November 15, 2016

VIA ELECTRONIC FILING

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: FirstLight Hydro Generating Company, FERC Project Nos. 2485 and 1889
October 31 and November 1, 2016 Study Meeting Summary

Dear Secretary Bose:

Pursuant to the schedule set forth in the Federal Energy Regulatory Commission's (FERC or Commission) Revised Process Plan and Schedule (Revised Schedule) issued May 5, 2016 for relicensing the Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project, FirstLight Hydro Generating Company (FirstLight) filed ten study reports and three addenda on October 14, 2016. Pursuant to the Revised Schedule, on October 31 and November 1, 2016, FirstLight held meetings to discuss the ten reports filed on October 14, 2016. Attached as Attachment A is FirstLight's meeting summary for both days.

In addition to the meeting summary, attached as Attachment B is the PowerPoint presentation made at the October 31 and November 1, 2016 meetings. FirstLight is filing its meeting summary and PowerPoint presentation with the Commission electronically. To access the document on the FERC website (http://www.ferc.gov), go to the "eLibrary" link, and enter the docket number, P-1889 or P-2485, to access the document. FirstLight is also making the same available for download at the following website: http://www.northfieldrelicensing.com.

Sincerely,

Gus Bakas

Attachment A: Meeting Minutes
Attachment B: PowerPoint Presentation

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ATTACHMENT A: MEETING SUMMARY

Location: Northfield Mountain Visitors Center, Northfield, MA

Date: October 31, 2016

Attendees:

Federal Energy Regulatory Commission
Patrick Crile
Nick Ettema (phone)
Brandon Cherry
Steve Kartalia (phone)
Bill Connelly

United States Fish and Wildlife Service
John Warner
Melissa Grader
Ken Sprankle
Julianne Rosset (phone)

USGS Conte Lab
Alex Haro
Ted Castro-Santos

National Marine Fisheries Service
Bill McDavitt
Bjorn Lake
Jeff Murphy (phone)
Sean McDermott

Massachusetts Division of Fish and Game
Caleb Slater
Jessie Leddick
Misty Anne Marold
Peter Hazelton

Crab Apple Whitewater
Frank Mooney

Appalachian Mountain Club
Norm Sims

American Whitewater
Bob Nasdor

Foley Hoag
Adam Kahn (phone)

BioDrawversity
Ethan Nedeau

Kleinschmidt Associates
Chris Tomichek
Kevin Nebiolo
Bryan Apell
Brandon Kulik

Van Ness Feldman
Julia Wood
Mike Swiger

FirstLight
Doug Bennett
Don Traester
Jim Donohue
Gus Bakas
Joe Lucas
Len Greene
Bob Stira

Massachusetts Department of Environmental Protection
Lealdon Langley

The Nature Conservancy
Katie Kennedy

No Affiliation
Don Pugh
Karl Meyer
Fred Errington

Connecticut River Watershed Council
Andrea Donlon
David Deen (phone)

Hampshire College
Sanon Rosen

Gomez and Sullivan Engineers
Tom Sullivan
Gary Lemay
John Hart
Kirk Smith
Jason George
Mark Wamser

Introductions, Meeting Purpose and Process Timeline

In advance of the meeting, the PowerPoint presentation (Attachment B) was posted to the FirstLight website and stakeholders were notified accordingly.

Mark Wamser (Gomez and Sullivan) opened the meeting and welcomed everyone. Mark asked everyone to introduce themselves. Mark noted that there were lots of studies to cover in the next 1.5 days, and that he was going to make an effort to stick to the agenda. He noted that the only studies being discussed were the 10 studies that were filed with FERC on October 14, 2016. He noted that seven studies would be reviewed today and the remaining three would be discussed tomorrow. Mark reviewed the FERC schedule relative to when stakeholder comments are due, when FirstLight (FL) responds to comments, and when FERC will issue its Determination.

Andrea Donlon (Connecticut River Watershed Council) asked about Odonate Study and when the study plan would be posted. Mark explained that the second year of field work was conducted by FL on its own due to the lower numbers of odonate observations detected in 2014 and that a study plan was not developed. Andrea noted that there was supposed to be an analysis of the Turners Falls Impoundment (TFI) and odonates in the original report. She asked if the revised report (2nd year of the study) would address this issue. Jason George (Gomez and Sullivan) indicated that FL is looking at the water level fluctuations in the TFI, and indicated that there were observations made at two sites in the TFI in 2016. The 2016 survey sites were selected in consultation with MA NHESP. The additional year of field work associated with icthyoplankton entrainment at Northfield Mountain (NFM) was also briefly discussed as it was additional field work that FL decided to do on its own. Mark and Jason stated that at this point they do not plan to have a study meeting for the addendums which will be filed in December 2016.

Bill McDavitt (National Marine Fisheries Service) asked about the juvenile shad study and whether comments on the study plan are due. Mark indicated that if the study is conducted in the fall of 2017, FL would reach out to stakeholders to finalize a study plan.

Study No. 3.3.1- Instream Flow Study in Bypass Reach and below Cabot

Kirk Smith (Gomez and Sullivan) reviewed the instream flow study results. He explained that the study entailed approximately 36 miles of river that were divided into five study reaches- Reaches 1-5. Kirk reviewed the geographic extents of Reach 1, Reach 2A, Reach 2B, Reach 3, and Reach 4. Reach 2 was subdivided into two sections—Reach 2A which was a 1D hydraulic model and Reach 2B which was a 2D hydraulic model. Reach 3 extends from Rawson Island to the Montague USGS Gage. Reach 4 (1D hydraulic model) extends from the Montague USGS Gage to the Sunderland Bridge (Route 116 Bridge).

Relative to Reach 1, Kirk reviewed five components as follows:

- Analysis of the plunge pool.
- Left Channel- a transect was placed at the most limiting barrier to fish passage. A zone of passage evaluation was conducted in the left channel.
- Center Channel – a HEC-RAS hydraulic model was conducted to evaluate the hydraulics in this channel. Kirk noted that the center channel has limited value in terms of habitat, and thus was assessed relative to fish passage.
- Right Channel- a habitat assessment using PHABSIM was conducted which included one transect.
- A habitat assessment was conducted in Reach 1 at Transects T-10 and T-11 located upstream of the Station No. 1 tailrace.

Bill McDavitt asked if FL apportioned the flow among the channels based on the bascule gate release. It was explained that flow was measured (gaged) at three locations including the Fall River, the outlet of the plunge pool, and the Right Channel. Then, based on the known releases from the bascule gate, flows through the Left and Center Channels were calculated.

Kirk showed the wetted area and volume versus flow at the plunge pool. He also reviewed a transect in the left channel showing the depth and wetted width of water under flows of 500, 1,500, 2,500 and 4,000 cfs (relative to zone of passage).

Kirk showed the mean column velocities of five transects through the center channel under four flows relative to the sustained and burst speed of adult shad. Kirk indicated that for the three center transects, the mean column velocities exceed the sustained swimming speed for all four flows. He noted that the cruising swim speed of adult shad was not shown on the plot, but the literature suggests it is approximately 7 feet/sec. Relative to the single transect in the right channel, Kirk reviewed the steady state habitat results. A table was presented showing for each target species the maximum weighted usable area (WUA) as well as the percentage of peak WUA provided at various flows. Melissa Grader (U.S. Fish and Wildlife Service) sought clarification that the column labeled as maximum WUA total flow represented the total flow release and the column labeled as maximum WUA flow was for the right channel flow only. Kirk confirmed that this was correct noting that the total flow included flow released from the bascule gate, plus the fishway release flow, plus the measured 49 cfs from the Fall River.

Kirk reviewed the same steady state habitat results table for Transects T-10 and T-11 of Reach 1. He explained that two scenarios were evaluated—a high backwater when Station No. 1 is operating and low backwater when Station No. 1 was not operating. For most species there was not much a difference in the shape of the WUA versus flow curves between the low and high backwater. He then reviewed the same steady state habitat results table for Reach 2 (which combined the results for Reach 2A, a 1D hydraulic model and Reach 2B a 2D hydraulic model).

Kirk noted that the Reach 3 hydraulics are influenced by the bypass flow (including Station No. 1 operation), Cabot operations and the Deerfield River flow. He explained that for the steady state habitat assessment various scenarios were assessed as shown below.

Scenario	Bypass Q	Cabot Q	Deerfield River Q
1	120, 200, 300, 500, 700, 1,000, 2,000, 3,000, and 5,000 cfs	2,500 cfs	200 cfs
2	Same as Scenario 1	7,000 cfs	200 cfs
3	Same as Scenario 1	14,000 cfs	200 cfs

Kirk noted that based on discussions in September with the stakeholder group, FL narrowed the number of combinations as a first cut. He noted that further discussion with stakeholders may be necessary to identify the other scenarios that they may be interested in. Mark Wamser indicated that we will need to convene a stakeholder meeting to discuss not only the other scenarios but also habitat time series. Andrea Donlon asked if the meeting would occur before comments are due on the study reports (due by December 15, 2016). Mark Wamser indicated that FL would strive to have the meeting before that date.

The analysis in Reach 3 included a steady habitat assessment, persistent habitat mapping, and habitat time series. Kirk noted that the habitat time series still needs to be completed and will be included in an addendum to the report.

For Reach 3, Kirk reviewed example steady state habitat result maps for American shad spawning and incubation. He reviewed two types of plots showing the WUA curves based on combinations of Cabot discharges, bypass flows and a constant flow of 200 cfs from the Deerfield River. Don Pugh noted that the color on the steady state WUA curves was difficult to read.

Kirk then reviewed example steady state habitat result findings showing composite suitability index map for American shad spawning and incubation. The map was colored coded for composite suitability ranges of 0-0.25, 0.25-0.5, 0.5-0.75 and 0.75-1. Kirk showed an example persistent habitat map for American shad spawning and incubation under two different Cabot discharges of 2,500 cfs and 14,000 cfs (and under a single bypass flow of 500 cfs. Kirk explained that “quality habitat” shown on the maps was determined to be a combined Suitability Index value greater than 0.5. Don Pugh asked if persistent habitat maps could be developed for higher bypass flows. Kirk indicated yes. Kirk said that tables were provided in the report, which include the actual square footage of persistent habitat. In yellow is the quality habitat for Scenario 1 (Cabot Q -2,500 cfs). In blue is the quality habitat for Scenario 2 (Cabot Q-14,000 cfs). The overlapping or green habitat shows the persistent habitat. [Correction: At a break in the meeting, John Warner (U.S. Fish and Wildlife Service) questioned if the color coding on the persistent habitat map was correct. In fact, he was correct and FirstLight will issue updated maps with the correct legend. The map coloring won't change; however, the yellow was for Scenario 2 (Cabot Q-14,000 cfs) and the blue was for Scenario 1 (Cabot Q-2,500 cfs). The overlapping green color is correct].

Jessie Leddick asked if persistent habitat maps were developed for yellow lampmussel since a relic was detected in Reach 3 years ago. Jason indicated that this work still needs to be completed.

Karl Meyer indicated that for the Reach 3 hydraulic model (specifically Rock Dam) it is important to note where flow in the bypass is coming from such as via the dam or Station No. 1. Tom Sullivan clarified that with the River2D model developed for Reach 2B and 3, it accounts for the magnitude of the flow input at the upper model boundary—the model does not discern the source(s) of the inflow.

Kirk explained that there were three components to the Reach 4 analysis- steady state habitat analysis, dual flow analysis and habitat time series. Kirk reviewed the same table showing the percentage of maximum WUA for various flows and life stage and species. Kirk reviewed an example habitat time series results for spawning, juvenile and adult American shad based on Montague USGS Gage hourly flows for the period Jan 1, 2000 to September 30, 2015.

He then summarized the work completed and outstanding.

Study No. 3.3.16- Habitat Assessment, Surveys and Modeling of Suitable Habitat for State-Listed Mussel Species in the Connecticut River below Cabot Station

Jason George reviewed the study objectives for the mussel study. He summarized the work completed to date which included a mussel survey and habitat assessment in 2014, which was completed with a report filing. He noted that no state-listed mussels were found in Reach 4. The second component of the study was to develop binary habitat suitability index (HSI) curves for three state listed mussels. He noted that three state-listed mussels were located in Reach 5 as follows: eastern pondmussel, yellow lampmussel and tidewater mucket.

Jason then reviewed the various rounds of developing the HSI curves with the panel of experts. The experts included Dr. David Strayer, Dr. Barry Wicklow, Dr. Cynthia Loftin and Ethan Nedeau while Jason George served as the moderator. A fifth panelist was invited but did not participate. The habitat parameters the panelist considered included: depth, velocity, substrate, cover, shear stress, relative shear stress. Jason said that there were three rounds of developing the binary HSI curves. Jason indicated that developing a number for shear stress and relative shear stress was difficult and, in the end, the panelists developed HSI criteria for depth, benthic velocity, substrate, and cover; panelists could not quantify a criteria for the relative shear stress in the river.

Melissa Grader noted that from Round 2, it appeared the moderator overrode the scoring. She indicated that she couldn't find consensus on the overrides and asked if we circled back with panelists. Jason George indicated that any changes made were sent back to the panelists for agreement/disagreement. Jason said that he has email documentation showing consensus of the panelists, and indicated that it could be provided.

Melissa noted that she read several comments on shear stress and asked why we did not include them. Jason indicated that he evaluated only high flows, since only at these high flows did shear stress seem to make a difference. Peter Hazelton asked how the panel could make a decision on the Cabot Station design flows if we only looked at high flows (1.5-year to 5-year flood flows). He asked what the relative shear stress would be at full Cabot discharge at the mussel beds.

