# PROPOSED 2019 ULTRASOUND ARRAY CONTROL STUDY

## 1.0 INTRODUCTION AND OBJECTIVES

This study plan builds on knowledge gained in 2016 and 2018 and furthers the investigation into whether the use of ultrasound technology would be an effective method to minimize shad attraction to the Cabot Station fish ladder while allowing shad to continue migrating up the bypass channel toward the Turners Falls Dam (TFD). In 2016, air entrainment from the Cabot Station turbine discharge and fish ladder attraction flow significantly increased the attenuation and scattering of the expected sound field, effectively reducing sound pressure levels below thresholds that would elicit strong and prolonged avoidance reactions from adult shad unless fish were within the immediate vicinity of the transducers including at the fish ladder entrance (Figure 1-1). In the 2016 study, there were three transducers with different horizontal orientations mounted to a pole that was located on the fish ladder wall near the entrance and two transducers, with different horizontal orientations, mounted on a pole installed approximately at the midpoint on the back of the powerhouse. Using the new data from sound measurements collected on November 15, 2017 and from the results of sound modeling, transducer locations, numbers, and orientations for the 2018 study were designed to minimize interference from air entrainment and optimize signal strength in an attempt to produce a continuous sound field spanning across the edge of the tailrace and with sound pressure levels (SPLs) greater than the 190 dB (Figure 1-2). Results of the 2018 study indicated that of the 112 adult American Shad that arrived at the Cabot Station tailrace, 85 fish (76%) moved upstream into the bypass reach entrance.

Since two elements (additional flow in the bypass reach and the ultrasound array) were added as part of the previous studies, it is not possible to ascertain which contributed to the increased number of fish moving upstream past Cabot Station and into the bypass reach. To determine if increased bypass flow or the ultrasound array or a combination of the two contributed to 76% of the tagged fish moving upstream to the bypass reach, it is proposed to conduct a movement study in 2019 with flow in the bypass reach, but without an ultrasound array in place and the Cabot Station fish ladder operating as normal.

In addition, the 2018 study revealed that Rock Dam and the channels around Rawson Island create physical and velocity barriers, respectively, which obstructed shad migration to the fishway at TFD. The 2019 study will be designed to collect additional information in these two areas of the bypass reach.

The goal of this 2019 study is to determine if the magnitude of the bypass reach flow or the ultrasound array is primarily responsible for adult American Shad moving upstream to the bypass reach. The study objectives are:

- To determine if a similar proportion of tagged migrating adult shad will migrate upstream of Cabot Station and into the bypass reach without the ultrasound array in place;
- To investigate adult shad migration in the area of Rawson Island and Rock Dam.
- To determine if adult shad migrate by the Station No .1 tailrace under a flow split of 50% spill from the TFD and 50% from Station No. 1. The 2018 study used a flow split of 67% spill from the TFD and 33% from Station No. 1, which appeared successful in terms of moving adult shad by Station No. 1 and toward the TFD. For the 2019 study both the 67%/33% and 50%/50% flow splits will be tested for two different total flow scenarios (4,400 and 6,500 cfs).

In addition to the objectives associated with upstream migrants, FirstLight also plans to investigate the rates of immediate and latent survival for emigrating post-spawn shad that pass through the Cabot Station turbines as they move back downstream.

# 2.0 MATERIALS AND METHODS

*Upstream Movement Evaluation*

FirstLight proposes to collect and radio tag a total of 250 early migrating adult shad at Holyoke Dam and monitor the movements of the tagged fish with a combination of Orion and Lotek receivers. The adult shad tagged at Holyoke Dam will be returned to the Connecticut River just upstream of Holyoke Dam. The monitoring equipment will be deployed and calibrated to inform on the effects of migration routes and behavior. The monitoring equipment will be deployed prior to the arrival of adult shad at Cabot Station. The study is planned for an approximate 4-week period encompassing the peak migration period, the month of May; however, the schedule may be adjusted based on river conditions and the timing of the adult shad run in 2019. Shad passage at the Holyoke Dam, located downstream of the study area, will be monitored to determine the exact timing of the 2019 study.

As shown in Figure 2-1, FirstLight proposes to release three bypass flow scenarios from the TFD, spillway fishway/attraction flow[1], and Station No. 1[2] for three consecutive days throughout the month of May. There would be one day of ramping on the day prior to large changes in flow releases. Some flexibility will be needed to make bypass flow changes "on-the-fly" based on the hydrologic conditions present.

