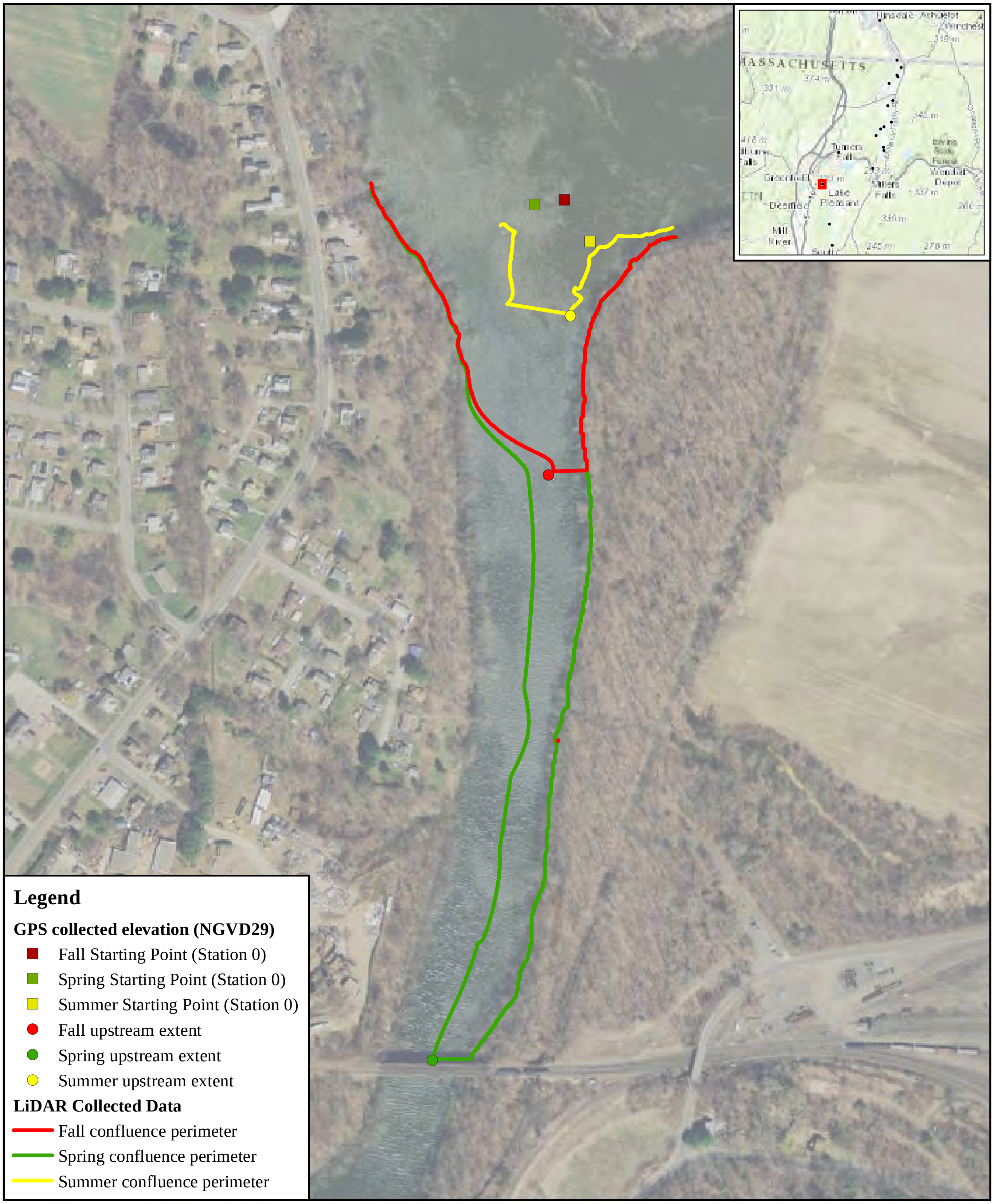


Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

Appendix B Figure.
Bottom Brook
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



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Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

Appendix B Figure.
Deerfield River
spring, summer, and fall thalweg survey start and end points

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Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

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Feet

Appendix B Figure.
Dry Brook
spring, summer, and fall
thalweg survey start and end
points

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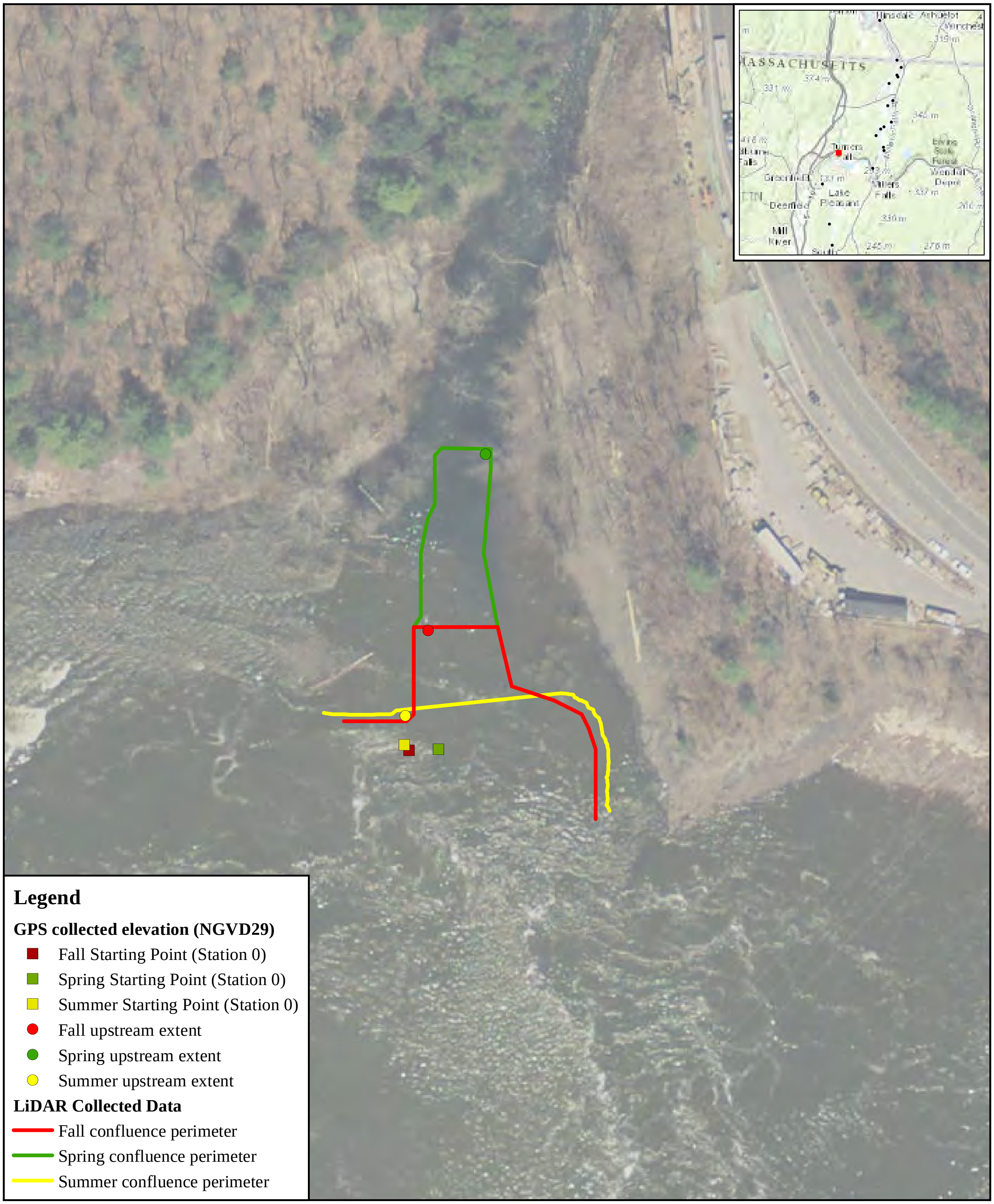