Jason reviewed the binary HSI tables for benthic velocity, depth and velocity and then explained how the HEC-RAS hydraulic model was used to estimate depths and velocities in Reach 5. He explained that there were a total of 15 transects assessed for purposes of the mussel assessment and that the hydraulic model produces a mean column velocity, which was converted to benthic velocity using a model/formula from the literature. Jessie Leddick asked if field measurements were taken to validate that the measured benthic velocity was similar to that produced with the model/formula. Jason indicated that velocity data was collected under one flow and that the field equipment cannot be used to measure velocity immediately above the channel bed. Gary Lemay noted that an ADCP was used to measure velocity about 1 foot above the bed and then used a logarithmic velocity distribution to fit the existing field data, which was then used to develop the benthic velocity near the bed.

Jessie asked if it the velocity data was collected under one flow. Gary indicated yes, but did not know the exact flow although noted it was a low flow since the data was collected this past summer.

Jason reviewed the five flow scenarios that were assessed in the hydraulic model (Side 41) and then stepped people through the process of computing the percentage of cells along a transect that met the suitability criteria. For example, 65% may indicate that 13 of 20 cells across the transect are suitable for the given species and life stage of mussel. Jason indicated that a qualitative categorization was developed based on the percentage of cells that met the HSI criteria as follows:

- None (No effect)- 0%
- Minimal- up to 10%
- Low- 10-20%
- Moderate- 20-40%
- Moderate-High- 40-60%
- High- 60-80%
- Severe- 80-100%

Misty Anne Marold (Massachusetts Division of Fish and Wildlife) asked how the qualitative categorization was developed and noted that the percentages in each category are not equal. Jason indicated it was our best estimate of grouping, but we are open to categorizing a different way.

Jason reviewed the conclusions of the study.

John Warner noted that the analysis assumed that all of Reach 5 had suitable habitat. Given this, how can FL conclude that flow is not the issue? Jason noted that based on the aquatic habitat mapping conducted in 2013 the substrate was sand. Jason said that the substrate was assumed suitable to tease out the depth and velocity impacts. John Warner asked how this assumption be applied to presence and absence.

Andrea Donlon asked if Delphi panelists are considered neutral. Jason indicated that FL reached out to several panelists and those willing to participate were approved by Natural Heritage. Tom Sullivan indicated that we felt comfortable having Ethan Nedeau on the panel given his long history with mussel work in New England. Tom also noted that Ethan was only 1 of the 5 panelists and if there was disagreement it would have been fleshed out.

In regard to relative shear stress Jason indicated that the panelists recognize that it is important factor, but they could not quantify it into a binary suitability criteria. He noted that the state-listed mussels are large and can anchor into the substrate, thus mobilizing them would require scouring of the substrate. Peter Hazelton noted that this was based on adult mussels; it would take less relative shear stress to mobilize a juvenile mussel. He would like to see more relative shear stress analysis for juvenile mussels. Misty Anne Marold also noted that one needs to factor in the rate of change of flow as it takes time for the mussel to burrow into the substrate. She indicated that no rate of change information was in the report. Tom Sullivan indicated that in regard to relative shear stress, stakeholders involved in a similar study on the Susquehanna

River (Conowingo Project) had the same problem—they could not reach consensus on how to assess relative shear stress.

Misty Anne Marold asked who specifically wrote the memos that went to the panelists. Jason indicated he did after consulting with Ethan and others. Misty Anne questioned the impartiality of Delphi panel assessment. He also indicated that the memos covered far more information than the habitat suitability information covered by the panel. Tom explained that the panelists were vetted by Natural Heritage and the method for conducting the Delphi assessment was explained in the study plan.

Study No. 3.3.2- Evaluate Upstream and Downstream Passage of Adult American Shad

Two people presented the adult shad study- Bryan Apell (Kleinschmidt) went through the study objectives and field component of the study and Kevin Nebiolo (Kleinschmidt) went through the data analysis.

Bryan indicated in March 2015, FL installed 29 radio telemetry and 14 PIT monitoring stations. He reviewed the maps showing the location of the radio telemetry system (Slides 49 and 50). Bill McDavitt asked if the fish detected at T-11 are considered to "encounter the Project". Kevin Nebiolo indicated yes, it is included in his model. Bill McDavitt asked where in the Northfield Mountain (NFM) tailrace the yagi was located. Bryan said the antennae was on the south side aimed at a 45 degree angle.

Don Pugh asked about the gatehouse ladder—do you consider "starting" at the new entrance as opposed to the vertical slot. Kevin indicated anywhere between P31 and P33.

Karl Meyer asked where the Station No. 1 antennae was located. Bryan indicated that a double yagi antenna was mounted on 20-foot pole on the backside of the Station No. 1 Powerhouse. Bryan indicated that the antennae was able to detect the entire channel and extends about 2/3rds across the bypass reach.

Bryan reviewed the model for the telemetry network starting downstream, including the fishways, and upstream to Turners Falls Impoundment. He explained that tagging was conducted over 12 days in May and June, 2015. The total number of tagged and released fish was 793 fish, including 397 double tagged fish and 396 PIT tagged fish. Bryan also reviewed TransCanada's number of tagged shad—an additional 154 fish were added to the overall sample size from the TransCanada study.

He explained that other operational data was obtained during the field study including temperature, dissolved oxygen (DO), and flow on a 15-minute interval.

Kevin Nebiolo then reviewed the results indicating that there were five main statistical approaches as follows:

- Hot Spot analyses
- Multi-State Markov Model (MSM)
- Cox Proportional Hazards
- Cormack-Jolly-Seber
- Catch Curve analysis for mortality

Ted Castro Santos (U.S. Geological Survey) asked if the MSM is conditional on movement happening. Kevin indicated yes it is conditional on movement.

Kevin explained that the analysis took a geographic approach starting downstream- below Cabot, and moving upstream to TFI, and then downstream for post-spawned adult shad. For each subnetwork model (such as Holyoke to Project, Montague Spoke, Cabot Ladder Attraction, etc.), Kevin reviewed the analysis objectives and the analytical method (see Slides 56-58 of the presentation).

Kevin indicated that a 3-step reduction and false positive removal was conducted between fall 2015 and spring 2016. The three steps included Naïve Bayes classifier algorithm, SQL database reduction (MS Access) and Visual Inspection. He noted that in July 2016 there was a data dissemination meeting for interested stakeholders. He summarized the stats involved with the project—1,034 tagged fish in the spring 2015, over 19M records that were reduced to 16M records.

Don Pugh asked when reducing the data how FL dealt with single detections with yagis. Kevin noted that he looked at each receiver and based on professional judgment made the decision that if that fish was there, it stayed in. Ted Castro Santos asked if Naïve Bayes was applied to each antenna. Kevin indicated yes.

Bjorn Lake (National Marine Fisheries Service) asked of the 215 shad at Holyoke, did FirstLight look at early versus late season fish. Kevin indicated no.

Relative to Slide 63: Cabot Ladder Attraction, Don Pugh asked if fish were attracted to the proximity or the entrance to the ladder. Kevin indicated that if we picked up a fish at T7 (dipole for Cabot) it was concluded that the fish was in the ladder.

Karl Meyer stated that when Station No. 1 is operating fish stack up (resulting in potential delay) and suggested that information on Station No. 1 discharges are missing from the study.

Relative to Slide 64: Cabot Ladder Attraction, Don Pugh asked if 7.55 hours starts when they arrive at Montague. Kevin indicated yes.

Kevin indicated that the entrance and internal efficiency of the Cabot ladder (Slide 65) was 68% and 15.3%, respectively, for an overall efficiency of 10.2% (product of entrance and internal efficiency). The time to event analysis showed that all fish that passed did so within 40 hours.

Relative to Slide 66: Bypass Reach, Bill Connelly asked if there were poor detection strings. Kevin indicated yes, 59% were dismissed. Bill noted that it may be worth relooking at how many fish were retained or thrown out at Rock Dam.

Kevin reviewed the spillway attraction findings indicating that the probability that an adult shad survives, transitions from the spillway and is detected within the spillway ladder is 65% at a low flow (2,569 cfs) and drops to 41% at a high flow (6,226 cfs). He then reviewed the findings of the spillway ladder entrance efficiency, which was 91%, and the overall ladder efficiency, which was 32.7%.

Bill McDavitt asked if the eel ladder was deployed in the Spillway ladder in 2014. It was noted that it was deployed, but not until the adult shad study was over.

Andrea Donlon noted that in the past there were not many fish reaching the Spillway ladder, but during the adult shad study there was more water passed in the bypass reach hence more fish at the Spillway ladder.

Kevin noted that overall gatehouse ladder efficiency was 76.9% and the internal efficiency was 91%.

Kevin also noted that no fish were detected in the Upper Reservoir.

Ken Sprankle noted that for survival/mortality, he would like to see these categories broken out in tabular form as opposed to a rate.

Don Pugh asked if we knew the flow during the route selection data analysis at the TF Dam and how many fish were present during each event. Kevin said we would have to look into this.

Ted Castro-Santos suggested that in the report we use different terminology for the downstream fish bypass and the bypass channel. Kevin agreed and stated the downstream fish bypass is also referred to as the sluiceway.

Don Pugh requested tables showing the numbers of fish.

Bob Stira noted that telemetry data has some limitations. He compared passage counts with passage efficiencies.

Ted Castro Santos wanted clarification that the entrance to the log sluice was station T-9.

Andrea Donlon noted that Karl Meyer had requested a hydraulic study of power canal that FERC dismissed early on. She asked Kevin if he had a sense of how the hydraulics impacts fish. Kevin replied no.

Bob Stira noted that in reviewing these findings we need to be aware that there is a tagging effect on fish. He noted that this study showed it took approximately 10 days for fish released at Holyoke to appear in the Turners Falls Project area, which is longer than past studies have shown.

Study No. 3.3.3- Evaluate Downstream Passage of Juvenile American Shad

Bryan Apell presented the downstream juvenile shad study findings. Bryan reviewed the work that was completed that included using a combination of techniques including hydroacoustics, radio telemetry and HI-Z Turb'N tags. He showed drawings of Cabot intake and indicated that 10% of the intake area was sampled with the hydroacoustics. There were 4 transducers located at the bottom of the canal that pointed in an upward direction that sampled approximately 9% of the canal area. At the NFM intake, transducers were placed in front of the trash racks and measured 24% of the intake area.

In addition to hydroacoustics, verification sampling was also conducted at the Cabot Station bypass sampler over several discrete (15) events to determine the species identity of targeted observed in the hydroacoustic data, which was compared to the proportion of juvenile shad passing via the downstream bypass sampler. Sampling was conducting during the evening hours beginning on September 9, 2015 and continuing until October 28, 2015.

Bryan noted that the location of the hydroacoustic equipment at NFM and in the power canal did not allow for data reduction to accurately estimate the run timing, duration and magnitude or entrainment of juvenile shad. Thus, some of the study objectives could not be accomplished. Bryan explained that at these two locations fish were engaging in milling behavior rather than moving in a downstream direction. He noted that this behavior reduces the ability of the hydroacoustic equipment to enumerate individual targets and would yield an overestimation as fish could move in and out of the beam multiple times.

Melissa Grader noted that the report states milling at NFM was due to low velocities and questioned why milling was not exhibited at Cabot station where velocities were lower. Bryan explained that velocities at the Cabot Station intake rack were likely lower than those at the NMPS intake rack but not where monitoring occurred at Cabot. The hydroacoustics were positioned behind the trash racks and at the precipice of going into the penstock where velocities were much greater and fish were committed.

Don Pugh asked if we would be able to look at the milling in the canal as an index of fish as opposed to counting fish to get an indication of run timing. Bryan stated that the data from Cabot Station is likely the best estimate of run timing.

Relative to entrainment at Cabot Station (Slide 88), Bryan indicated that about 1,660,166 shad -sized targets were estimated to be entrained at Cabot Station between August 1 and November 14, 2015. He also noted that almost half (46%) of the overall estimate was attributed to fish moving through Unit 6, yet it was operated less than Units 1 or 2 over the study period. Bill Connelly asked if there was a rationale as to why fish would move more through Unit 6; Bryan speculated that perhaps the wall leading up to Unit 6 could potentially play a role.

Bryan stated that based on concurrent observations at the bypass sampler and Cabot Station intake, it was estimated that an average of roughly 43% of juvenile shad exit the canal via the downstream bypass and 57% are subject to entrainment at Cabot Station. These results were contradictory to earlier studies conducted in the early 1990, which estimated much higher bypass efficiency. Diel movement was investigated at the Cabot Station intake using hydroacoustics methods. Shad size targets were observed to be entrained during each hour of the day at Cabot Station but were most prevalent during the afternoon and evening hours, with a peak of 20:00.

Bryan noted that the entrainment findings from this study are different from earlier studies. Melissa Grader asked if there were any operational or structural changes between the older and current studies. Bryan indicated that Cabot turbines were swapped out to gain electrical capacity, but that there was no change in the flow capacity. Relative to operations, Doug Bennett (FL) indicated that deregulation did not have an impact on the timing of generation at Cabot.

Don Pugh requested the operational data for Cabot generation, Station No 1 generation, and Turners Falls Dam spill for the period the study was conducted. FirstLight agreed to provide the data.

Andrea asked if the study was conducted when Unit 4 at NFM was operational. Bryan indicated no, Unit 4 was out of operation during the study.

Melissa asked how we would overcome using hydroacoustics at NFM to get a better idea of the number of fish entering the intake. Bryan stated that ideally the hydroacoustics would be placed further down the intake tunnel such that fish would be committed at this point; however, after many discussions with FL it is not possible to access that area due to safety and engineering logistics issues.

Bjorn Lake asked when milling was occurring. Bryan indicated that only data collected during pumping and idle (i.e. the absence of generation or pumping) was analyzed due to limitations of entrained air during the generation cycle. The milling was only occurring during pumping operations and was not evident during idle conditions.

Don Pugh asked if we were going to see the same problem with adult eel at this location. Bryan said he did not think so because FL did not propose hydroacoustics for eel. FL is using DIDSON cameras.

Bill Connelly asked if we saw a temporal signal in the hydroacoustic data at NFM. Bryan explained that entrainment was observed throughout the study period at Cabot Station with three distinct peaks.