**Figure 2-1: Proposed Bypass Release Schedule during Ultrasound Array Control Study**

**MAY**

| Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday |
|---|---|---|---|---|---|---|
| 28 | 29 | 30 | **1** | **2** | **3** | **4** |
| **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| **12** | **13** | **14** | **15** | **16** | **17** | **18** |
| **19** | **20** | **21** | **22** | **23** | **24** | **25** |
| **26** | **27** | **28** | **29** | **30** | **31** | 1 |

| | |
|---|---|
| | ramp day |
| | 4,400 cfs with 3,000 cfs (68%) from TFD and 1,400 cfs (32%) via Station No. 1 |
| | 4,400 cfs with 2,190 cfs (50%) from TFD and 2,210 cfs (50%) via Station No. 1 |
| | 6,500 cfs with 4,290 cfs (66%) from TFD and 2,210 cfs (34%) via Station No. 1 |

Assuming flows are within the control of FirstLight's facilities (Cabot = 13,728 cfs and Station No. 1 = 2,210 cfs), there will be a flow split between the magnitude of flow passed "upstream of Station No. 1" and from Station No. 1 itself. Per current water use agreements, TF Hydro and PaperLogic (other users of Turners Falls canal water) currently only operate when the hydraulic capacities of Cabot Station and Station No. 1 (collectively 15,938 cfs) are exceeded. Consideration was given to having these two facilities provide

[1] In Figure 2-1, the TFD flow is the sum of spill plus the Spillway ladder flow and attraction flow.
[2] The full hydraulic capacity of Station No. 1 is 2,210 cfs

a portion (approximately 402 cfs collectively) of any future bypass flows upstream of Station No. 1. However, for purposes of the 2019 study, TF Hydro and PaperLogic will only operate after the Cabot and Station No. 1 discharge capacity is exceeded, thus they will not provide any portion of the flow above Station No. 1. In addition, another flow source upstream of Station No. 1 is the Fall River. Because there currently is no United States Geological Survey (USGS) gage or equivalent on the Fall River, we have assumed for purposes of the 2019 study that it will not contribute to the flow upstream of Station No. 1. Thus, the main two sources of flow upstream of Station No. 1 will be provided from the Spillway Ladder fishway flow/attraction flow (equates to ~ 320 cfs) and from spill over Bascule Gate No. 1. If flows exceed the hydraulic capacities of the Cabot Station and Station No. 1 (and TF Hydro and PaperLogic), then the additional flow will be passed at Bascule Gate No. 1, followed by other conveyance structures if the flows continue to rise.

Relative to the flow split (i.e., the percentage of the total bypass flow provided by Station No. 1 versus the Spillway Ladder fishway flow/attraction flow and spill from Bascule Gate No. 1), in the 2018 study approximately 33% of the bypass flow came from Station No. 1 and the remaining 67% from the Spillway Ladder fishway flow/attraction flow and spill from Bascule Gate No. 1 Results of the 2018 ultrasound study demonstrated that the 2:1 flow split was successful at moving fish to the Spillway Ladder. In 2019, FirstLight will test flow splits of 2 (spill):1 (Station No. 1) for different total bypass flows (4,400 and 6,500 cfs) and 1 (spill): 1 (Station No. 1) for different total bypass flow of 4,400 cfs in accordance with the schedule in Figure 2-1.

At the end of the study, FirstLight will provide the following hourly data: total naturally routed flow[3], TFD spill (and from which gate), Station No. 1 generation (to be converted to cfs), and Cabot Station generation (to be converted to cfs). Having this information will inform parties if the 33%/67% and 50%/50% flow splits are achieved when flows are within the operational capacity of the Project.

As a frame of reference, the estimated May flows at the TFD over the period of record in 10% exceedance increments are shown in Table 2-1.

**Table 2-1: Estimated Turners Falls Dam Flows in May in 10% Exceedance Intervals**

| **Exceedance Interval** | **10%** | **20%** | **30%** | **40%** | **50%** | **60%** | **70%** | **80%** | **90%** |
|---|---|---|---|---|---|---|---|---|---|
| Flow (cfs) | 42,000 | 32,000 | 27,000 | 22,000 | 19,000 | 17,000 | 14,000 | 11,000 | 9,000 |

A total of 250 adult shad will be collected from the Holyoke Dam fish lift; tagged and released upstream of the Holyoke Dam. These 250 shad will be released in five batches of 50 fish in early May.

Each test shad will be tagged with a radio tag. The radio tags will be appropriate for esophageal implantation and sized approximately as follows: 26 mm length, 9.6 mm diameter, and 4 g weight.