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

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Appendix B Figure.
Fall River
spring, summer, and fall thalweg survey start and end points

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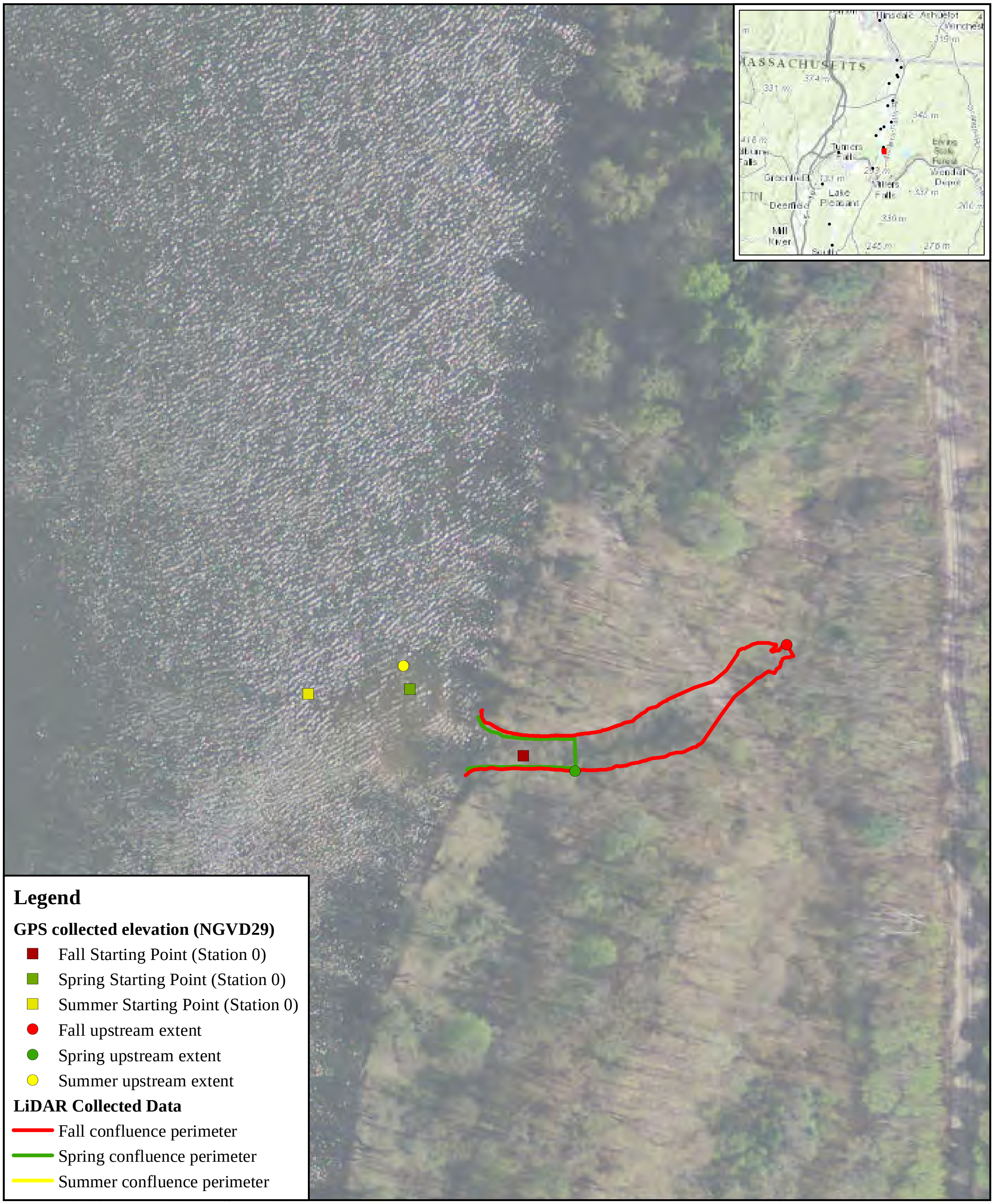

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Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

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Appendix B Figure.
Fourmile Brook
spring, summer, and fall
thalweg survey start and end
points