Bryan then reviewed the radio telemetry component of study, noting that tagged juvenile shad were monitored at 13 locations in the study area using both aerial yagi and in-water dropper antennas. Bryan explained that originally hatchery fish were going to be used, but there was poor survival, thus all juvenile shad in the study were wild fish. Bryan reviewed aerial maps showing the telemetry monitoring stations.

Don Pugh noted that were a lot of undetected tags and asked if we found the same condition with the adult shad. Bryan did not believe it was an issue with adult shad. He noted that the undetected juvenile shad is probably related to tag retention or mortality.

Bryan explained that all juvenile shad were collected at the Cabot bypass sampler, put in a 90-gallon live well and then were trucked to the Turners Falls Dam Gatehouse where they were divided into 3-1,000-gallon circular holding tanks with flow-through ambient river water supplied from the impoundment. Juvenile shad from the holding tanks were transported in small groups to release locations by boat in a live well. A Lotek NanoTag Series Model NTQ-1 was externally affixed to 218 juvenile shad.

Don Pugh asked what was the time from capture to release of the juvenile shad. Bryan indicated it varied, but on average, it was less 48 hours and they strived for 24 hours. Bryan indicated they had a control group and tagged fish with tin BB weights of the same weight as the nano-tags. Bryan said that no untagged fish were held as part of the control.

Bryan explained how the rate of movement was determined. He reviewed Side 99 relative to the canal escapement after drawdown noting that prior to the drawdown, 17 juvenile shad were tagged and released into the canal the evening of October 4, 2015. Don asked if after releasing the fish were they immediately tracked. Bryan indicated they were not tracked immediately, but it was confirmed the tags were active.

Ken Sprankle asked about the detection probability of the tags and specifically if it is possible that a fish pumped to the Upper Reservoir could lose its tag. Bryan said yes, it is possible. Bryan did say that they observed fish shedding tags in the control group.

Melissa noted that there seemed to be quite a difference in weight distribution in the dummy tag as opposed to the real tag and asked if we ever saw a fish with real tags swimming on their side. Bryan said he did observe it in real tagged fish, but that it was a low percentage.

Andrea asked for clarification of the numbers presented on Slide 100 and Don Pugh reiterated that tabular data would help.

Norm Sims asked if tagged juvenile shad are eaten by a larger fish would they still be captured by telemetry. Bryan said yes, potentially but it would depend on depth of the fish.

Don stated that mobile tracking after the drawdown should have detected tags since the power canal is not deep. Bryan noted that they either missed some in the mobile survey or some escaped the canal without detection at the stationary monitoring stations. Bryan noted that the whole canal was tracked from Gatehouse to Cabot Station. Melissa asked relative to the canal drawdown was there any thought of doing a second tracking event after re-watering to determine if the fish were still around. Bryan stated that they did not conduct another mobile survey after re-watering.

Bryan presented information on entrainment estimates and flow at Cabot Station.

Andrea asked if FL abandoned the re-doing the juvenile shad telemetry study this fall 2016. Bryan said yes due to extremely low flows. He indicated that FL is evaluating whether we can meet the study objectives without re-doing the study in fall 2017.

Misty Anne Marold requested that tables in the mussel report be provided in a usable format, other than PDF.

Bill Connelly asked what we thought the problem was with the collecting, holding and tagging methods and if we'd do anything different. Bryan thought maybe releasing fish closer to NFM, but FL would have to get back to him later on this issue.

Study No. 3.3.7- Fish Entrainment and Turbine Passage Mortality Study

Brandon Kulik and Chris Tomichek presented the findings of the fish entrainment and turbine passage mortality study. Brandon reviewed study objectives and discussed the resident fish species assessment. He noted that the velocity near the intakes was computed at Station No. 1, Cabot and NFM and compared against fish swimming speeds (using cruising speed as a metric) as a way to assess risk of involuntary entrainment or impingement. For entrainment, if the swim speed was less than the mean intake velocity, then the fish were assumed to be at risk to entrainment or impingement. Morphometric literature was used to determine critical width using skull width as the critical factor as this body part is non-compressible, Fish with critical widths less than the trashrack spacing were assumed to be susceptible to impingement. If critical width was greater than the trashrack spacing, the fish could potentially be impinged if cruising speed was estimated to be less than mean intake velocity. Turbine passage mortality estimates for resident species were obtained from applicable empirical datasets of more than 30 candidate hydro projects with similar characteristics (head, runner velocity, and hydraulic capacity) as Station No. 1, and Cabot. Fish entrainment mortality loss at NFM was conservatively assumed to be 100% to avoid untested assumptions about the number of times a fish could be entrained during pump back and subsequent generation.

Species-specific information was assembled and scored using a Traits Based Analysis. Based on categories of habitat and biology, swim speed, survival, likelihood, and population impact, a "risk" score was assigned to each criterion and then summed to produce a net "risk score" for each species independently for Station No. 1, Cabot and NFM. A category value of 0 meant no impact to the given fish, while a value of 3 meant highest potential impact to the given fish. Net risk scores could potentially range up to 15; a risk score of 0-5 could thus be characterized as "low" risk; 6-10 "moderate", and 11-15 as "high" risk. Most species scored as either "low" or "moderate".

Andrea Donlon asked if fish could get impinged sideways. Brandon indicated that healthy fish will orient facing into the current (*i.e*. parallel to trash rack openings) so our analysis looked at body/head width to determine impingement.

Bill McDavitt asked where the velocities estimates were taken. Brandon indicated immediately in front of the trashracks.

Melissa asked if FL ran the Franke model for Station No. 1, Cabot and NFM. Brandon indicated no, but they used the supporting empirical database behind the Franke model. He said they correlated the Francis turbines at each of the three facilities (Station No. 1, Cabot and NFM) to other source studies that were included in the 1990s studies based on turbine characteristics and applicable study species. In cases where species-specific study data were unavailable, FirstLight applied data from surrogate species with similar or more fragile body characteristics.

Chris Tomichek led the second part of the study presentation regarding migratory fish entrainment and survival. She noted that no adult shad were entrained at NFM or Station No. 1. Relative to juvenile shad, of the 16 that went through the power canal, only one was detected at Station No. 1, but no entrainment was confirmed.

Chris explained that turbine mortality studies of juvenile shad and adult eel were conducted at Cabot, Station No. 1and over bascule gates 1 and 4 at the Turners Falls Dam. Three flows were passed over the bascule gates- 1,500 cfs, 2,500 cfs and 5,000 cfs. Chris reviewed the juvenile shad findings where 120 fish were passed through Cabot Unit 2 (Cabot), 90 through Units 2/3 (Station No. 1) and 90 through Unit 1 (Station No. 1). One-hour survival of juvenile shad at Cabot Unit 2 was 95%, whereas survival at Station Unit 1 and Units 2/3 were 68% and 77%, respectively. In terms of mortality at bascule gate 1 under discharges of 1,500 cfs, 2,500 cfs and 5,000 cfs, there was 69%, 48% and 76% survival, respectively. In terms of mortality at bascule gate 4 under discharges of 1,500 cfs, 2,500 cfs and 5,000 cfs, there was 64%, 59% and 74% survival, respectively.

Relative to the adult eel findings, there were 50, 30 and 30 eels passed through Cabot Unit 2, Station No. 1 Units 2/3 and Station No. 1 Unit 1, respectively. In addition, 35, 30 and 30 adult eels were passed over bascule gates 1 and 4 under flows of 1,500 cfs, 2,500 cfs and 5,000 cfs. One-hour survival at Cabot Unit 2 was 98%, whereas survival at Station Unit 1 and Units 2/3 were 62% and 90%, respectively. In terms of mortality at bascule gate 1 under discharges of 1,500 cfs, 2,500 cfs and 5,000 cfs, there was 88%, 86% and 86% survival, respectively. In terms of mortality at bascule gate 4 under discharges of 1,500 cfs, 2,500 cfs and 5,000 cfs there was 89%, 90% and 93% survival, respectively.

Andrea Donlon asked about the 48-hour juvenile shad survival rate. Chris stated that a 48-hour survival could not be calculated because control mortality was too high.

Study No. 3.3.15- Assessment of Adult Sea Lamprey Spawning within the Turners Falls Project and Northfield Mountain Project Area

Bryan Apell reviewed the study objectives for the sea lamprey spawning study. A total of 40 adult sea lamprey were tagged of which 20 were released in the early portion of the run (5/21/15) and 20 released in the later portion of the run (5/28/16) at two locations. Bryan indicated that mobile tracking was conducted.

The assessment looked at 29 redds in five spawning sites, near Stebbins Island, Fall River, Millers River confluence, Deerfield River and the Hatfield S Curve below the Route 116 Bridge. Marked redds were routinely monitored for depth, velocity, temperature, substrate, damage and general observations. The five sites were capped and two caps produced ammocoetes --at the Hatfield S Curve and Fall River.

Bryan explained that site specific data was collected at each site when visited over the spawning period including depth, velocity and the dominant substrate. He showed a table (Slide 131) showing the range of depths and velocities collected during site visits as well as the averages of each. He noted that the highest depths and velocities were measured at the seven redds around Stebbins Island.

Melissa Grader asked if river elevation and flow data was available from the start to end of the monitoring period. Mark Wamser indicated that we have information on the Vernon tailrace elevation and flow, flow in the Ashuelot and Millers River since both have USGS Gage, and flow at the Hatfield S Curve from the Montague USGS Gage. Mark noted that we don't have river elevation data at any of the sites other than the

Vernon tailrace and no data (flow or elevation) is available at the Fall River site. Mark noted that we could provide the information we have available.

Bryan noted that there was not a lot of spawning habitat in the Turners Falls Impoundment other than near Stebbins Island.

Don Pugh asked if we determined, based on the site visits, when the sea lamprey were actually building the nests as the depths/velocities you have recorded are over the entire period. Don noted that the range of depths and velocities shown on Slide 131 were outside the HSI criteria for sea lamprey spawning. Bryan indicated that they were not continuously at the spawning site so he could not tell exactly the river stage and flow relative to when the sea lamprey were building the nests but nest building was observed and could be cross referenced to river discharge via the USGS gage.

John Warner also noted that at the five sites depth and water velocity data were collected outside the range of the HSI criteria. Bryan stated the he would look at their field notes to see if anything was noted relative to when the sea lamprey were building nests to potentially refine the HSI criteria.

Melissa Grader asked if the five sites were selected based on radio telemetry or habitat mapping. Bryan indicated both; they surveyed the area for the criteria that makes for good spawning habitat and relied on radio telemetry as well. He indicated that at least two nest building sites were discovered through the tracking of tagged lamprey including the Hatfield S curve spawning location.

Study No. 3.3.13- Impacts of the Turners Falls Project and Northfield Mountain Project on Littoral Zone Fish Habitat and Spawning Habitat

Brandon Kulik presented the findings of the littoral zone spawning. He noted that studies were conducted during the early spring (broadcast adhesive eggs) and late spring (nearshore shoal areas, nest builders) periods. All field work was conducted via visual observation; no telemetry was used. All spawning sites found were geo-positioned with an RTK-GPS so that the elevation as well as the location of the nests could be documented. The bulk of the spawning was located near Stebbins Island, and below the French King Gorge near Bartons Cove during both periods. A total of 17 sites were located in the early spring and 15 sites in the late spring (total of 32 sites). Julianne Rossett (U.S. Fish and Wildlife Service) asked of the 32 spawning sites, how many were occupied or showed evidence of egg masses. Brandon stated that it was on the order of 60-70% of them. He also noted that in some cases during the early spring the species that created spawning redds had to be identified by inference based on habitat use since it was not possible to observe the adults.

Brandon presented a map of where observed spawning activities occurred. He then went through how the hydraulic model (developed as part of Study No. 3.2.2) was used to determine if Project operations had an impact on spawning areas. Melissa Grader asked if the hydraulic model was used to assess sea lamprey redds. Brandon indicated that the hydraulic model was not used but lamprey spawning was assessed as a part of study 3.3.15. Bryan Apell noted that they obtained GPS coordinate data on the sea lamprey redds. Mark Wamser noted that the hydraulic model is of the mainstem Connecticut River only, so the redds found in the Ashuelot, Millers and Fall Rivers could not be assessed with the model.

Location: Northfield Mountain Visitors Center, Northfield, MA

Location: November 1, 2016

Attendees:

Federal Energy Regulatory Commission
Patrick Crile
Brandon Cherry
Bill Connelly
Nick Palso (phone)
John Baummer (phone)

US Environmental Protection Agency
Toby Stover (phone)

National Marine Fisheries Service
Bill McDavitt (phone)

Massachusetts Department of Environmental Protection
David Cameron
Brian Harrington
David Foulis
Bob Kubit

Connecticut River Watershed Council
Andrea Donlon
David Deen (phone)

Connecticut River Streambank Erosion Committee
Tom Miner
Maryanne Gallagher
Mike Bathory

Franklin Regional Council of Governments
Kimberly MacPhee

Appalachian Mountain Club
Norm Sims

Crab Apple Whitewater
Frank Mooney

Hampshire College
Sanon Rosen

TransCanada
John Ragonese

FirstLight
Doug Bennett
Don Traester
Jim Donohue
Gus Bakas
Joe Lucas
Len Greene
Ed Hathaway
Chuck Momnie

Simon & Associates
Bob Simons

Cardno
Andrew Simon
Jen Hammond

Consultant
Kit Choi (phone)

TRC Solutions
Sarah Verville
Wendy Bley

American Whitewater
Bob Nasdor

New England Flow
Tom Christopher

Foley Hoag
Adam Kahn

Gomez and Sullivan Engineers
Tom Sullivan
Tim Sullivan
John Hart
Mark Wamser

Van Ness Feldman
Julia Wood
Mike Swiger

Study No. 3.1.3 Sediment Management Plan

Tim Sullivan (Gomez and Sullivan) presented an update of the Sediment Management Plan. He explained that the focus of the presentation was what has been done in the past year, which was completion of the physical model and development of proposed management measures (items 1-9 on Slides 143 and 144).