Radio tags are anticipated to transmit on several frequencies within the 148 to 151-megahertz band. The transmitters will employ a motion sensor and be configured such that the 3-second burst interval will shift randomly to minimize repeated collision of tags on the same frequency. The tag life will be no less than 90 days. Care will be taken to reduce the amount of time spent handling shad. Previous studies have shown that prolonged morphometric checks and measurements increase the probability that a tagged fish will fall back. At this time, FirstLight does not propose to sex or take any morphometric measurements of the fish used in the movement analysis, we will only determine if the fish is free of injury. Study fish will be captured, tagged, and returned to receiving waters immediately after tagging. To understand sex ratios and

[3] Naturally routed flow includes: Vernon discharge + Ashuelot River USGS Gage Flow + Millers River USGS gage flow.

morphometric characteristics of the spawning population, FirstLight will collect a separate representative sample of shad to observe and record individual's sex, length, weight, and overall condition.

Tagged shad will be monitored using a combination of aerial Yagi antennas, in-water antennas (e.g., dipoles or stripped coaxial cable antennas) and mobile tracking. Antenna type and size will vary depending on site-specific constraints. Telemetry antennas will be deployed as either a singular antenna or grouped together. Prior to the anticipated tagging of American Shad, monitoring equipment will be deployed at the Project and calibrated.

Data-logging receivers will be connected to either a single antenna or antenna arrays as necessary. Date, time of day, tag frequency (i.e., channel), tag pulse code (unique to each tag), signal strength, and detection location (i.e., antenna number) will be stored for each signal reception. Data will be downloaded from receivers weekly.

Twenty-four monitoring stations are proposed for this study (Table 2-2) as shown in Figures 2-2, 2-3, and 2-4 (note Station T23, located at a bridge downstream from the Project, is not depicted on the figures).

**Table 2-2. The proposed radio telemetry monitoring stations for the 2019 shad movement evaluation at the Turners Falls Project.**

| Monitoring Station ID | Location |
|---|---|
| T01 | Montague Wastewater Treatment Plant (Yagi) |
| T02 | Entrance to the Deerfield River (Yagi) |
| T03E | Downstream End, East Channel of Smead Island (Yagi) |
| T03W | Downstream End, West Channel of Smead Island (Yagi) |
| T04 | Left Side of the Cabot Station Tailrace (Yagi) |
| T05 | Right Side of the Cabot Station Tailrace (Yagi) |
| T06 | Cabot Ladder Entrance (Dipole) |
| T07 | Cabot Station Far Field (Yagi) |
| T08 | Conte Discharge Area (Yagi) |
| T09 | Rock Dam (Dipole) |
| T10 | Lower Left Channel Rawson Island (Yagi) |
| T11 | Middle Channel at Rawson Island (Dipole) |
| T12 | Left Channel at Rawson Island (Dipole) |
| T13 | Bypass Reach, Upstream of Rawson Island (Yagi) |
| T14 | Bypass Reach, Downstream of Station No. 1 (Yagi) |
| T15 | Bypass Reach Upstream of Station 1 (Yagi) |
| T16 | Spillway Ladder Entrance (Dipole) |
| T17 | Spillway Ladder Vicinity (Yagi) |
| T18 | Cabot Station Forebay (Yagi) |
| T19 | Log Sluice (Dipole) |
| T20 | Copley Tunnel (where canal widens – Yagi) |
| T21 | Nourse Farms Greenfield (Yagi) |
| T22 | Hatfield Wastewater Treatment Plant (Yagi) |

| Monitoring Station ID | Location |
|---|---|
| **T23** | **Route 202 Bridge Holyoke, MA (Yagi)** |

*Downstream Movement Assessment*

FirstLight proposes to tag 200 American Shad at the exit of Cabot Ladder in May and release them in the canal. The downstream directed movements of all tagged fish (Holyoke and Cabot releases) as they approach, and pass Cabot Station will be monitored and assessed with a combination of mark-recapture methods and time-to-event modeling. Fish that were captured and tagged at the Cabot Ladder exit to return days or weeks later will more than likely have spawned and will be emigrating. Another group of at least 20 euthenized fish will be tagged and released via the log sluice during a high and low Cabot operating scenario and their movements tracked downstream. FirstLight intends to track this specific cohort of dead fish to track their float downstream because we are ensured they were dead upon tagging and of their starting location. Mobile tracking to recover all or most dead fish to assess immediate and latent mortality will occur in the stretch of river once per week between Hatfield WWTP and the entrance of the bypass reach at the Cabot Station discharge.