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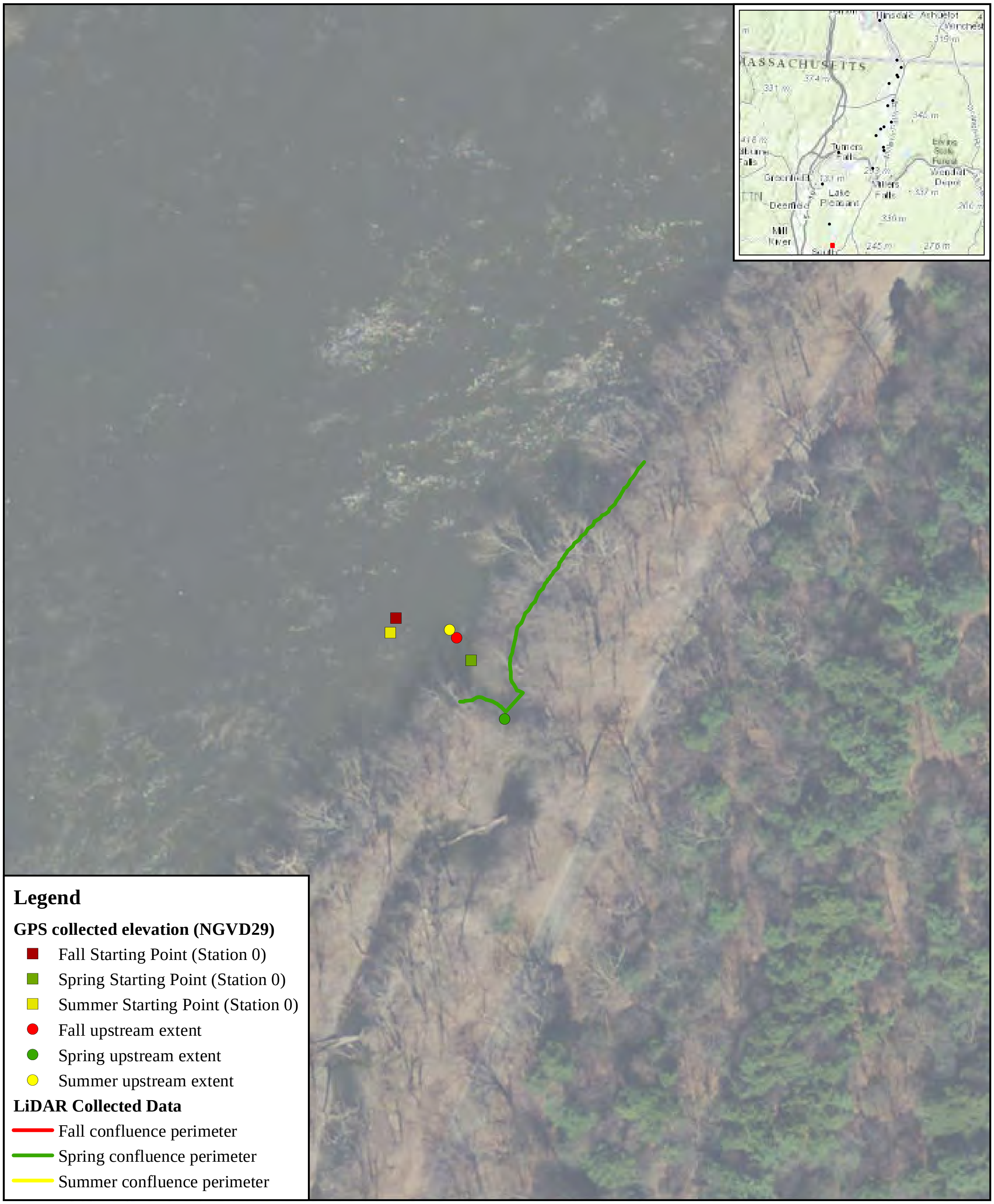
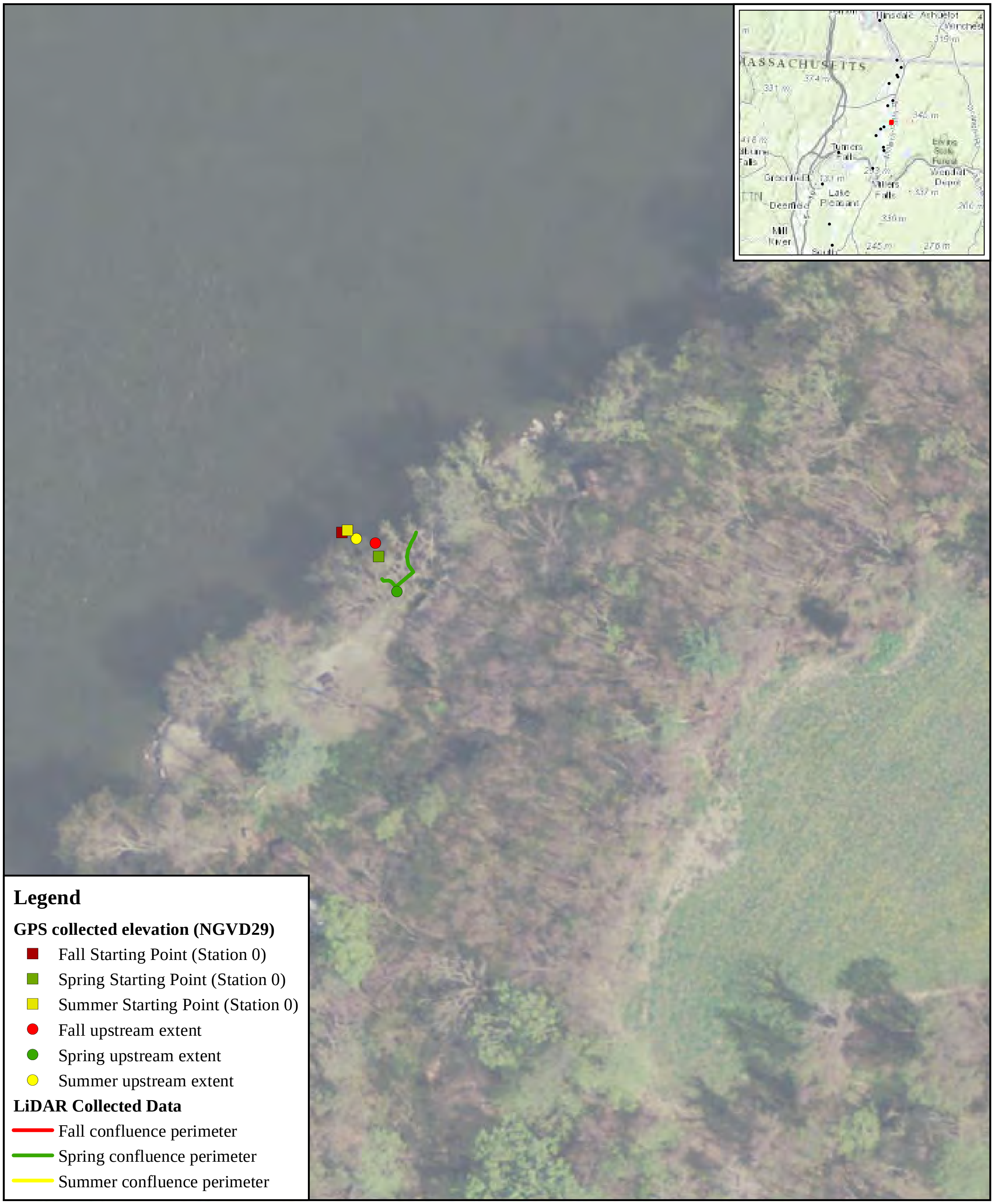


Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

Appendix B Figure.
Gunn Brook
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



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Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