Tim noted that Alden Research Laboratory had developed three models: a Computational Hydrodynamic Sedimentation model of the Upper Reservoir (UR model); a CFD model of the Northfield Mountain tailrace area, and a physical model of the tailrace area. Tim also reviewed the findings of the pilot dredge of the Upper Reservoir (UR).

The UR model found that the root cause of sedimentation in the UR likely begins with relatively high concentrations of entrained bed and suspended sediment loads from the Connecticut River transported during pumping phases. The UR model also found that potential changes in UR operating procedures or physical modifications to the UR intake configuration would only result in a minimal impact on reducing sediment uptake. Thus, changes in UR operating procedures and physical modifications to the UR intake configuration were eliminated from further consideration.

The CFD model of the NFM tailrace area found that the majority of sediment uptake to the UR occurred during operational conditions with three or four pumps. The CFD model examined the feasibility of two potential sediment exclusion structures which would span the mouth of the NFM tailrace in order to prevent the entrainment of sediment into the Project works. Based on the results of the modeling, the sediment exclusion structures were found to be more effective than the UR alternatives, however, they were still found to have limited effectiveness in reducing sediment entrainment. Tim noted that based on the results of the tailrace modeling, FirstLight decided to investigate the potential for a sediment exclusion structure at the tailrace further by developing a physical model.

The physical model assessed two different structures – one with a fixed crest overflow and one with a moveable crest overflow. The modeling showed that a moveable crest overflow was slightly more effective than a fixed crest overflow; however, the effectiveness of either structure was limited and therefore eliminated from further consideration.

Tim then discussed the pilot dredge project, which showed that hydraulic dredging could be a viable management measure. The nine sediment management measures proposed by FirstLight were then reviewed and discussed. The intent of the management measures are to monitor and manage the amount of sediment in the UR. The recommended measures are those which have the potential to be most effective in minimizing sediment entrainment into Project works and the Connecticut River during dewatering of the UR.

Andrea Donlon asked whether the reason the sediment that was pulled into the shaft in 2010 was due to too much sediment, the location of the sediment or that the UR was drained too fast. Andrea asked why there are no trigger points included in the report as to when dredging would be conducted. Andrea asked how often the dredge would be conducted. Tim responded that Alden's UR modeling report (filed 3 years ago) examined the conditions at which the bed sediment would become mobilized. Tim also noted that bathymetric surveys of the UR would be conducted every 1-2 years, in order to provide data on how much sediment has accumulated in the UR between surveys.

Tom Miner asked if the high concentration of sediment in the river was a contributor to the sediment in the UR, why the study didn't look at erosion as a potential source of high sediment concentrations, and why the recommended management measure didn't look at methods to reduce erosion as a way to reduce sediment. Tim responded that the erosion causation study, which was to be discussed next, examined the cause of erosion in the TFI. Tim also indicated that both bedload and suspended sediment contribute to the sediment seen in the UR. Tom Sullivan noted that during high flow events in the river there is a high suspended sediment concertation throughout the river, including upstream of Vernon. Tom also noted that the modelling showed that dredging the UR was more effective as a management tool than constructing a structure in the tailrace area to reduce sediment entrainment during pumping operations.

Andrea Donlon read from a page in the Alden report regarding historic project operation and asked whether the UR had ever historically been drawn down to elevation 920', and if the intent of such a drawdown was to flush out sediment so that it doesn't accumulate. Mark Wamser explained in the data Gomez and Sullivan had for the past 15 years, he did not think that the UR was lowered below elevation 938'. Mark said he would look at the Alden report reference to 920' and see what was intended. Tim asked that Andrea put this question in her written comments and FL will provide a response in the written response to stakeholder comments.

John Baummer from FERC asked if a sediment management plan was going to be filed by FL with the Final License Application. Tim explained that the final study report, which includes the recommended management protocols is the sediment management plan. John noted that two different methods for collecting bathymetric data had been used in the past—single beam and multi-beam, thus making it difficult to quantify any change in sediment volume between years. Tim recognized this and noted that ideally a multi-beam unit will be used consistently. John also recommended that the management measures use the same methods for the bathymetry surveys so that an apples to apples comparison could be made going forward and Tim agreed.

Study No. 3.1.2 Erosion Causation Study (Tim Sullivan – GSE)

Tim then presented the results of the Erosion Causation Study. He noted that, in accordance with the study plan, potential causes of erosion had been broken into two categories- potential primary causes and potential secondary causes. Potential primary causes are those thought to be most prevalent throughout the Turners Falls Impoundment (TFI).

Tim explained that the study found that potential secondary causes had minimal impact on erosion processes throughout the TFI other than a few localized areas. Thus, the bulk of study focused on the potential primary causes, which are land management practices and anthropogenic influences, ice, hydraulic sheer stress due to flowing water, water level fluctuations due to high flows, and boat waves.

Detailed study sites were one of the cornerstones of the study. There were 25 sites evaluated. The sites represent the geographic range of the TFI but also the full range of river bank features and characteristics, erosion conditions, and hydraulic conditions. The 25 sites included both restored and non-restored sites. The 25 sites also included 16 sites, which have been surveyed since the 1990s and 9 newly identified sites. The 16 sites established in the 1990s were classified as calibration sites. Representative sites were sites that provided supplemental information or filled gaps in information. Bank Stability and Toe Erosion Model (BSTEM) analysis was run at all 25 sites and field data was collected at all sites. Potential primary causes were examined in depth at each site. Results were then extrapolated throughout the entire TFI such that the entire TFI shoreline was assigned a cause or causes of erosion. Two sets of maps were developed, which identified the causes of erosion at each individual site and then at every river bank segment.

Hydrology and Hydraulics findings (slides 150 -153)

Tim emphasized the importance of understanding the maximum generating capacity of Vernon, Northfield Mountain, and the Turners Falls (TF) Hydroelectric Projects. He noted that at flows above the maximum hydraulic capacity of 17,130 cfs at Vernon, Vernon operations are run of river and that inflow to the TFI is "natural." Tim also noted that at flows greater than 30,000 cfs, the French King Gorge, where the TFI narrows, becomes the primary hydraulic control for the middle and upper portions of the TFI.

Tim explained that the study found that there were four distinct hydraulic reaches. He explained that each of the plants evaluated can only affect their specific reach (Reach 1 – Lower reach; Reach 2 – Northfield Mountain reach, Reach 3- Middle reach and Reach 4 – Upper reach). For instance, Northfield Mountain operations can only potentially impact erosion in the reach in which NFM is located.

Norm Sims asked in which reach is the French King Bridge located. Tim responded that it is located in Reach 1.

Tim continued with the key hydraulic findings. In the lower three reaches there are three flow thresholds. Low – below the hydraulic capacity of Vernon (17,130 cfs); Moderate (17,130 cfs to 37,000 cfs) and High (above 37,000 cfs). He reiterated that above a flow of 37,000, the river flow was beyond the combined control of Vernon and NFM and therefore is considered a naturally occurring high flow. In Reach 4 (from Vernon to the state line), there are two flow thresholds. One is above 17,130 cfs and the second is below 17,130 cfs (Vernon's hydraulic capacity). Tim noted that while NFM can operate at flows above 37,000 cfs, data analyzed on an hourly basis over the 15 year period (2000-2014) found that it did so only from 0.025% of the time with 4 units operating to 2.6% of the time with 1 unit operating. Tim also noted that one of the primary findings was that low flows rest on the lower bank; moderate range flows rest on the lower or upper bank; and high flows rest on the upper bank.

Norm asked when NFM doesn't operate, what's the flow at NFM if 17,130 is coming out of Vernon? Can it be 37,000 cfs? Tim responded that 37,000 cfs can occur without NFM operating due to naturally occurring high flow events.

Bill McDavitt (on phone) asked what the range of head pond fluctuations was. Tim responded that the water levels during the low flow periods were generally within a 2 ft daily fluctuation throughout the TFI. At moderate to high flows, there is about a 1 ft fluctuation in the vicinity of NFM that dampens as you move upstream before being approximately a ½ ft fluctuation above Stebbins Island. He noted that those fluctuation ranges were under typical operations, but that the TFI fluctuations rarely exceeded 4 ft per day.

Bill also asked how much higher the water level at 37,000 cfs is. Tim said he couldn't give the exact numbers (they are in the report) and the level would vary at different points within the TFI, but that the key is that the elevation goes from the lower bank to upper bank at 37,000 cfs. John Hart noted that the figures in Section 5 of the report show water level variations at different river flows and downstream boundary conditions. Bill said that he understands the 37,000 cfs threshold but noted that given the impoundment's "backwater environment", and the low slope on bank, that it doesn't seem like there is a lot of potential for sheer stress. Bob Simons noted that 37,000 cfs is the low end of the high flow threshold and that erosion at some sites didn't start until flows are much higher than 37,000 cfs.

Tim finished reviewing the key findings of the hydrology and hydraulics analysis.

Tim characterized the lower bank (showed pictures) as being relatively flat, and generally un-vegetated. The upper bank is steeper and often has vegetation, though there is typically no vegetation, where most erosion occurs. He explained that the modeling showed that erosion really only occurs once the water level reaches the upper bank. Fluctuations on the lower bank creates little or no erosion. Only when the water level reaches upper bank is there significant erosion.

Tim described that they did a water level duration analysis at a subset of the detailed study sites and found that the water level of the TFI was on the lower bank 78-99% of the time depending on the location of the site in the TFI.

Tim noted that flows required to reach the upper bank for the vast majority of sites was greater than 37,000 cfs. He noted that the BSTEM analysis showed that 95% of all erosion occurred at flows greater than 37,000 cfs for the majority of detailed study sites.

Application of BSTEM

Andrew Simon gave an overview of how the BSTEM model was developed and how it was used for this study. He noted that it included evaluating modeled energy grade line slopes and water surface elevations at an hourly basis over the 15-year study period and that every other input to the BSTEM model is from field collected data at all 25 sites. Bob Simons reiterated that the BSTEM model was calibrated based on

15 years of actual data. He explained that this is an unusually strong modeling application, and that typically there is no historic site-specific data to calibrate the model. Tim then provided an example of the BSTEM results (see slide 154).

Bill McDavitt asked how they ran BSTEM at sites with restoration that occurred sometime during the 15 year modeled period. Tim explained that at such sites, they modeled the same site with two different runs – pre- and post-restoration for the same site.

Tim then reviewed the findings of the modeling effort. He explained that the results of the modeling found that there were both dominant and contributing causes of erosion at each site. Dominant causes were those that were responsible for >50% of erosion at a given site. Contributing causes were those that were responsible for more than 5% of erosion, but less than 50%.

Tim described that the dominant cause for the majority of erosion was natural high flows, which was responsible for 78% of all bank erosion, and had the greatest impact on erosion at all 25 sites. Boat waves are a dominant cause of erosion at 13% of all TFI riverbanks (Reach 1, mostly in the Barton Cove area). Vernon operations were found to be the dominant cause of erosion at 9% of all TFI riverbanks (Reach 4). Northfield Mountain and Turners Falls operations were not found to be a dominant cause of erosion at any riverbank segment.

Tim explained that there are seven detailed study sites in the Northfield Mountain reach (Reach 2) and that NFM operations contributed to less than 5% of the total erosion at five of those sites. At one site NFM operations contributed to approximately 20% of the erosion and at the last site, it contributed to 7% of the erosion.

Tim also noted that the dominant primary causes followed a spatial pattern. Vernon operations were a dominant primary cause in the area from Vernon Dam to Stebbins Island; high flows were a dominant primary cause from Stebbins Island to upstream of the entrance to Barton Cove; and boat waves were a dominant primary cause from upstream of the entrance to Barton Cove to Turners Falls Dam.

Tim noted that natural high flows are such a dominant cause of erosion that there were no contributing primary causes of erosion for 68% of the riverbank length. Land use was found to be a potential contributing cause at 44% of the riverbank segments.

Maryanne Gallagher asked whether the rate of water level fluctuation is included in the PowerPoint. Tim responded that the rate of fluctuation is in the report.

Andrea asked about the difference in the terms “dominant” and “primary” causes that were used in the report. Tim agreed the nomenclature could be confusing, but noted the term “primary” cause came from the study plan and that the study plan identified those causes which would be considered primary causes of erosion. The model results were consistently described as having dominant and contributing causes. He also noted that both dominant and contributing causes could be primary causes.

With respect to the finding that Vernon operation was a dominant primary cause of erosion, John Ragonese asked where the 9% or 4 miles came from. Bob responded that the total length of river miles included both river banks and did not mean river miles. John then asked if Tim could review the map legend for the group, which Tim did. Tim also explained the nomenclature used in the mapping key.

Extrapolation Methodology

Tim explained the extrapolation method (see slide 150), describing each of the 7 major steps in the process. This was a multi-step process to extrapolate the BSTEM results of the 25 study sites to every riverbank segment identified during the 2013 Full River Reconnaissance survey.

Evaluation Regarding Impacts of Ice on Erosion

Tim then explained how ice was evaluated. He noted that ice had been added as a primary cause of erosion as a result of the closure of Vermont Yankee. He noted that the impact of ice on erosion was not quantified because it was not a cause of erosion examined in BSTEM. Tim noted that they looked at historic analysis of ice formation and breakup in the TFI, in other river systems, and then did field monitoring in the winter of 2014-2015 and 2015-2016. They found that ice that melts in place doesn't cause much erosional impact. Ice floes moving downstream and creating ice jams is when/where the ice can cause erosion. He noted that there was no significant ice breakup event in winter of 2014-15. He explained that Project operations do not cause ice break-up events, and that these are naturally occurring events that are the result of the right combination of weather and flow. He noted that ice could be a dominant primary cause of erosion in the future given the right weather and hydrologic conditions.