In 2015, FirstLight tagged 100 fish during their migration at the exit of Cabot Ladder and found that 17 immediately fell back. Of the 83 remaining Cabot released fish, 36 were recaptured trying to emigrate from the Cabot Canal. Of those 36 fish, 12 exited through the powerhouse, 21 via the sluiceway, 1 did not escape, and 2 escaped via unknown routes. Overall, 77 fish escaped the canal in 2015 from 3 different release locations, 39% escaped through the powerhouse, 45% through the log sluice, 5% did not escape and 10% escaped via unknown routes. Overall, we should expect approximately 1/3 of the tagged fish released at Cabot to eventually escape the Cabot canal via the Cabot powerhouse. Based on previous work about 1/3 of the fish are expected to return to Cabot Station; therefore, out of a sample of 200 fish we should expect 66 fish to return.

# 3.0 DATA ANALYSIS AND REPORTING

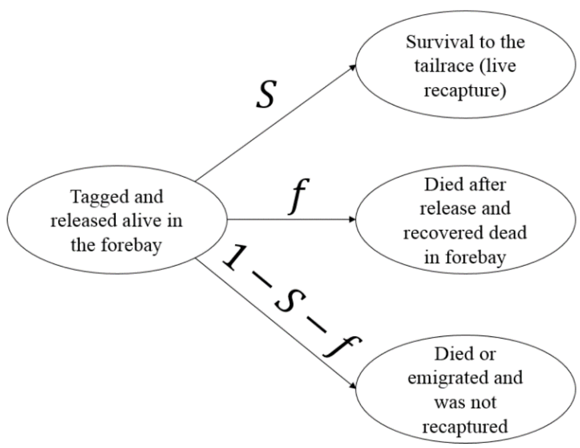
Radio telemetry data and fishway counts will be analyzed to determine the proportion of shad that continue past Cabot Station and up the bypass reach. It is not our intention to conduct a time series analysis of the fishway data. The telemetry data will allow for a quantitative assessment of the behavior of shad if assessed within a competing risks framework using Cox Proportional Hazards (CoxPH) regression to understand what conditions make transition from one state to the next more likely. Within a competing risks framework, movement always occurs from a central location or spoke. A series of CoxPH models will assess movement within the Cabot Station tailrace, Cabot Station forebay, and choice of route at Rawson Island. Time-dependent covariates include the bypass flow (sum of Station No. 1 discharge and spill over TFD, TFD spillway fishway flow/attraction flow, the Fall River[4] and other discharges along the canal), Cabot Station discharge (cfs), diurnal (day/night), and water temperature.

The proportion of fish expected to arrive at the Spillway Ladder will be assessed with a Cormack Jolly Seber (CJS) mark recapture model. The proportion of fish expected to survive downstream passage through Cabot Forebay will be assessed with a live-recapture dead-recovery model. Live-recapture models, like the CJS, quantify the probability of an individual being detected (i.e., live-recapture) at a sampling location, and are determined with two parameters: the probability that the animal survives until the next sampling

[4] Flows on the Fall River will be estimated using a nearby USGS gage and adjusting the flows by a ratio of drainage area to represent the Fall River.

location, and the probability that it is alive and is recaptured at another location[5]. However, if a fish was not recovered, we are not sure of its final state; the fish may have emigrated from the study area without detection or it could have died. Live-recapture dead-recovery models differ from live-recapture models because they incorporate information from fish known to be dead. Fish are recovered in a dead-state with fixed and mobile tracking methods that use coded mortality radio-signals to identify dead fish.

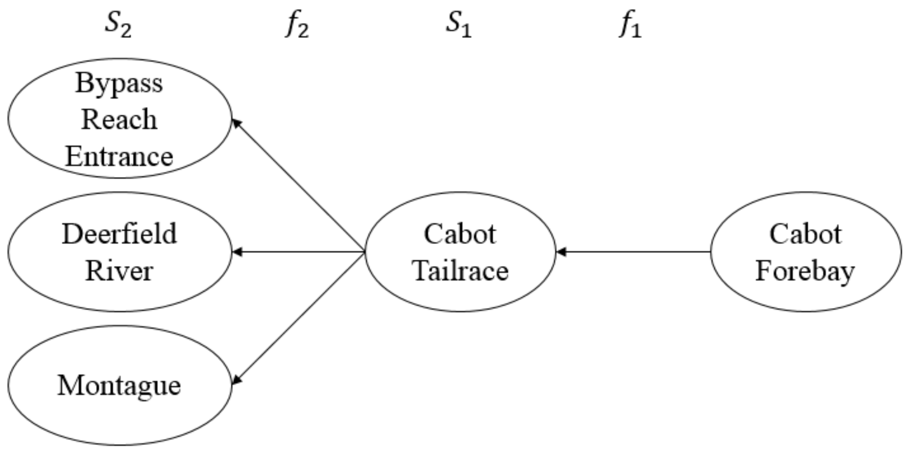
The software MARK employs the live-recapture dead-recovery method using the Brownie parameterization. To demonstrate, consider a fish that is tagged and released alive upstream of the Cabot forebay. The fish may experience 1 of 3 fates: (1) it can survive passage through Cabot Station and to the next downstream station with some probability $S$; (2) it can die and be recovered and reported dead via combination of mobile and stationary telemetry in the forebay with probability $f$; or (3) it can die or emigrate through the study area undetected with probability $1 - S - f$. Recovery data supplies information directly about those fish which die without passing through Cabot Station. The following diagram depicts the possible fates of a fish up to the first live recapture location:




Where $S$ is the probability of surviving from location (i) to location (j), and $f$ is the recovery rate, which is the probability of dying, being retrieved via telemetry, and reported. So, $f$ combines the mortality event with two other events (retrieval and reporting). We will always report fish that died as long as we can retrieve them; therefore, the reporting probability is always 1.0. Thus, the higher the retrieval rate, the better our estimate of initial forebay-mortality. Recovering dead fish between receiver detection zones with mobile tracking is paramount, as the higher the recovery rate, the better our estimate of true survival $S$. FirstLight will also optimize fixed stations to maximize detection ranges and minimize the potential for receiver outages. FirstLight will construct a separate live-recapture dead-recovery model for those fish that pass through the turbines and those that pass via the log sluice.

FirstLight will assess immediate survival to the next live-recapture location in the telemetry network, which is given with:

[5] Cooch, E., & White, G. (2001). Using MARK: a gentle introduction. Ithaca, NY: Cornell University.




Where $f_1$ is the probability of a fish dying in forebay, being recovered with mobile or fixed telemetry equipment and being reported; $S_1$ is the probability of surviving until the next downstream station (which happens to be the Cabot tailrace); $f_2$ is the probability of dying within the stretch of river between Cabot tailrace and the next telemetered reach, being recovered via mobile or fixed telemetry equipment and being reported; and $S_2$ is the probability of surviving and being recaptured alive at the next telemetry station in the telemetry network, whether that be at the Conte discharge, the Deerfield River, or downstream at Montague. Latent mortality will be assessed in the stretch of river from Montague to Hatfield where $f_3$ is the probability of dying within the stretch of river between Montague and Hatfield and $S_3$ is the probability of being recaptured alive at the southern end of Hatfield (Monitoring Station T22, Hatfield WWTP).

With this method, latent mortality will be assessed within the stretch of river between the tailrace and the next telemetered reach in the telemetry network (Hatfield). After tagging, this study method tracks fish via passive measures; whereas traditional turbine passage survival studies with balloon tags require extra capture and handling effort be placed on the fish, including removing the fish from the water, assessing condition, and placing them in a tank for observation. Given the delicate nature of the fish, extra handling pressure may cause undue mortality, biasing our estimate of latent mortality.

Thus, number of fish assessed will more than likely be less than 200 tagged at the exit to Cabot Ladder as it is assumed this population is still migrating upstream to spawn and not all will survive to emigrate. The first recapture occasion will be within the immediate Cabot Station tailrace and is intended to ascertain true survival through Cabot Station. The second recapture occasion will be the set of receivers that make up the immediate neighbor of the tailrace receiver (bypass reach entrance, Deerfield River, and Montague wastewater), immediate mortality is assessed between the tailrace and these receivers. The third live-recapture occasion will be the Hatfield WWTP, and latent mortality will be assessed in the stretch of river from here to Montague.

A report will be prepared detailing methods, results, a discussion and conclusions. The report will be completed by October 15, 2019.