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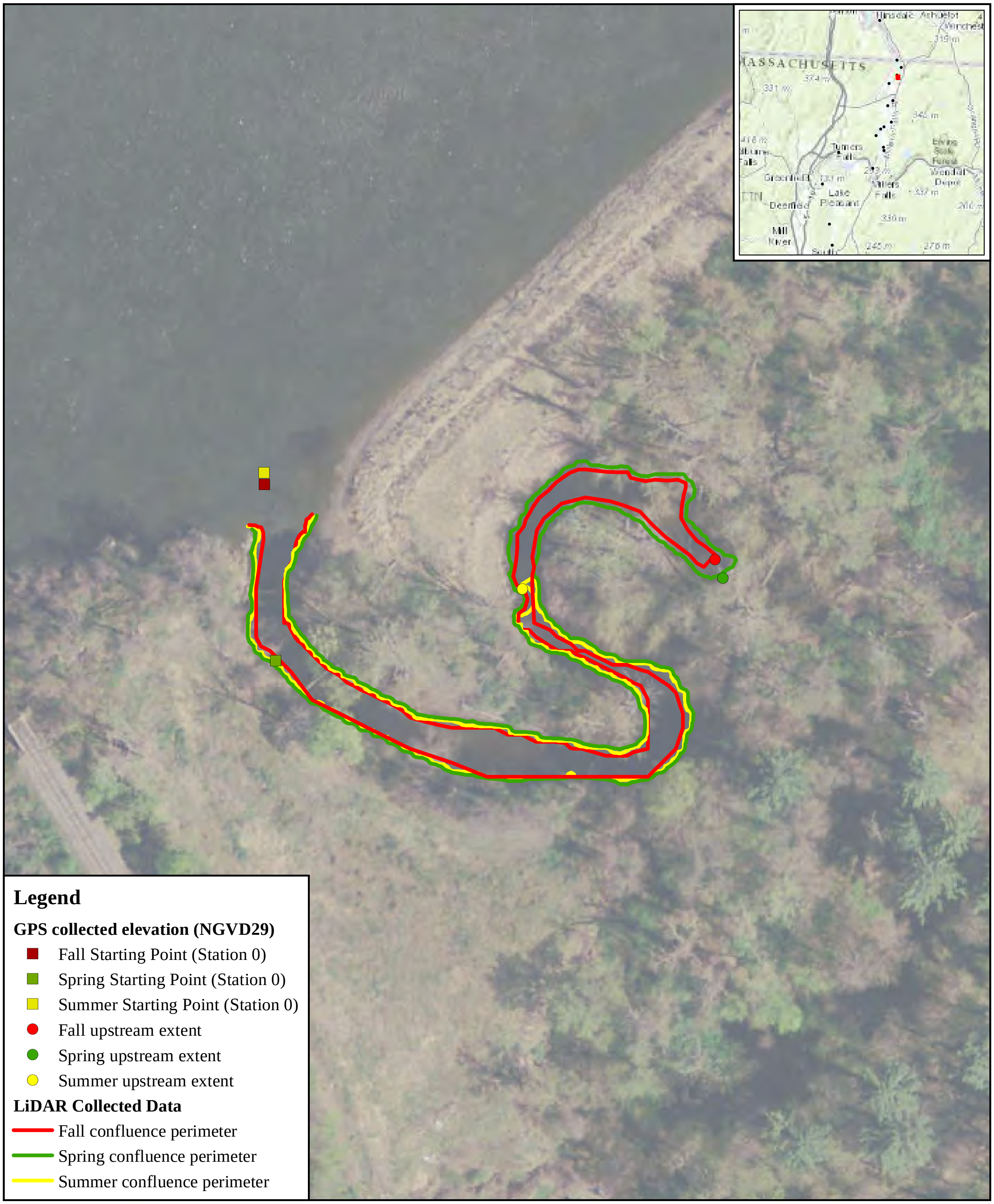
Appendix B Figure.
Merriam Brook
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

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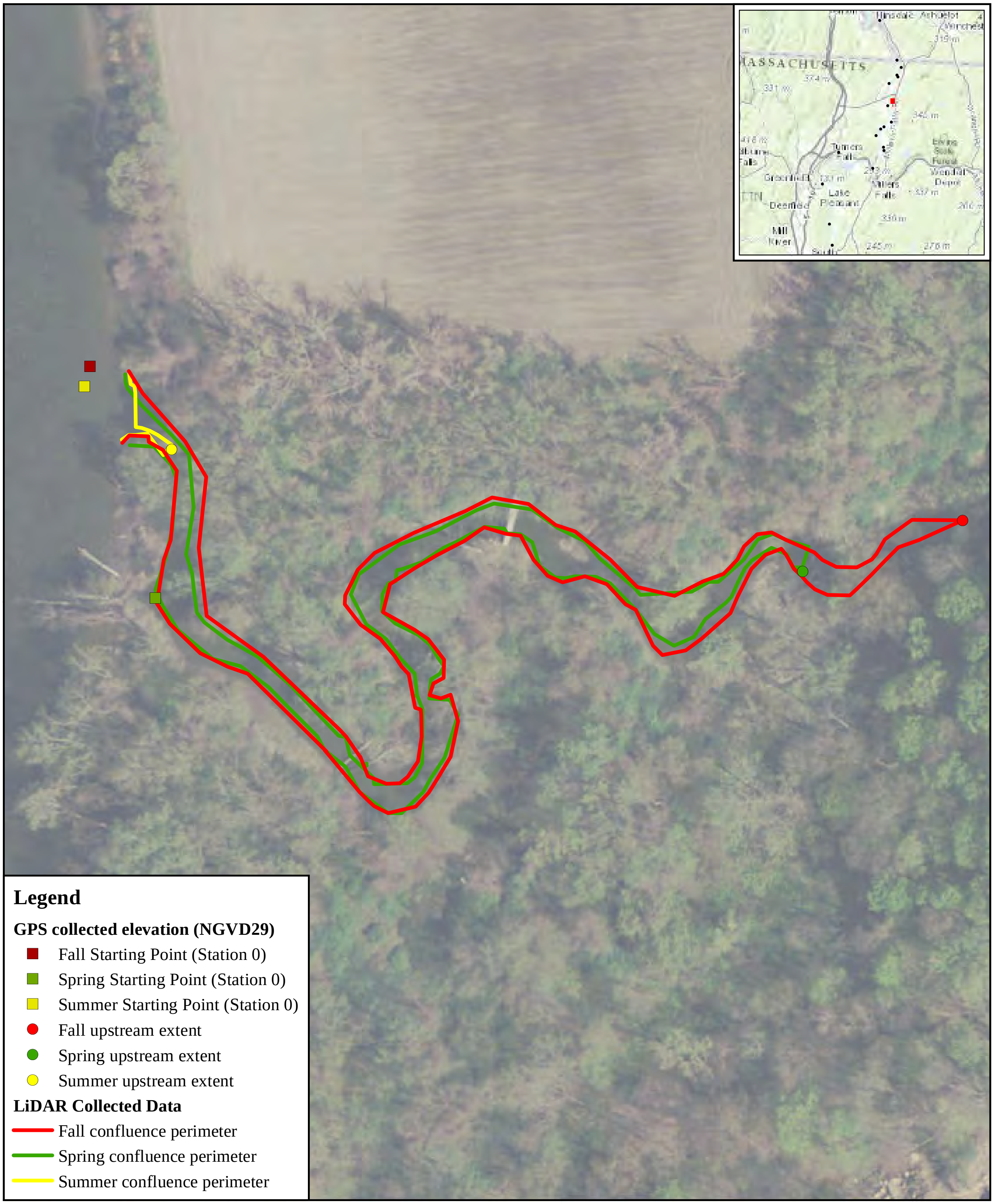
Feet

Appendix B Figure.
Mill Brook
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