Evaluation of Land Management Practices

Tim then discussed how land management practices were evaluated (slide 162). The evaluation looked at agricultural and developed areas, using data from the 2013 Full River Reconnaissance survey. Areas where the riparian buffers were less than 50 feet and the adjacent land use was either agricultural or developed were classified as being a potential contributing cause of erosion. The analyses found that 44% of river bank (19 miles) is in this category.

Questions

Patrick Crile (FERC) asked Tim to review again how they took the study/model sites and extrapolated those findings to the rest of the river. Tim reviewed the extrapolation method again. Patrick asked if for the restoration sites they used pre-restoration site characteristics. Tim said they did. Tim provided an example of how this was done.

Andrea asked how the hydraulics were used in the model. Tim explained that the hydraulic model reaches were not used in BSTEM. They were used to perform the extrapolation and classify the varying hydraulic conditions. Andrew added some further explanation of the role of the hydraulic model in the BSTEM modeling, energy grade line slope, and stage which varied over the 15 year period every hour.

Bob Nasdor asked about water level fluctuations in reaches 1 and 2, noting that he understood that the Barton Cove area can fluctuate 5-6 feet, and wondering why such fluctuations would have no impact on erosion, while boat wakes do. John Hart pointed Bob to figures in Section 5 of the report, which show the daily TFI fluctuation over the 15 year modeled period. He noted that the median daily fluctuation is about 2 feet/day in Barton Cove. The maximum daily fluctuation daily is 5-6 feet, but this occurs less than 5 % of days.

Bob reiterated his question of how typical 2-3 ft fluctuation was found not to have any impact on the erosion. Tim explained that there were 3 erosion sites in the Barton Cove area. The BSTEM analysis showed that boat waves were found to be the dominant cause of erosion. Tim noted that this area of the TFI is more lake like as opposed to riverine and the repeated impact of boat waves on a relatively narrow band of riverbank has a significant impact on erosion. In the more riverine portion of Reach 1, he noted that fluctuations of 2-3 feet occurs mostly on the lower bank, which is largely bedrock and boulders or low-lying wetland areas in this reach. Therefore there is little impact to erosion from the typical fluctuations. Bob asked if there is less fluctuation in Reach 2 than Reach 1. John Hart indicated they were about the same.

Kimberly McPhee (FRCOG) asked a question about the energy grade line slope (EGLS), as defined in report. She wondered if this was used as a proxy for calculating the shear stress in BSTEM. Andrew explained how the how EGLS was used in the model. This led to some detailed technical discussion about the relationship between EGLS, Manning's Equation, and how EGLS is used in the BSTEM model. Andrew concluded by indicating that using EGLS is actually an enhancement over modeling shear stress by using just water surface elevation.

Kimberly asked another technical question about how water pressure and erosion due to water moving in and out of the river bank were modeled with BSTEM. She suggested that her own observations of how erosion occurs, and the type of erosion that occurs, seem different from what the model results show.

Andrew explained that the BSTEM model handles the types of erosion she was describing, which was the particle-by-particle erosion that occurs by hydraulic forces from the water flowing in the channel. It also accounts for the shear stresses imposed by impacts from boat waves. He went on to explain that the hydraulic erosion process was what she was observing. Andrew also explained that although the model includes a dynamic groundwater table to move up and down as water moves into the bank according to the hourly stage data, that the model does not specifically simulate seepage erosion. He then went on to describe the types of erosion accounted for in the BSTEM model, including hydraulic, particle-by-particle erosion from flows, cantilever failure due to undercutting, and planar failure. He also noted that the model inputs started with geometry data from the year 2000. He noted that in situ river-bank materials have not changed since 2000, and that the geotechnical-material information came from tests within holes augured into the banks and surface erodibility was from surficial testing.

Andrea asked about the 3 different flow ranges and how they were used or not used in the modeling. Tim explained that two separate analyses conducted. The HEC-RAS hydraulic model was used to model the hydraulic characteristics of the TFI. BSTEM was used to get the flow at which 50% or 95% of erosion occurred at a given site. Based on the results of the moderate or high flow analysis, the results of the models and the previously established flow thresholds were used to look at each site and assign dominant cause and contributing causes of erosion related to natural high flows, natural moderate flows, or Vernon operations. Andrew reviewed the details of how the 15 year hourly time step (131,000 time steps) was used in the model. Bob Simons added that cumulative distribution of erosion is a function of flow and that cumulative distribution of erosion plots were developed based on the BSTEM results. He also noted that suspended sediment concentration follows the same pattern, and is a function of river flow.

Bill McDavitt asked about what the model showed during the period of 2001-2002 (August and September), which was a period of very low flows. He wondered if during such a period normal project operations/fluctuations were more of a contributing factor to erosion. This led to a discussion of the potential differences in erosion causation during particular periods in the modeled record. Tim explained that the study took the whole 15 year period into account. Thus any periods of very low flow, and the erosion that occurred during that period, would have been taken into consideration. Bill asked a follow up question about whether the NFM erosion effect might be enhanced when the river is very low. Tim reiterated that when water levels and flows are low, the fluctuations occur on the lower bank, so there isn't much erosion. Bill's final question was about cross section geometry data. He asked if the BSTEM model was calibrated on an annual basis and if the model results were checked against the changes observed from the annual surveys. Andrew answered yes, that they calibrated the model for the period and a calibration check was run to compare against actual results.

Bob Simons added that the study was very robust because in a typical application of BSTEM, there is not before and after cross-section data to calibrate to. After further discussion, Tom Sullivan indicated that if someone was interested in looking at the model results for a specific time period, they should request exactly what they want in written comments.

John Ragonese asked why modeled WSEL data was used in the BSTEM model, rather than actual WSEL data. Mark Wamser reminded John that the hydraulic model was calibrated with data from an array of water level loggers in the TFI in 2014 and the calibration was very good. The hydraulic modeling data allowed a 15 year period for BSTEM modeling at the 25 sites throughout the TFI. The information regarding calibration of the hydraulic model is in Study Report No. 3.2.2.

John Ragonese asked several questions about how Vernon operations were handled in the model. It was explained that FL had used historic hourly Vernon discharge data, and Tim described how Vernon was handled in more detail. John Hart noted that they did not model Vernon "off" in the BSTEM model. John Ragonese said he understood and suggested that it might be better to characterize Vernon operations as "discharge below Vernon" rather than as Vernon operations.

Andrea asked a question about how the BSTEM model looks at the erosion process over time. She noted that some of the bank restoration projects have failed and then been reconstructed. Andrew explained that the BSTEM model's determination of erosion was cumulative over time, so that it did consider the cumulative effect of the causes and amount of erosion, including all intervening events.

Mike Bathory read a quote from a newspaper about observed erosion and erosion effects in TFI. He asked how the model results could be reconciled with the newspaper's assessment. This led to further discussion about the validity of the BSTEM model, and in particular how boat waves impact portions of the shoreline. Tim noted that it is the repeated striking of the boat-wave along the bank that causes erosion. Tim reiterated that wave impacts were identified by turning waves "on" and "off" in the model and comparing the results.

Patrick Crile asked a question about the EGLS and how it is different for a natural flow of 20,000 cfs, versus a flow of 20,000 comprised of 10,000 natural flow plus 10,000 NFM flow. This led to further discussion about the EGLS. It was noted that the EGLS is pretty flat under the lower flows and that the EGLS changes with changing NFM flows.

Kimberly asked about how sensitive the EGLS is to NFM operations. She wondered if the same conditions would exist absent the Vernon and TF dams. Tom Sullivan reminded everyone that the study did not look at "no dam" conditions. Andrew indicated that there is no way to speculate what the EGLS condition would be or what the model results would show under a "no dam" condition. Tom also reiterated that at high flows (generally over 30,000 cfs), the hydraulic control on the river shifts to the French King Gorge, not the TF dam.

Norm indicated that he would like to see the discharge data from NFM over past 5 years, as well as the changes in TFI elevation over the past five years. Mark said they could share the actual data, if Norm would specify in writing exactly what data and for what periods he wanted.

Mary Gallagher asked for the sections of river bank where NFM was a contributing cause to erosion – what type of erosion was it, and what action of operation contributes to that. Tim noted that there are figures in the report showing the type of erosion that is occurring. He also pointed to a section of the report that goes through what is happening in each reach and at each site.

Study No. 3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Wendy Bley (TRC) summarized the results of the Assessment of Effects of Project Operation on Recreation and Land Use. She noted that the assessment focused on project operational effects (water levels and flows) on water-based recreation sites and facilities. Land use was considered in three other studies (3.1.2 Erosion Causation Study), (3.1.1 Full River Reconnaissance Study), and (3.6.5 Land Use Inventory. Wendy then identified the sites that were assessed (slides 166-167). With respect to methodology, Wendy described that the results of the other recreation studies were reviewed, as well as studies that contained relevant information including a) the hydraulic study of TFI, b) instream flow studies in the bypass reach and below Cabot Station, c) the River2D modelling study of the NFM intake/tailrace area, and d) the erosion causation study. With respect to the recreation studies, the surveys from the Recreation Use/User Contact survey were reviewed to glean recreationists' comments on water levels and flows at a particular site.

Wendy noted that each site was evaluated based on hydraulic conditions at the closest modeled transects. An assumption was made that 3 feet of water depth was needed to launch motor boats and 2 feet of water depth was needed to launch canoes and kayaks. Wendy then presented two examples of how the analysis was conducted – Pauchaug Boat Launch and Riverview Boat Dock.

Questions on Pauchaug Boat Launch

Bob Nasdor asked if the analysis was based on using a median water surface elevation (WSEL). Wendy indicated no, stating that the WSEL duration curves for each recreation site are based on 15 years of hourly WSEL data.

Andrea Donlon asked how often the WSEL goes below 181. Wendy responded that 15% of the time on average it's below 181 during the recreation season.

Bob Nasdor suggested that the analysis should be based on daylight hours because boaters don't use the sites at night.

Tom Miner stated that based on his personal experience, he cannot launch a power boat in the early morning.

Norm Sims stated that launching canoes can also be difficult due to mud and that on a recent experience he was unable to get across a mud flat.

Questions on Riverview Boat Dock

Norm Sims stated that he does not think that Riverview is a launch site because the carry from the parking lot to the boat dock is a long way. He also noted that power boats cannot launch from this site.

Andrea Donlon asked whether the study looked at paddlers paddling downstream who are facing an upstream flow (when NFM is pumping). Wendy noted that the assessment focused on the QII and powerboats because Riverview is designed for paddling access. She also noted that the velocity is relatively low (2 fps) here, which equates to 1.4 miles per hour. Norm Sims noted that it is relatively easy to paddle against a velocity in this range.

Bob Nasdor stated that the WSEL assessment at Poplar Street is not useful when it's so difficult to get down the bank to the water to launch a canoe or kayak.

Norm Sims stated that launching canoes at the Sunderland Bridge on river left this summer was not possible because of low water levels. Doug Bennett of FirstLight noted that the northeast was in a drought this past summer hence the low summer flow. Norm also commented that there should be an assessment of a put-in immediately below the TF Dam on river left.

Andrea Donlon asked whether flows in the bypass reach affected fishing. She also noted that swimming takes place at Rock Dam although FirstLight discourages swimming at this location. Wendy responded that the assessment focused on whether water levels affected the ability to access the site. The study didn't try to make any judgments on the suitability of a flow for a recreational activity such as fishing or swimming in the river.

Mark Wamser then concluded the meeting. He reminded the participants of the schedule for next steps, including that FirstLight would be filing a meeting summary within 15 days. He reminded participants that if they have information requests, they should put those requests in their written comments, which are due 30 days after the meeting summary.

ATTACHMENT B: POWERPOINT PRESENTATION

FirstLight Power Resources

Turners Falls Hydroelectric Project (FERC No. 1889)

Northfield Mountain Pumped Storage Project (FERC No. 2485)

Oct/Nov 2016 Study Report Meeting

October 31-November 1, 2016

Report Filings

- 10 reports filed on 10/14/2016.
- 3 addendums filed on 10/14/2016.