# Figures

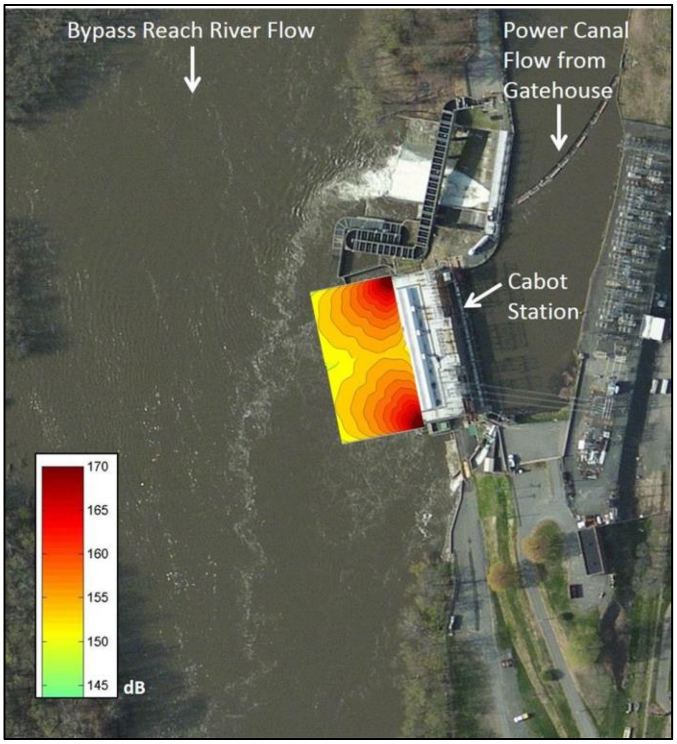



Figure 1-1. Sound field from the 2016 Ultrasound Study.


Figure 1-2. Sound field from the 2018 Ultrasound Study.