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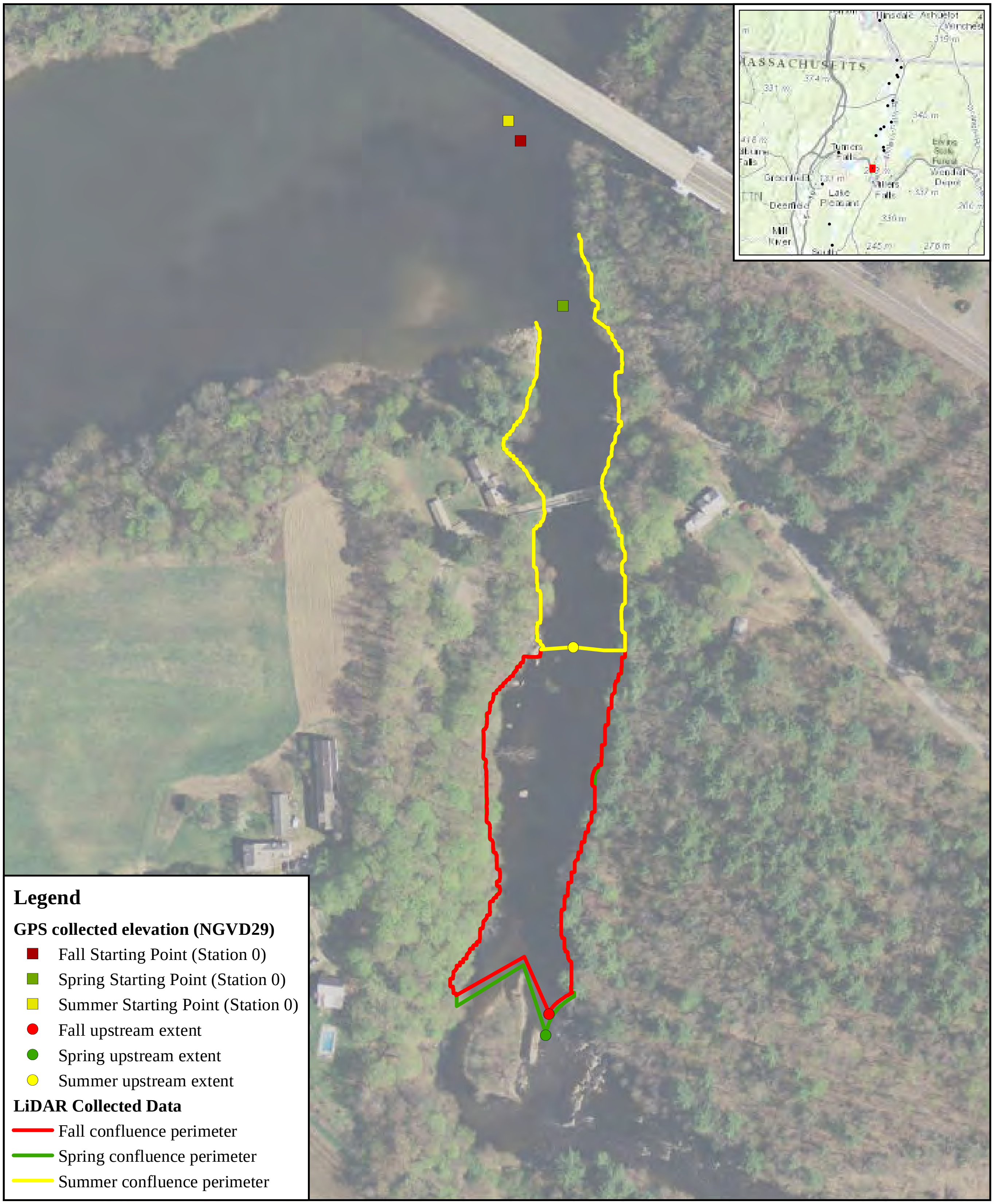
Feet

Appendix B Figure.
Millers Brook
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



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Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

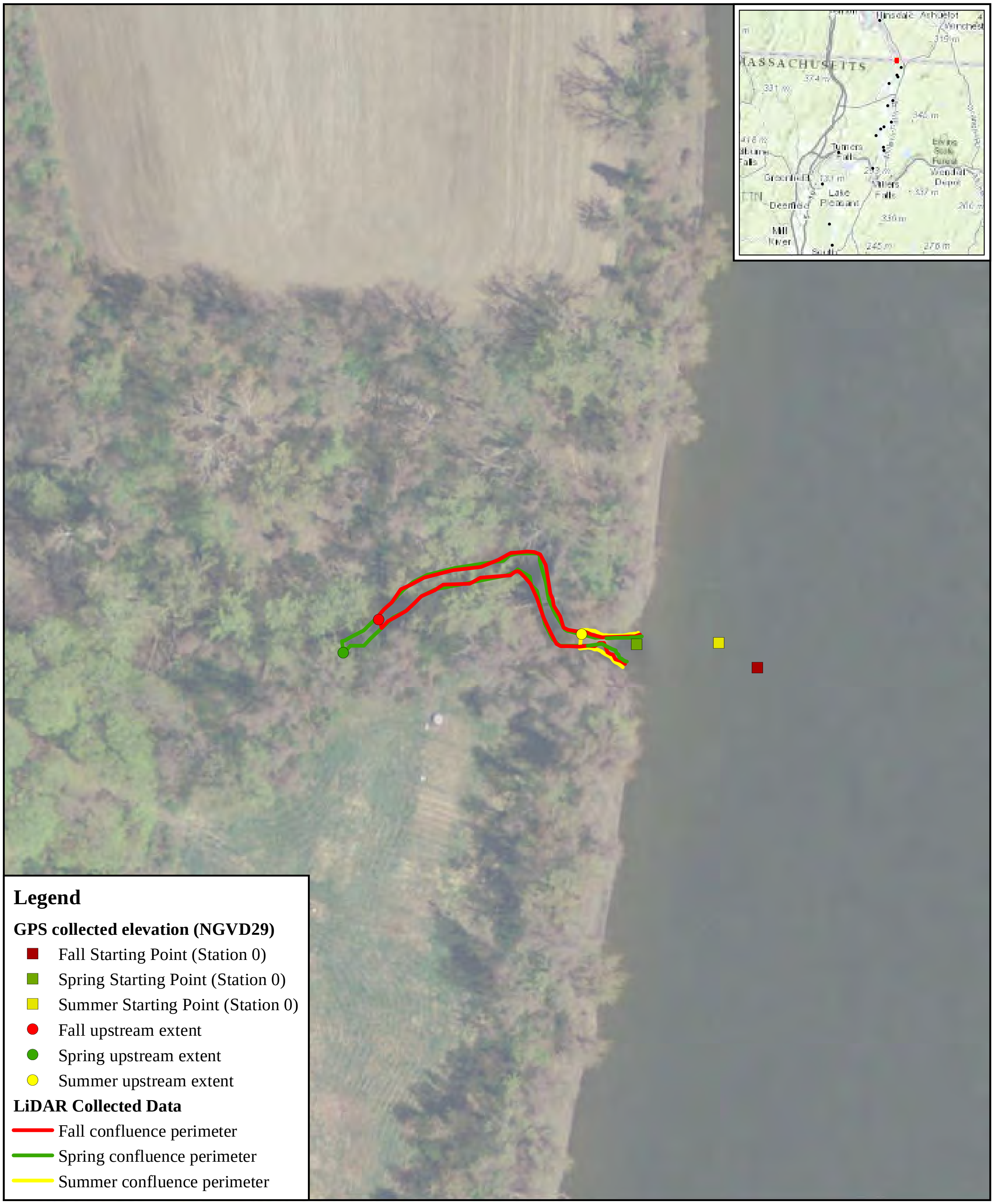
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 50 100 200
Feet