FirstLight Power Resources

Relicensing Process - Next Steps

Study Report Meeting (Stakeholders and FirstLight)

- October 31-November 1, 2016

Study Report Meeting Summary Filed (FirstLight)

- November 15, 2016

Disagreements/Modifications to Study/Propose New Study (Stakeholders)

- December 15, 2016

File Responses to Disagreements (Stakeholders and FirstLight)

- January 14, 2017 (Saturday, thus defaults to January 16, 2017)

FERC Issues Determination

- February 13, 2017

Study Recap

FERC Filing Date	No. of Studies	Study Name Abbreviations
09/15/2014	2	Full River Reconnaissance, Rec Inventory
12/31/2014	2	Archaeological- Phase 1A only, Historic Structures
09/14/2015	9	Hydraulic Model Study, Aquatic Habitat Mapping, Tributary Access, Canal Drawdown, NFM Land Management, Whitewater, Day/Overnight Rec Facilities, Rec Study of NFM, Traditional Cultural Properties.
03/01/2016	13	Water Quality, US Passage Eel, Shad Spawning, CFD Modeling, River2D model of NFM tailrace, Odonates, Fish Assemblage, Cabot Emergency Gates, Ichthyoplankton, Terrestrial Wildlife & Botanical, RTE, Rec Use/User Survey, Land Use Inventory
10/14/2016	10	Erosion Causation, Sediment Monitoring, IFIM Study, US & DS Adult Shad, DS Juvenile Shad (Interim), Entrainment, Littoral Zone, Sea Lamprey Spawning, Mussels, Project Ops impact on Rec
12/31/2016		Supplemental Ichthyoplankton (Year 2), Supplemental Odonate Work (Year 2)
03/01/2017	3	DS Eel (2-year study), Ultrasound Array, Operations Model
Total	39	

Agenda

October 31, 2016

Times	Study
9:00-9:30 am	Introductions, Review of Meeting Purpose, Meeting Objectives, Schedule
	Fish and Aquatic
9:30 am-Noon (15 min break built into schedule)	3.3.1- Instream Flow Study in Bypass Reach and below Cabot (45 minutes)
	3.3.16- Habitat Assessment, Surveys and Modeling of Suitable Habitat for State-Listed Mussel Species in the Connecticut River below Cabot Station (45 minutes)
	3.3.2- Evaluate Upstream and Downstream Passage of Adult American Shad (45 minutes)
Noon-1:00 pm	**Lunch on your own**
1:00-4:00 pm (15 min break built into schedule)	3.3.3- Evaluate Downstream Passage of Juvenile American Shad (40 minutes)
	3.3.7- Fish Entrainment and Mortality (40 minutes)
	3.3.13- Impacts of the Turners Falls Project and Northfield Mountain Project on Littoral Zone Fish Habitat and Spawning Habitat (40 minutes)
	3.3.15- Assessment of Adult Sea Lamprey Spawning within the Turners Falls Project and Northfield Mountain Project Area (40 minutes)

November 1, 2016

Times	Study
	Geology and Soils
8:30-11:20 am (15 min break built into schedule)	3.1.3- Northfield Mountain Project Sediment Management Plan (30 minutes)
	3.1.2- Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability (120 minutes)
	Recreation
11:20-Noon	3.6.6- Assessment of Effects of Project Operation on Recreation and Land Use (40 minutes)
Noon	Adjourn

Fish and Aquatic Resources

3.3.1-Instream Flow Study

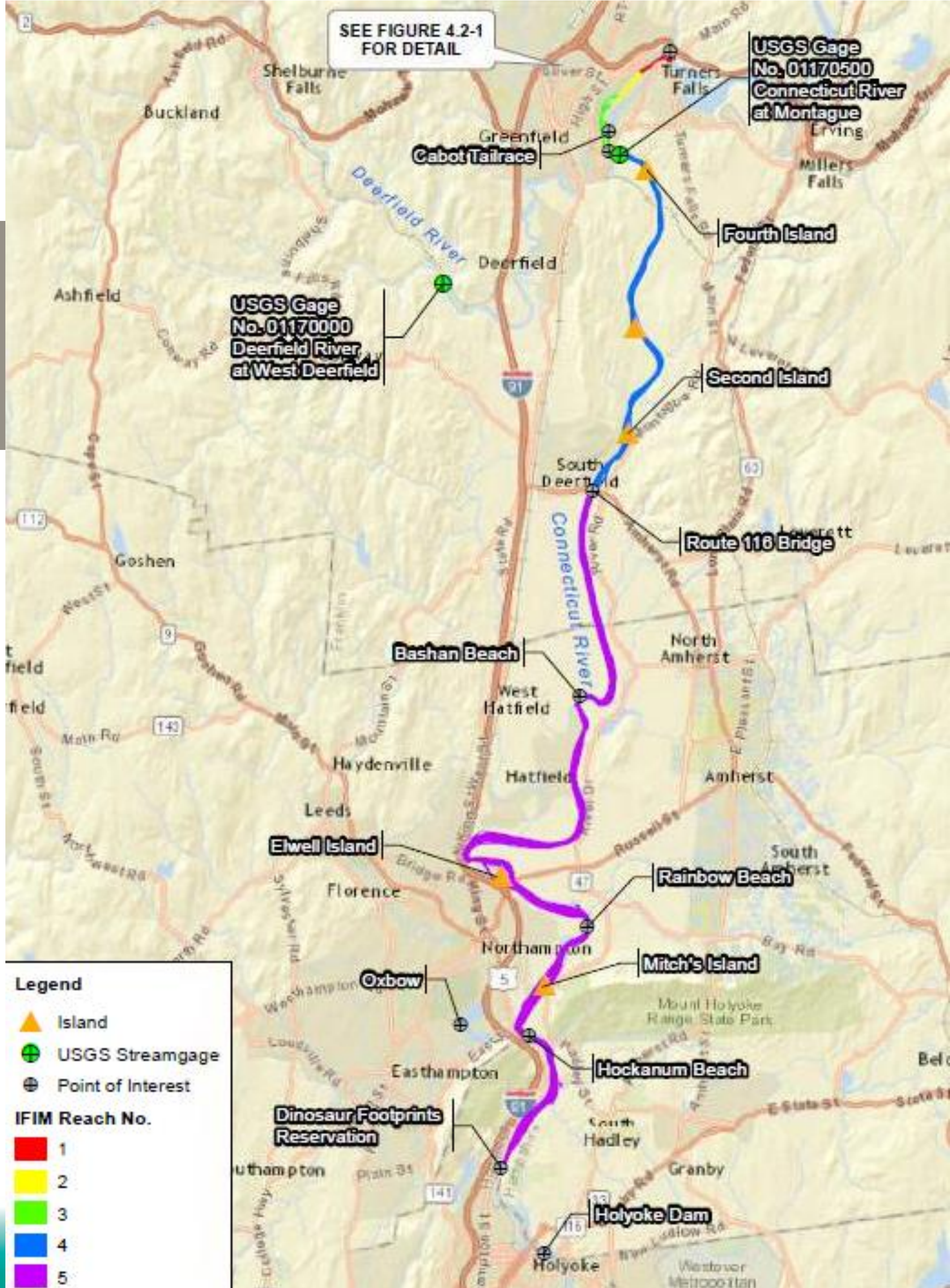
Study Objectives

Assess the potential effects of discharges from Turners Falls Dam, Station No. 1, and Cabot Station on wetted area and aquatic habitat suitability in the Connecticut River:

- between Turners Falls Dam and Cabot Station (i.e., the bypass reach),
- below Cabot Station downstream to the Route 116 Bridge in Sunderland, MA, and
- between the Route 116 Bridge and Dinosaur Footprints Reservation

FirstLight Power Resources

3.3.1-Instream Flow Study



3.3.1-Instream Flow Study

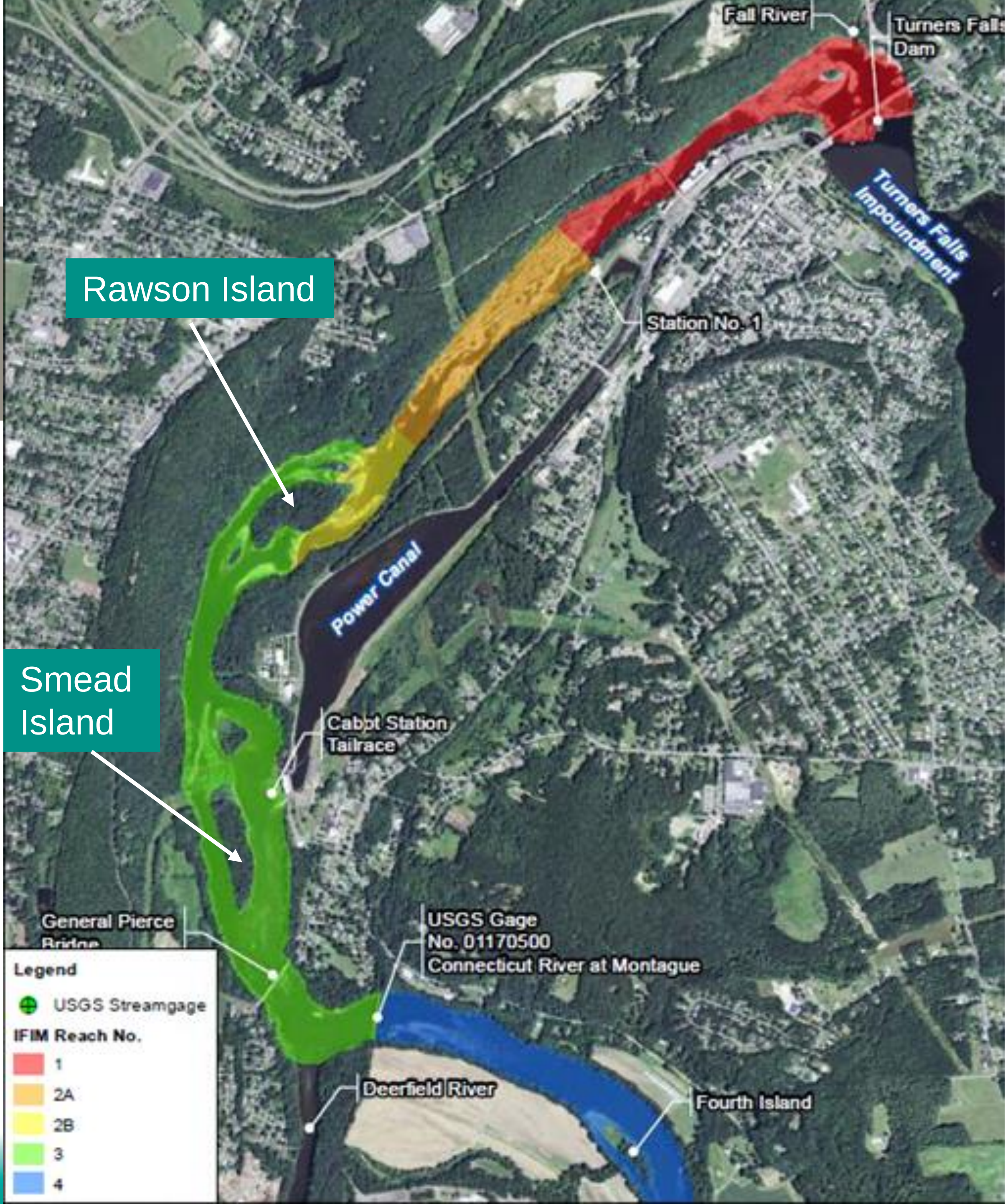
Reach 1 Study Area

- Plunge Pool- objective to develop stage vs discharge & wetted area relationship
- Left Channel- objective to determine ZOP of most limiting barrier at various discharges
- Center Channel- objective to describe channel hydraulic at various discharges
- Right Channel- objective to determine habitat in channel at various discharges.
- Lower Reach 1- includes Transects T-10 and T-11 (above Station No. 1 and part of steady state habitat assessment)

FirstLight Power Resources

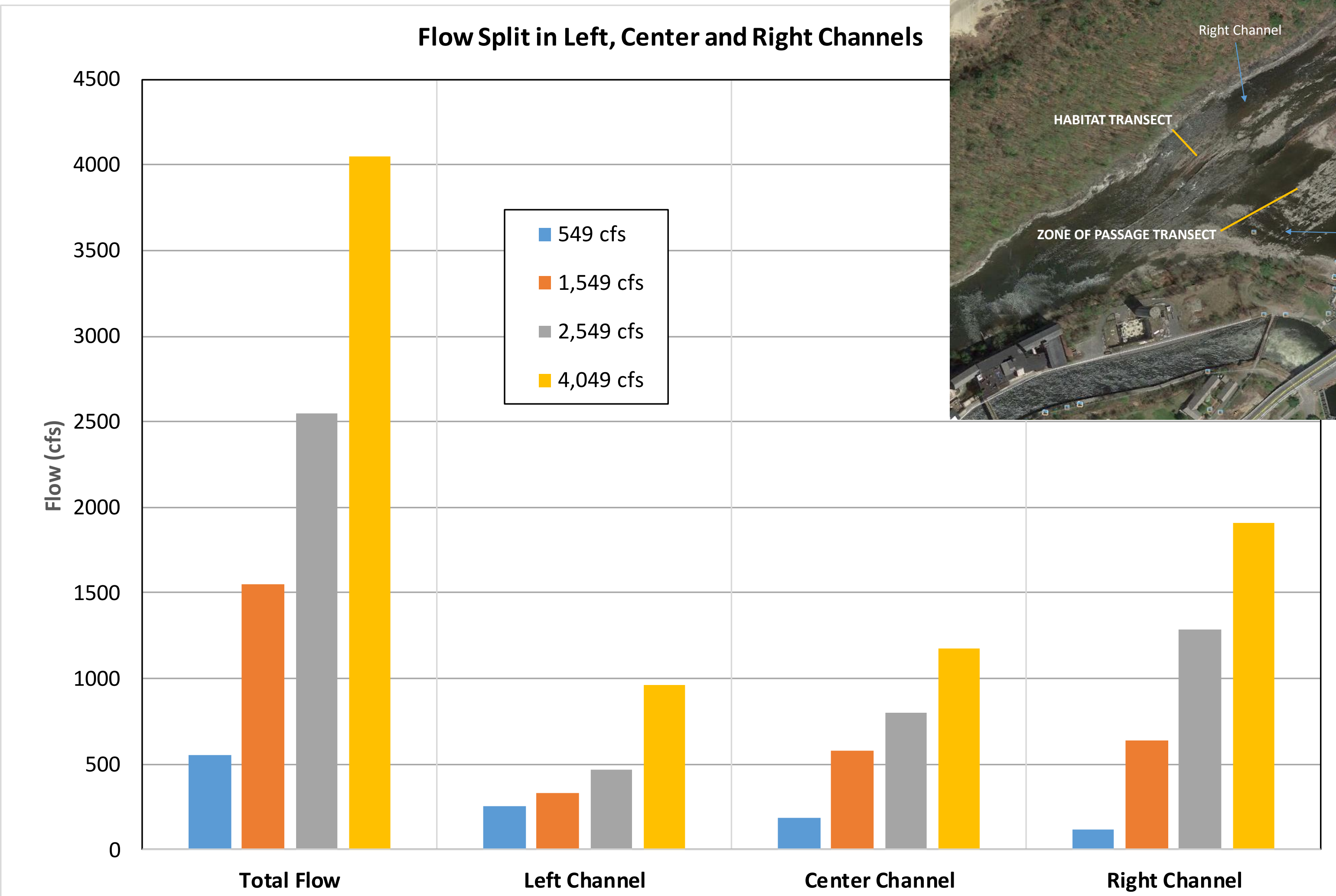
Study Reaches 1, 2A, 2B, 3, 4

- Reach 1- TF Dam to Station No. 1 tailrace--includes plunge pool, left channel, center channel, right channel. Habitat assessment of Lower Reach 1 Transects T-10 and T-11 using 1D Modeling.
- Reach 2A- Station No. 1 tailrace to ~1,000 ft upstream of Rawson Island. Habitat assessment of Transects T-1 to T-9 (1D Modeling).
- Reach 2B- ~ 1,000 ft upstream of Rawson Island to Rock Dam. Habitat assessment using 2D Modeling.
- Reach 3- Rock Dam to Montague USGS Gage. Habitat assessment using 2D Modeling.
- Reach 4- Montague USGS Gage to Route 116 Bridge. Habitat assessment using 1D Modeling.