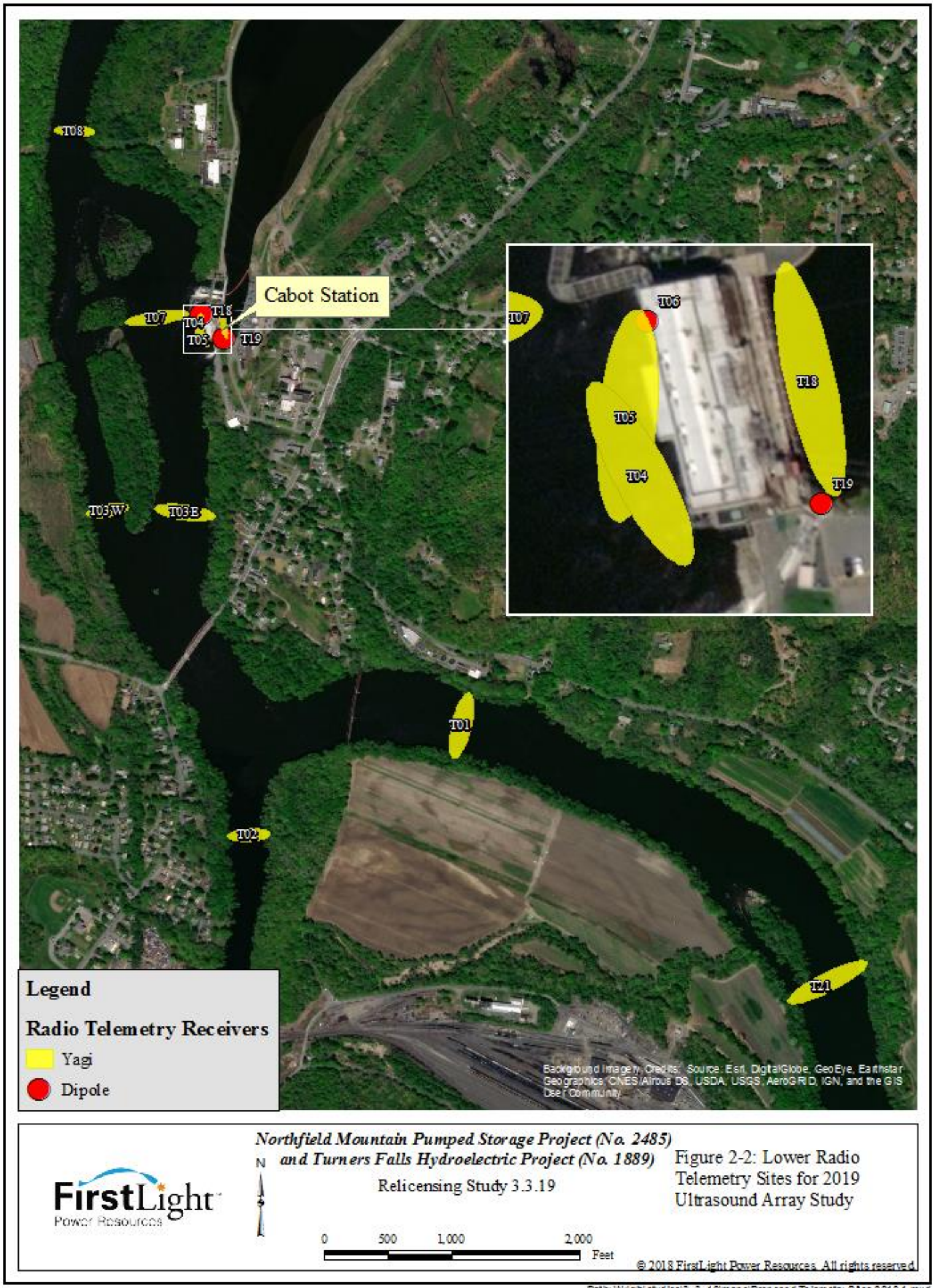



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Figure 2-3: Radio Telemetry Sites Near Rawson Island for 2019 Ultrasound Array Study

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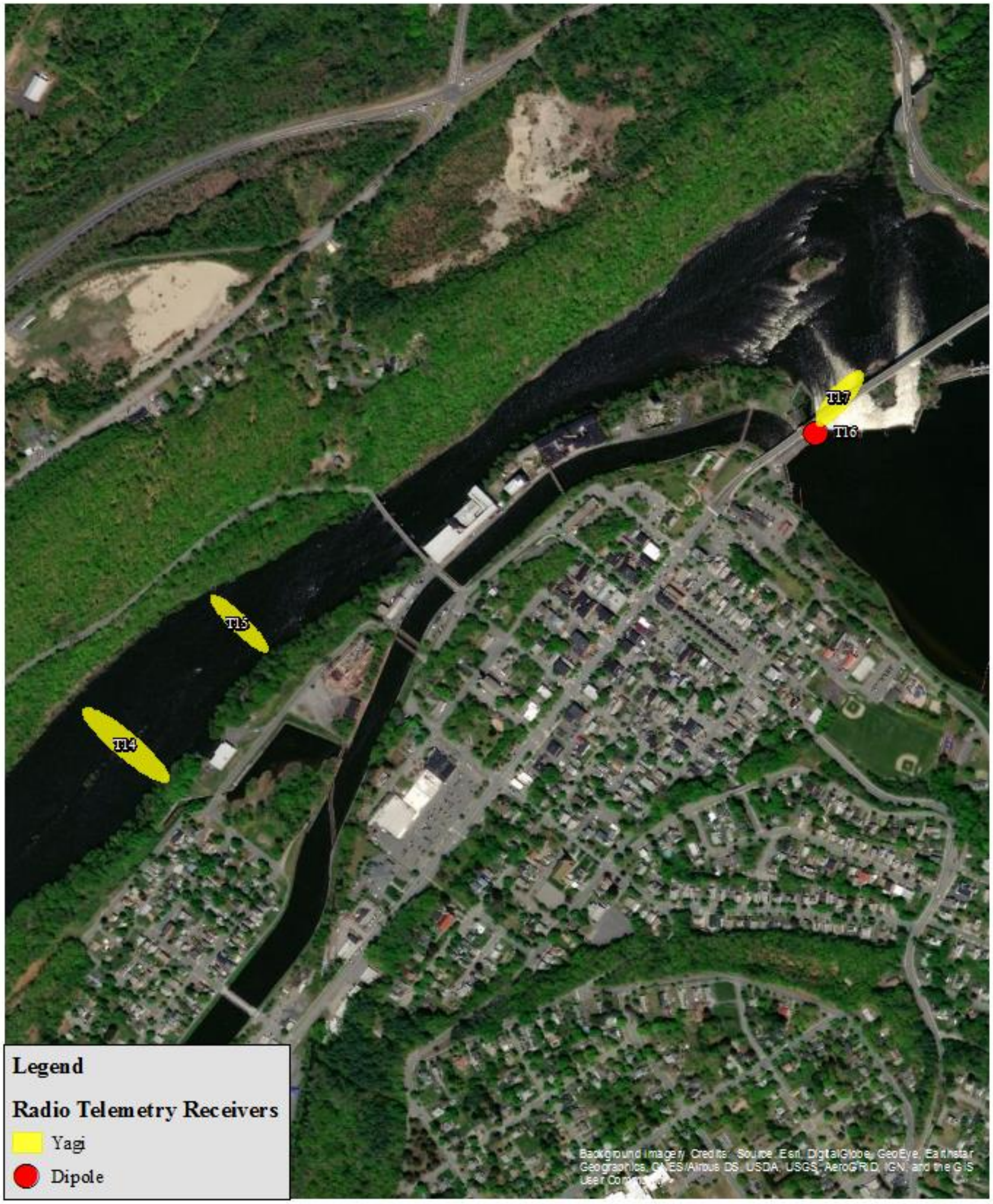