Appendix B Figure.
Millers River
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



FirstLight GDF SUEZ

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

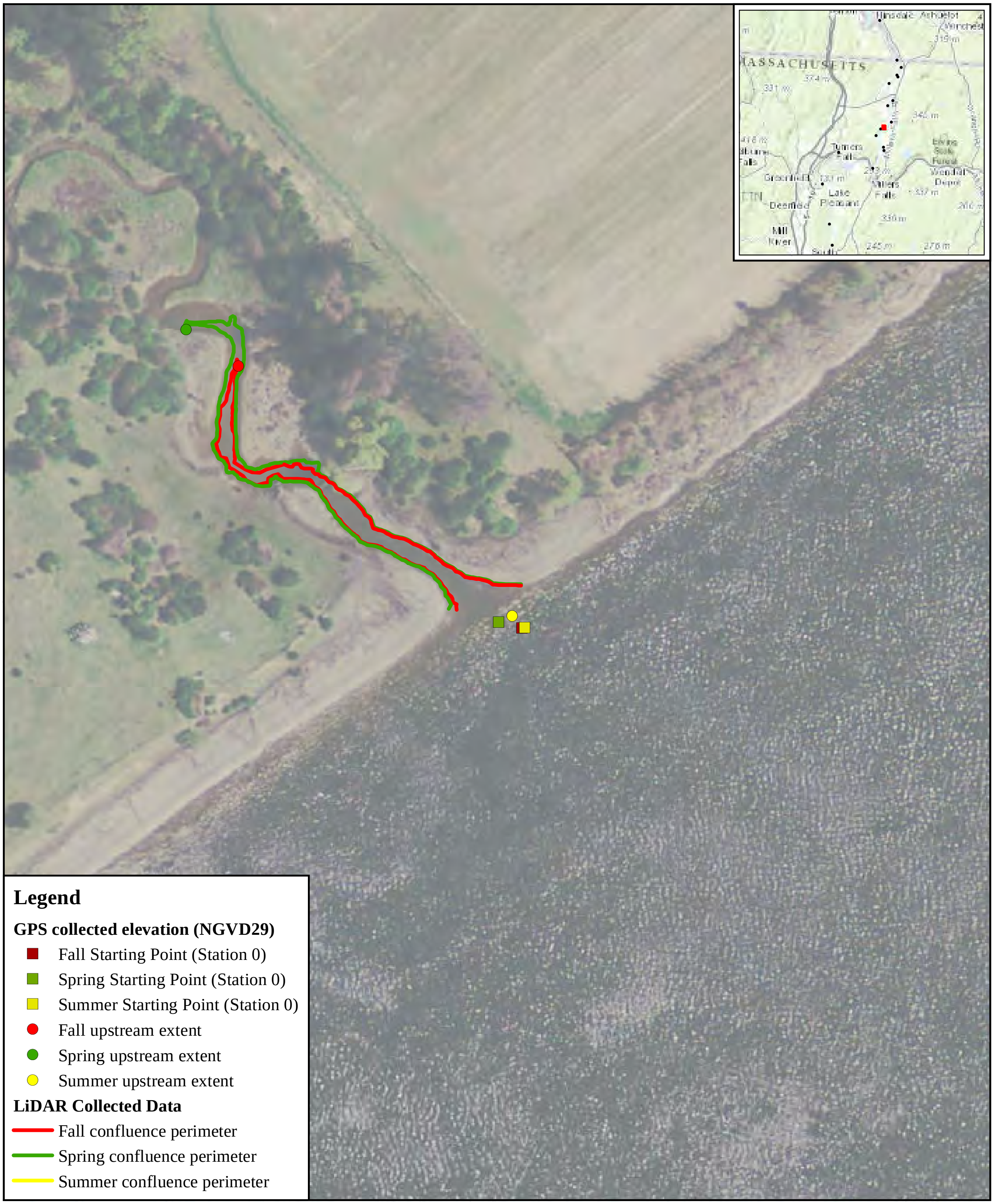
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 50 100 200 Feet

Appendix B Figure.
Newton Brook
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



FirstLight GDF SUEZ

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

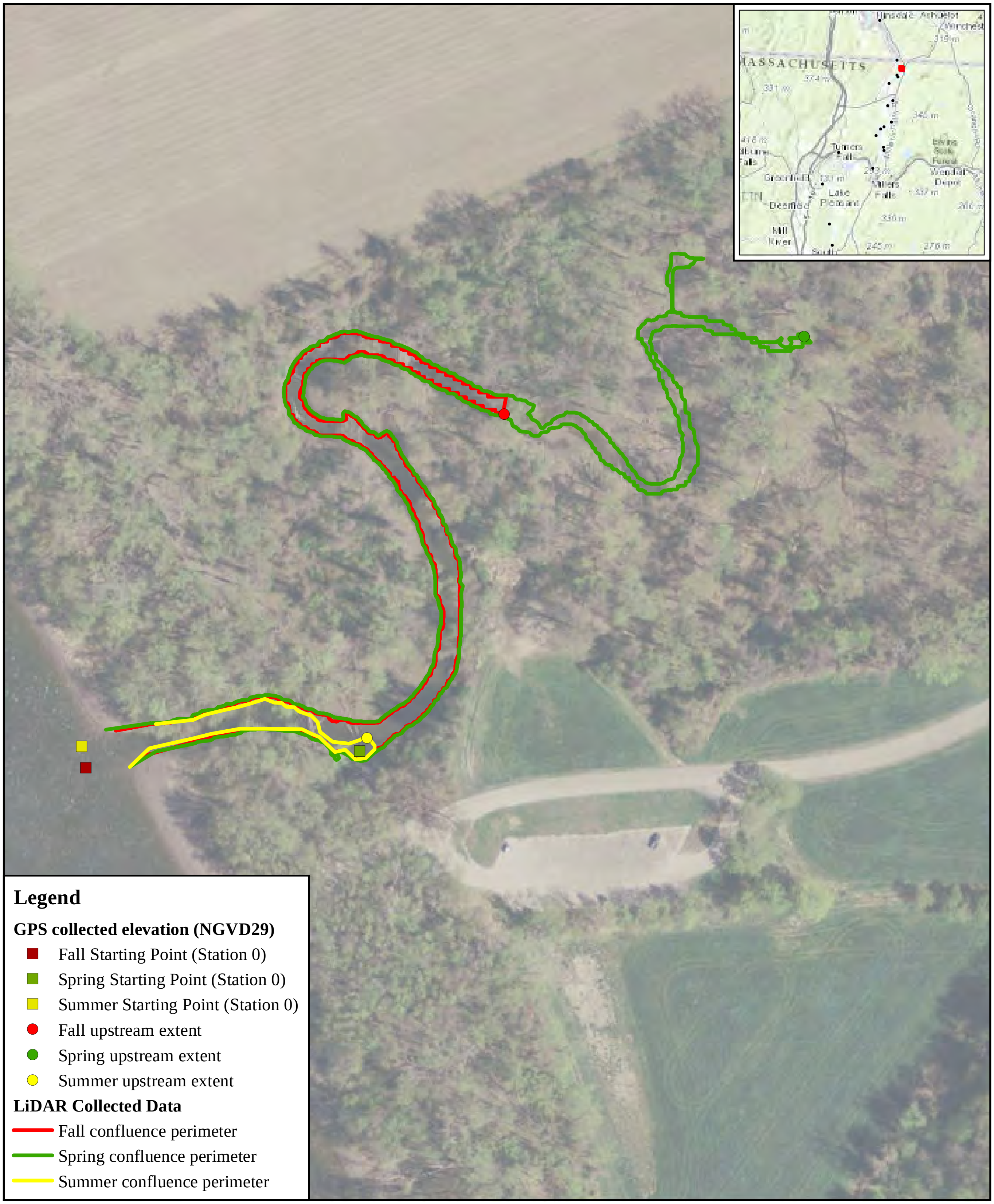
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 50 100 200
Feet