3.3.1-Instream Flow Study

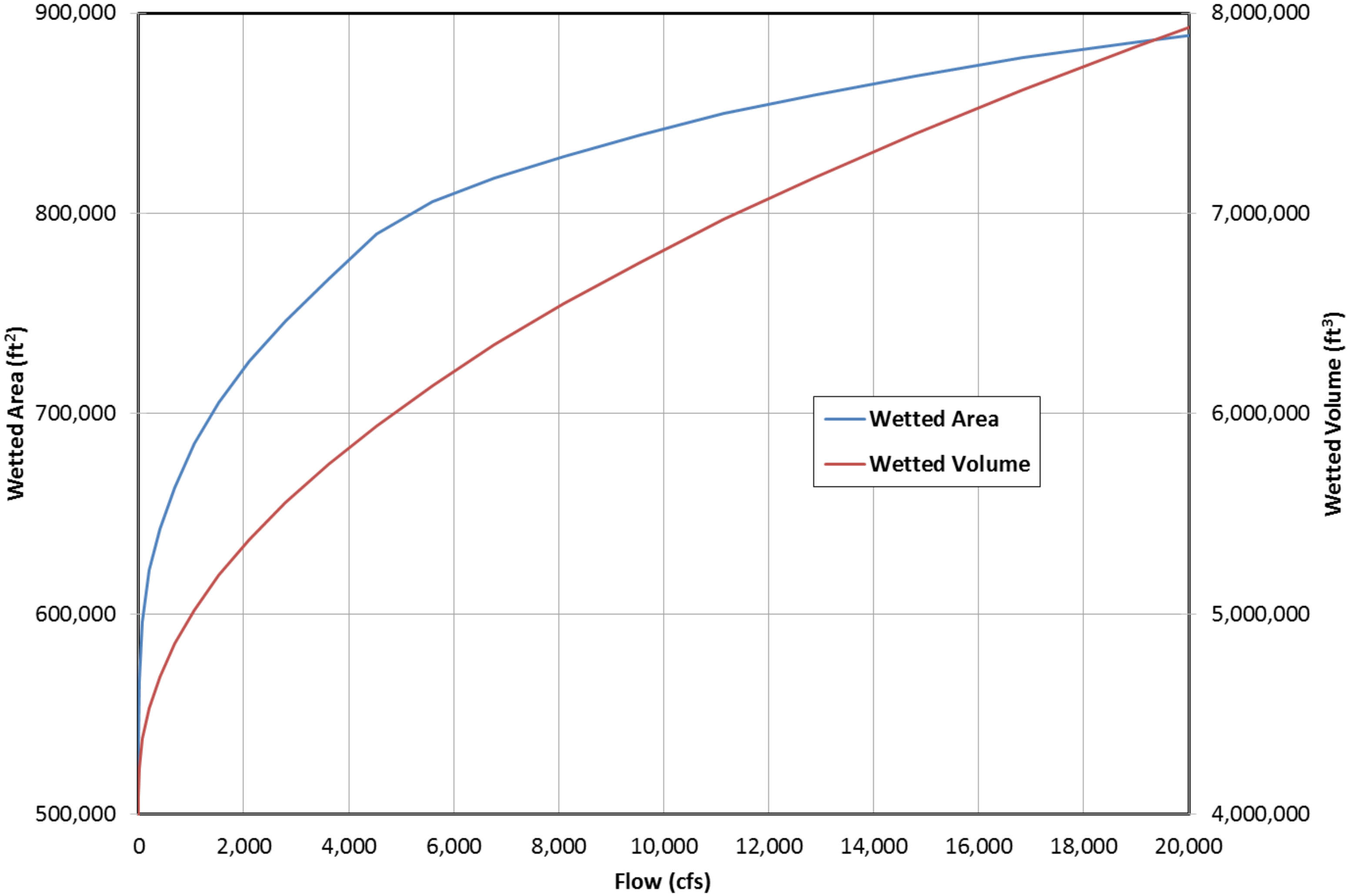
Reach 1- Flow Distribution in Left, Right and Center Channels



3.3.1-Instream Flow Study

Reach 1- Plunge Pool

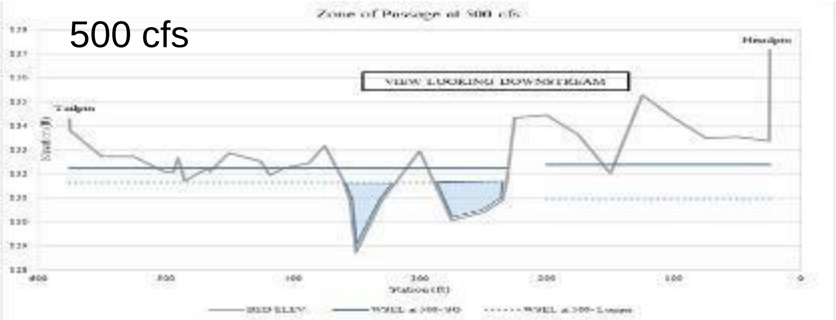
- Wetted Area and Volume vs Discharge

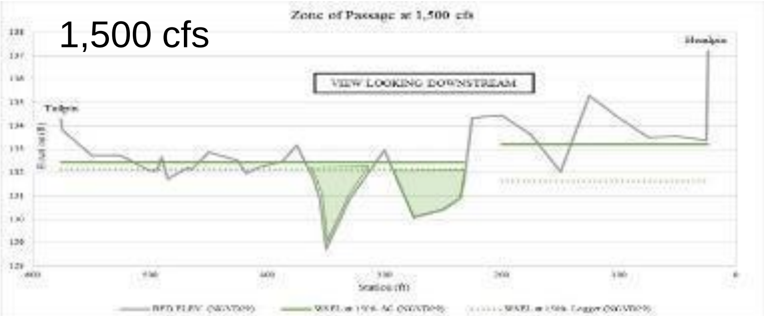


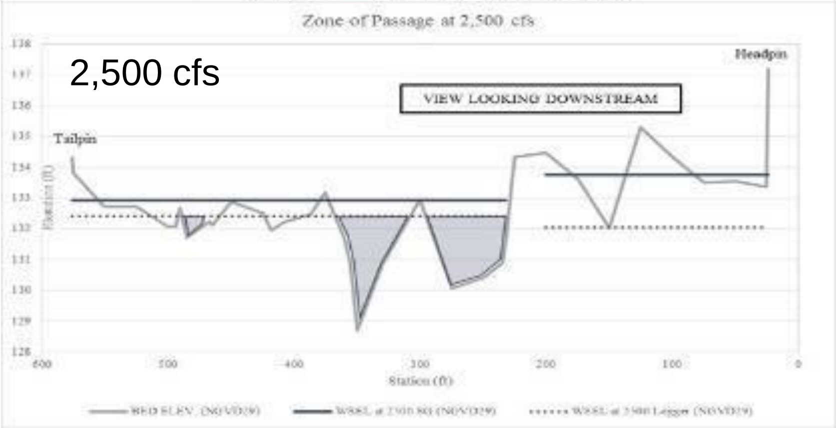
3.3.1-Instream Flow Study

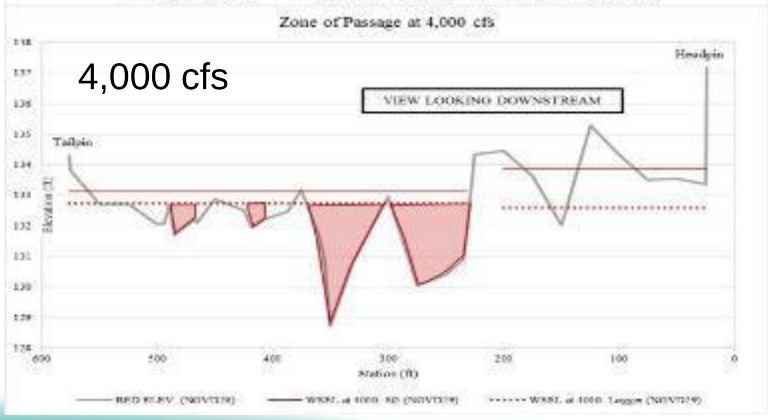
Reach 1-Left Channel (ZOP)

- The channel passage barrier transect is 576 feet long;
- Deepest portion 3.5 feet deep at a total bypass flow of 125 cfs
- Bypass flow releases less than 1,500 cfs wet only the right-most 300-ft portion of the channel (looking downstream),
- higher flow wets the left-most 150 feet of the transect.