*Northfield Mountain Pumped Storage Project (No. 2485)*
*and Turners Falls Hydroelectric Project (No. 1889)*

Relicensing Study 3.3.19

N

0 375 750 1,500 Feet

Figure 2-4: Upper Radio Telemetry Sites for 2019 Ultrasound Array Study

FirstLight Power Resources



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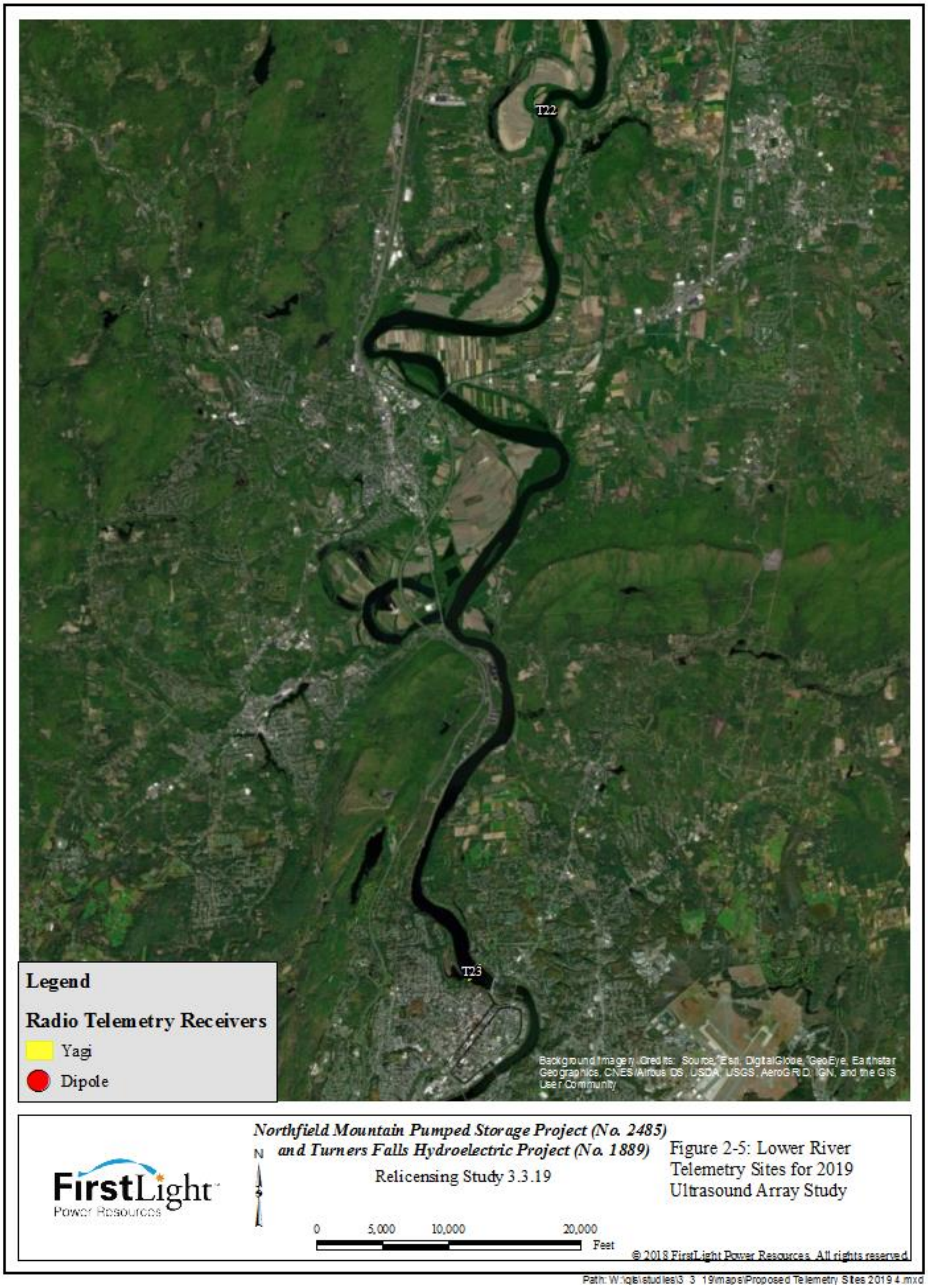


Figure 2-5: Lower River Telemetry Sites for 2019 Ultrasound Array Study