Appendix B Figure.
Otter Run
spring, summer, and fall thalweg survey start and end points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



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Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

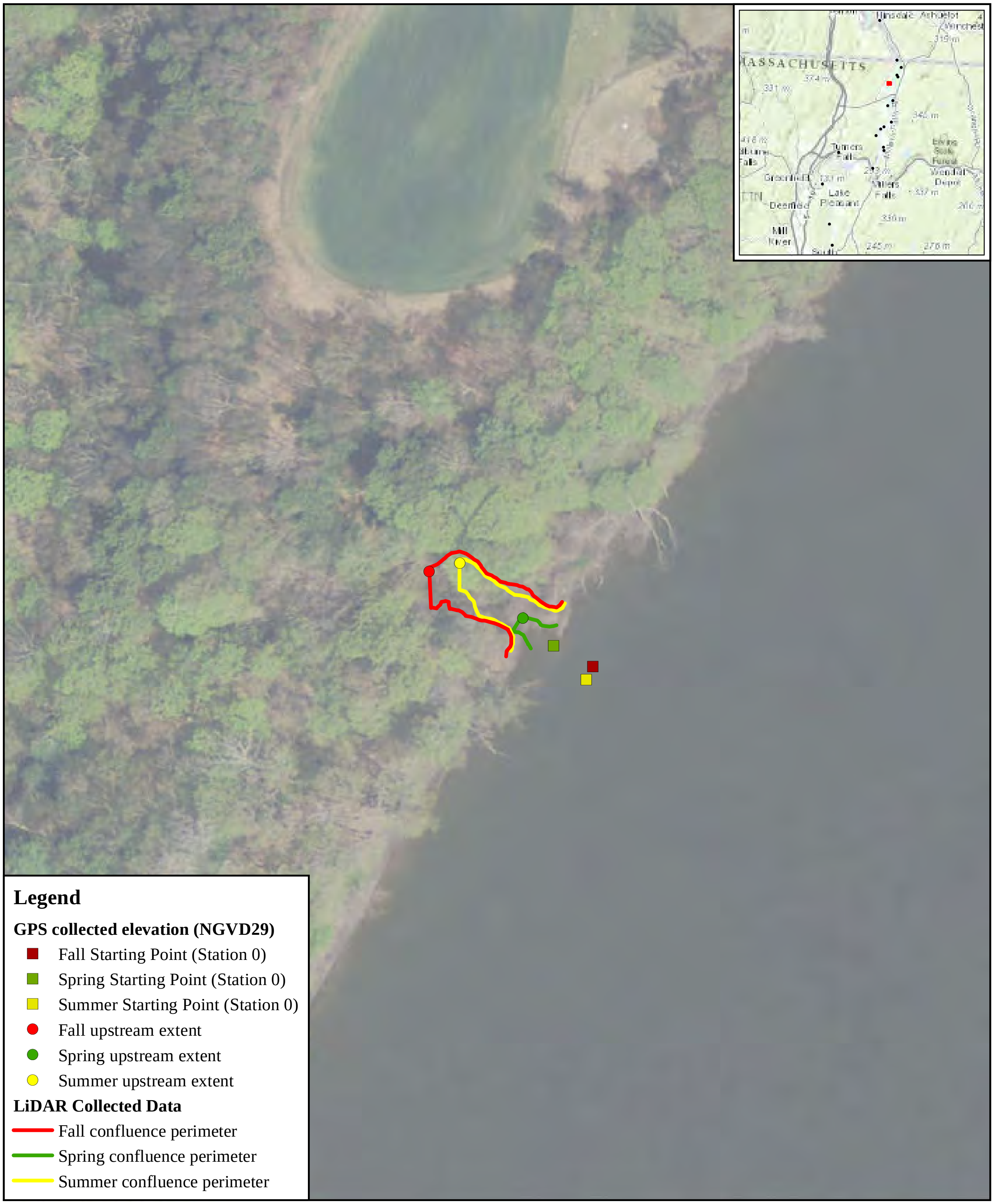
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 50 100 200 Feet

Appendix B Figure.
Pauchaug Brook
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



Legend

GPS collected elevation (NGVD29)

- Fall Starting Point (Station 0)
- Spring Starting Point (Station 0)
- Summer Starting Point (Station 0)
- Fall upstream extent
- Spring upstream extent
- Summer upstream extent

LiDAR Collected Data

- Fall confluence perimeter
- Spring confluence perimeter
- Summer confluence perimeter

FirstLight GDF SUEZ

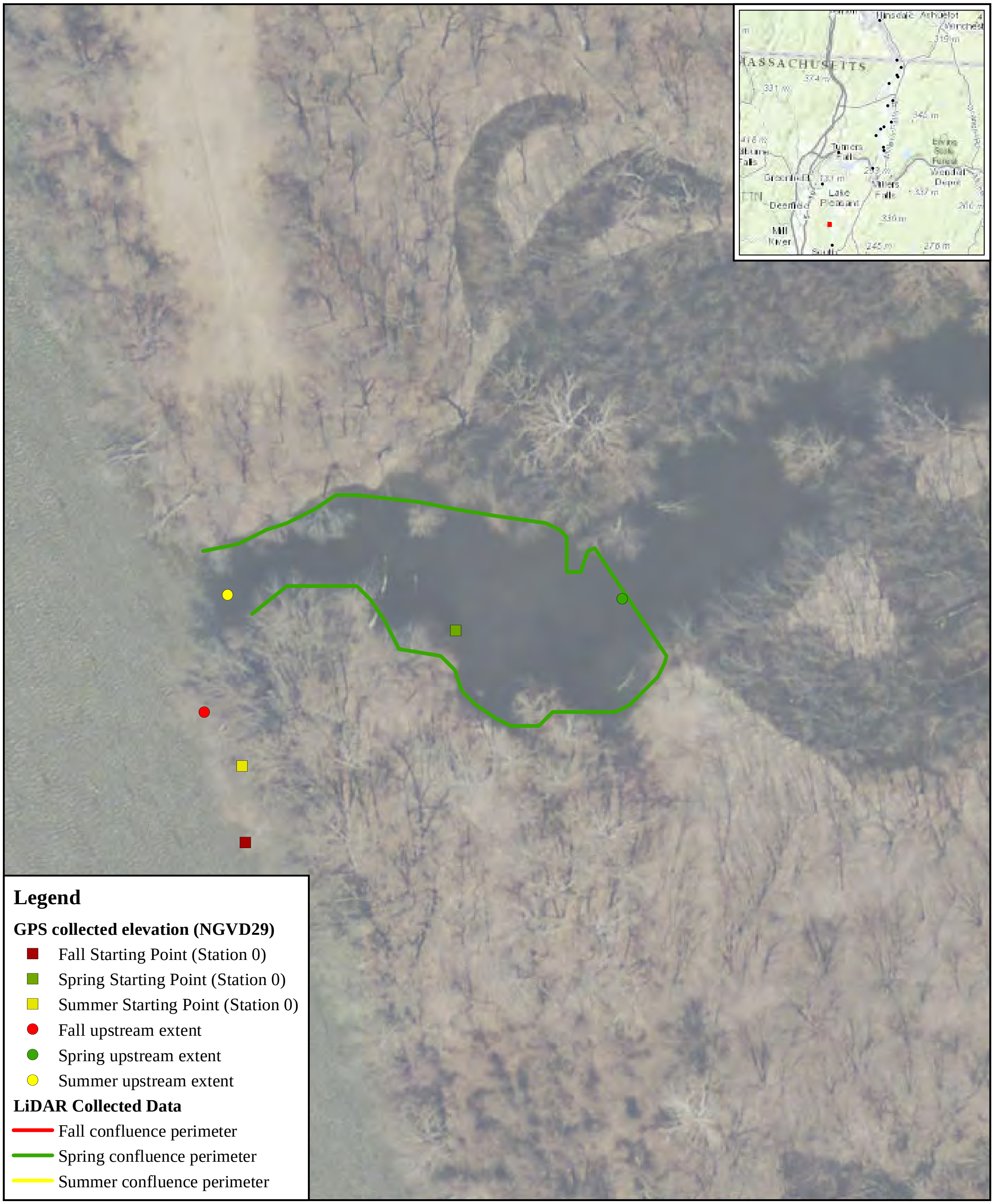
Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 50 100 200 Feet

Appendix B Figure.
Mallory Brook
spring, summer, and fall thalweg survey start and end points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



FirstLight
GDF SUEZ

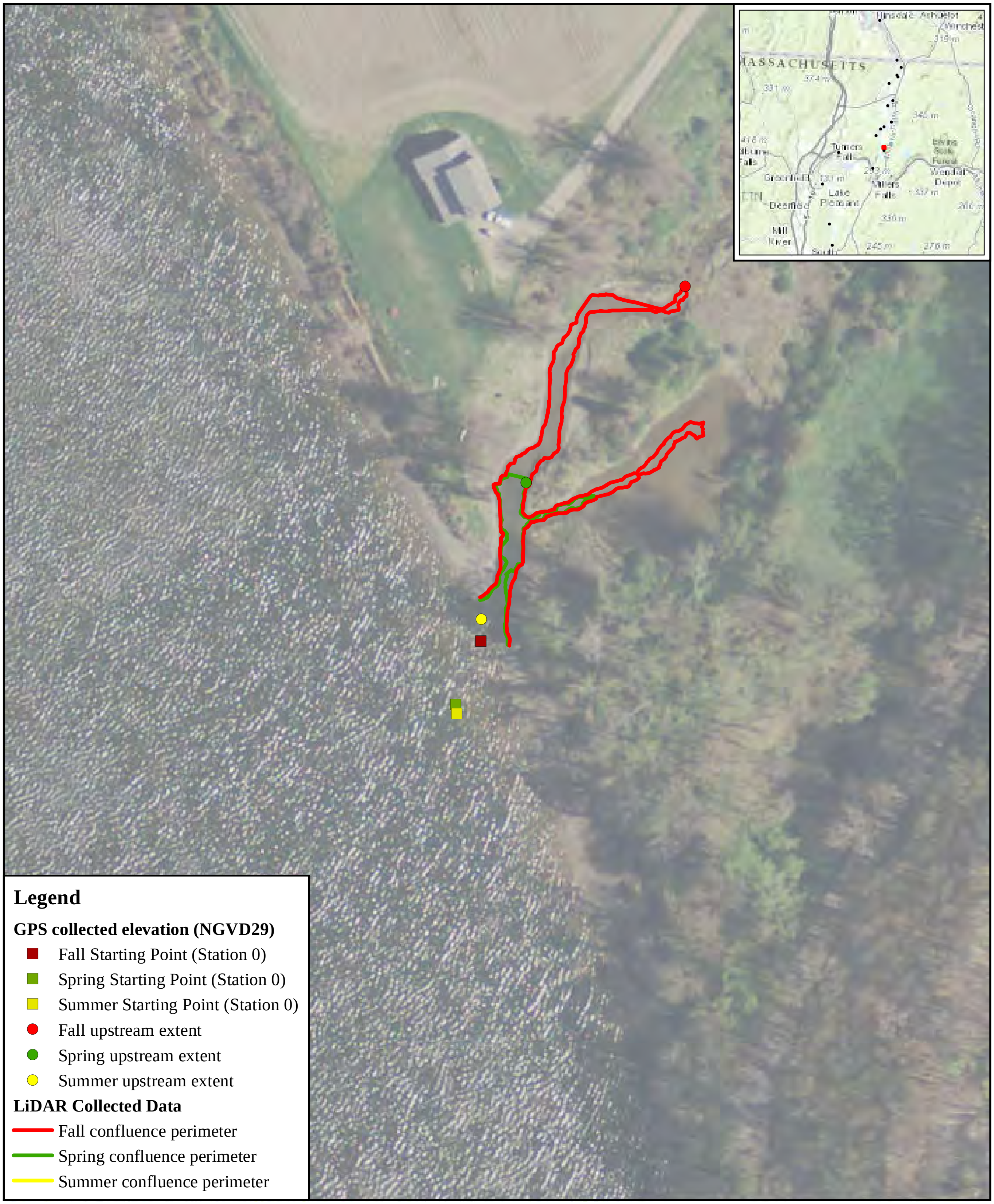
Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 50 100 200
Feet

Appendix B Figure.
Sawmill River
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd



FirstLight GDF SUEZ

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study No. 3.3.17
Tributary and Backwater Area
Access and Habitat Study

N

0 50 100 200
Feet

Appendix B Figure.
Pine Meadow Brook
spring, summer, and fall
thalweg survey start and end
points

Path: W:\gis\studies\3_3_17\maps\Appendix_B.mxd