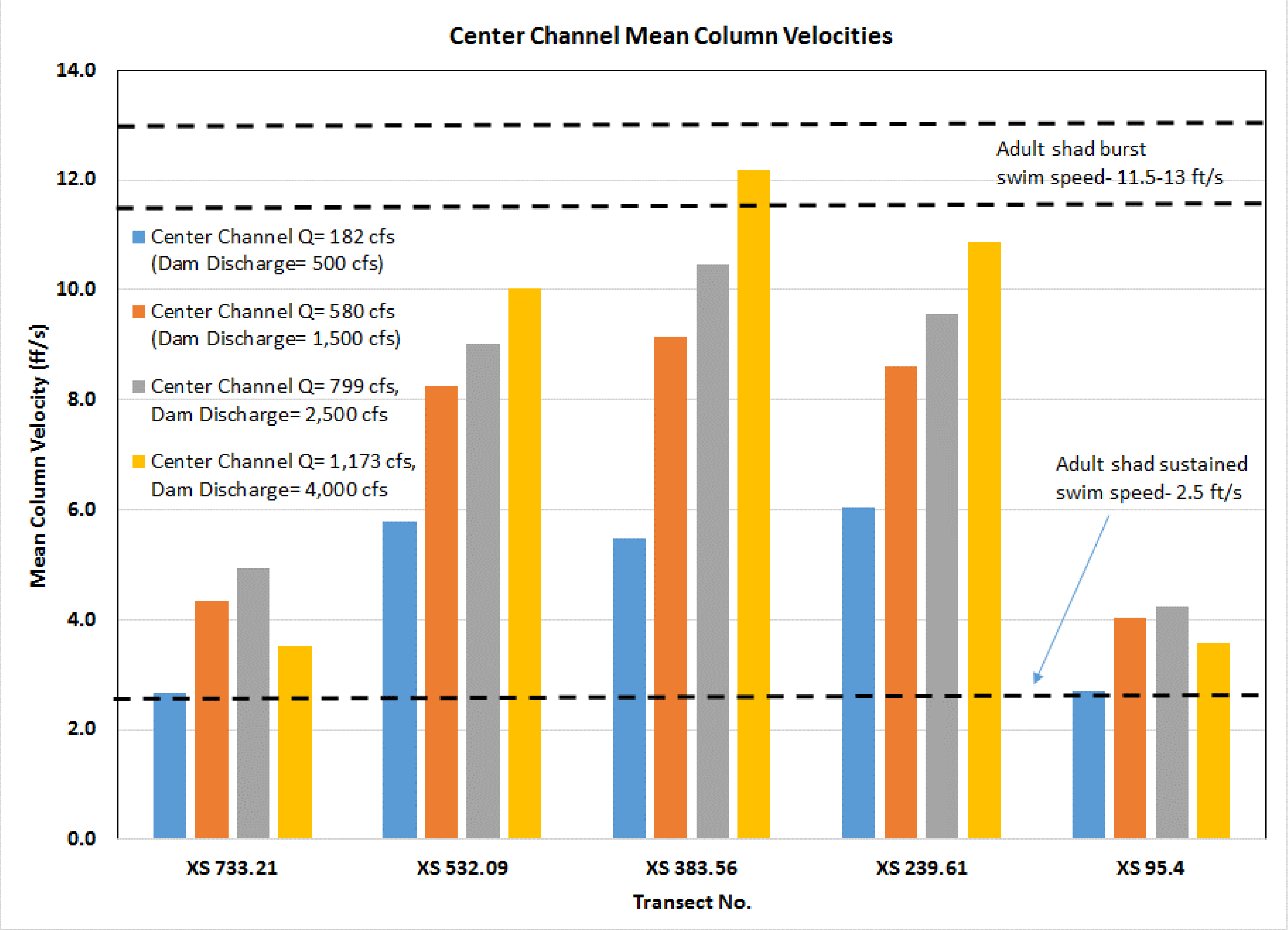








Reach 1 Center Channel- Mean Channel Velocities



FirstLight Power Resources

3.3.1-Instream Flow Study

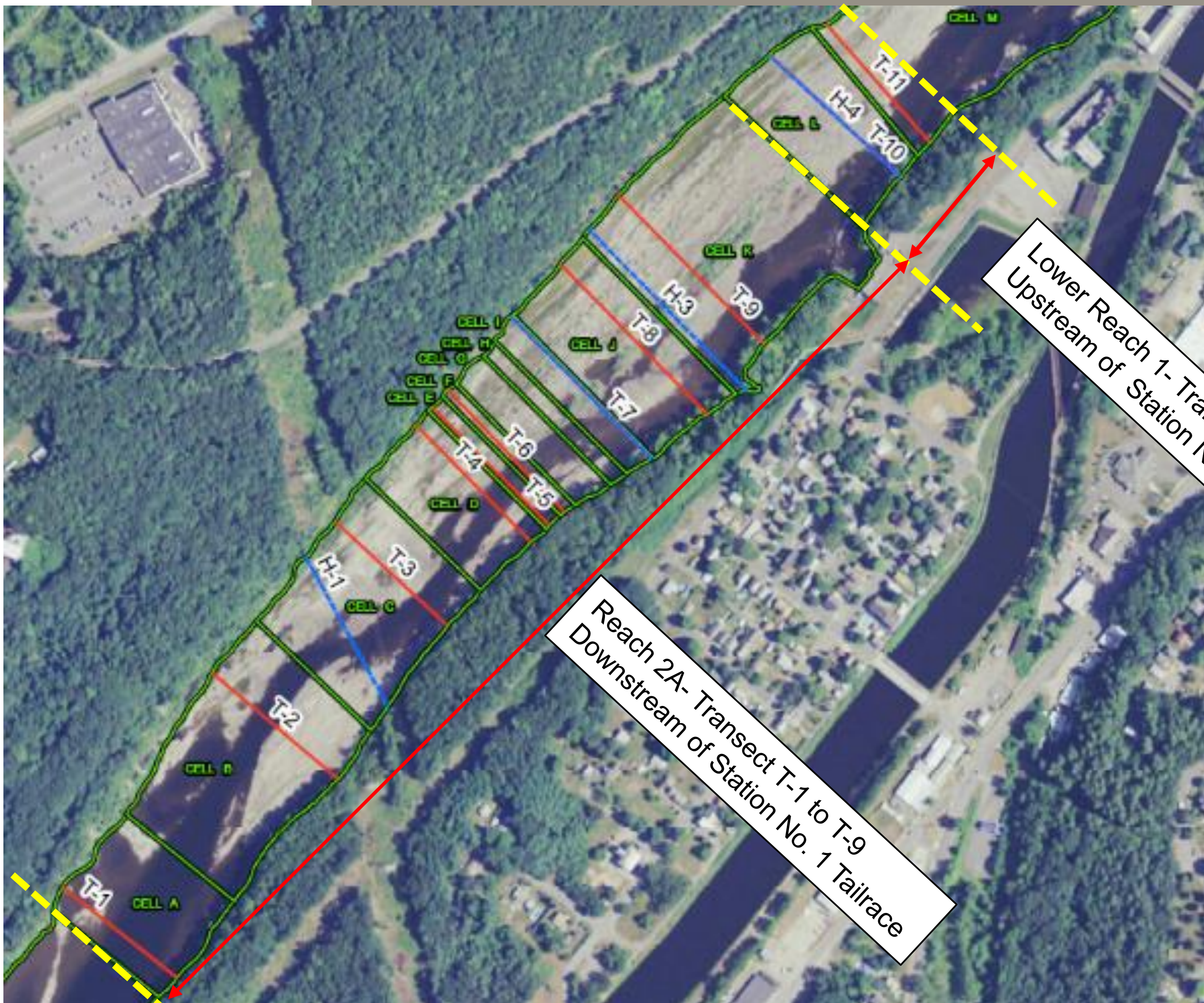
Reach 1-Right Channel- Habitat analysis

- Flow shown represents full bypass flow

Table 7.1.1.1-1: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 1 (Right Channel-Flow shown is full bypass flow)

Species	Life stage	Months Present	Maximum WUA Total Flow (cfs)	Maximum WUA Flow (cfs)	Maximum WUA (ft^2)	562 (cfs) 0.08 (cfsm)	591 (cfs) 0.08 (cfsm)	802 (cfs) 0.11 (cfsm)	1,281 (cfs) 0.18 (cfsm)	1,583 (cfs) 0.22 (cfsm)	1,719 (cfs) 0.24 (cfsm)	2,106 (cfs) 0.3 (cfsm)	2,551 (cfs) 0.38 (cfsm)	3,062 (cfs) 0.43 (cfsm)	4,105 (cfs) 0.53 (cfsm)
Fallfish	Spawning/Incu	May-June	802	250	86,628	90%	95%	100%	88%	68%	56%	34%	26%	20%	13%
Fallfish	Fry	May-June	591	140	66,936	99%	100%	79%	65%	43%	39%	32%	17%	12%	8%
Fallfish	Juvenile	Year Round	802	250	83,561	83%	89%	100%	83%	77%	68%	46%	35%	32%	24%
Fallfish	Adult	Year Round	1583	662	33,506	49%	52%	72%	96%	100%	98%	88%	76%	66%	39%
Longnose Dace	Juvenile	Year Round	802	250	83,561	83%	89%	100%	83%	77%	68%	46%	35%	32%	24%
Longnose Dace	Adult	Year Round	591	140	74,344	98%	100%	97%	63%	43%	37%	29%	23%	21%	13%
White Sucker	Spawning/Incu	May-June	591	140	41,330	98%	100%	87%	70%	48%	37%	26%	28%	21%	8%
White Sucker	Fry	Apr-May	591	140	66,936	99%	100%	79%	65%	43%	39%	32%	17%	12%	8%
White Sucker	Adult/Juvenile	Year Round	562	0	-	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Walleye	Spawning/Incu	April-May	3062	1,500	86,372	8%	10%	21%	45%	60%	72%	92%	98%	100%	99%
Walleye	Fry	April-May	562	125	13,105	100%	92%	42%	16%	5%	9%	16%	1%	3%	2%
Walleye	Juvenile	Year Round	591	140	58,234	98%	100%	75%	47%	30%	25%	18%	24%	13%	5%
Walleye	Adult	Year Round	562	0	-	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tessellated Darter	Adult/Juvenile	Year Round	562	125	38,259	100%	98%	54%	28%	16%	12%	17%	17%	5%	5%
Sea Lamprey	Spawning/Incu	May-June	1583	662	18,221	60%	65%	77%	83%	100%	87%	58%	32%	33%	16%
Macroinvertebrates	Larva	Year Round	1719	750	74,190	41%	45%	68%	95%	99%	100%	96%	93%	87%	79%
Shallow Slow	Shallow Slow	Year Round	562	125	45,830	100%	91%	44%	23%	3%	7%	23%	1%	2%	4%
Shallow Fast	Shallow Fast	Year Round	562	125	56,586	100%	97%	69%	32%	23%	20%	22%	16%	8%	5%
Deep Slow	Deep Slow	Year Round	1281	500	14,944	7%	17%	66%	100%	36%	16%	0%	0%	0%	0%
Deep Fast	Deep Fast	Year Round	1719	1,000	98,741	0%	3%	24%	70%	89%	96%	100%	89%	80%	63%

3.3.1-Instream Flow Study



FirstLight Power Resources

3.3.1-Instream Flow Study

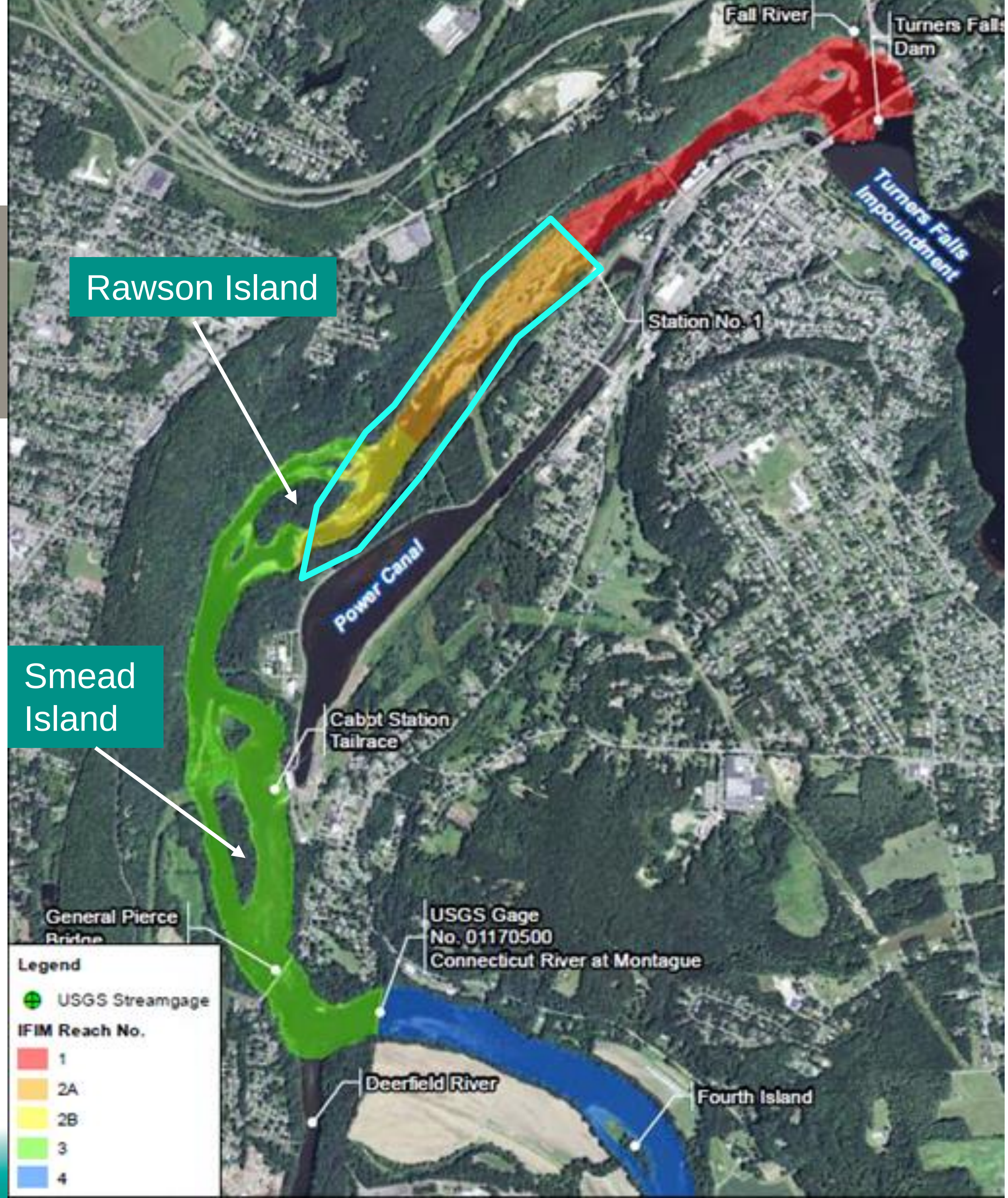
Reach 1-Transects T-10 & T-11, Low Backwater (also one for high backwater)- Steady State Habitat Results

Table 7.1.1.2-1: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 1 (Transects 10 & 11) for Low Backwater Condition

Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft^2)	120 (cfs)	150 (cfs)	200 (cfs)	250 (cfs)	400 (cfs)	500 (cfs)	600 (cfs)	700 (cfs)	800 (cfs)	1000 (cfs)	1200 (cfs)	1400 (cfs)	1600 (cfs)	1800 (cfs)	2000 (cfs)	3000 (cfs)	4000 (cfs)	5000 (cfs)
					0.02 (cfsm)	0.02 (cfsm)	0.03 (cfsm)	0.03 (cfsm)	0.06 (cfsm)	0.07 (cfsm)	0.08 (cfsm)	0.1 (cfsm)	0.11 (cfsm)	0.14 (cfsm)	017 (cfsm)	0.2 (cfsm)	0.22 (cfsm)	0.25 (cfsm)	0.28 (cfsm)	0.42 (cfsm)	0.56 (cfsm)	0.70 (cfsm)
American Shad	Spawning/Incu	May-June	7,500	870,142	9.5%	11.0%	13.3%	15.4%	18.9%	21.6%	24.1%	26.5%	28.8%	32.8%	37.9%	43.1%	47.5%	52.9%	58.2%	71.7%	81.6%	88.8%
American Shad	Juvenile	June-Oct	2,000	619,823	27.3%	29.7%	33.6%	36.9%	42.1%	43.8%	45.0%	46.1%	47.6%	52.8%	66.3%	78.8%	86.1%	93.8%	100.0%	96.9%	89.1%	80.4%
American Shad	Adult	May-June	7,500	626,206	10.8%	12.5%	14.8%	17.0%	18.8%	21.1%	23.5%	25.5%	27.5%	31.4%	35.7%	39.7%	42.2%	46.0%	49.7%	65.8%	80.6%	89.3%
Shortnose Sturgeon	Spawning	April-May	6,000	874,855	7.2%	10.1%	13.7%	16.3%	21.4%	23.8%	26.4%	28.6%	30.5%	33.0%	37.2%	43.0%	49.0%	56.7%	65.5%	84.2%	94.4%	98.8%
Shortnose Sturgeon	Egg-Larvae	May	3,000	1,360,780	20.3%	22.2%	25.1%	27.9%	32.4%	33.7%	35.1%	37.4%	41.4%	51.0%	67.4%	80.2%	87.5%	94.3%	99.4%	100.0%	99.9%	99.2%
Shortnose Sturgeon	Fry	May	700	59,453	57.3%	63.0%	71.0%	79.1%	89.9%	94.9%	98.2%	100.0%	100.0%	97.5%	95.4%	94.5%	91.5%	91.3%	91.8%	70.6%	52.7%	38.0%
Fallfish	Spawning/Incu	May-June	120	6,038	100.0%	91.1%	78.0%	66.5%	58.5%	44.5%	31.8%	20.3%	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fallfish	Fry	May-June	200	28,739	85.9%	96.3%	100.0%	97.6%	86.8%	82.2%	68.5%	53.3%	46.0%	33.6%	28.2%	25.4%	21.9%	18.5%	15.5%	4.8%	1.5%	0.7%
Fallfish	Juvenile	Year Round	2,000	233,847	49.6%	48.0%	50.7%	58.0%	67.2%	72.5%	73.0%	72.8%	75.5%	77.0%	80.6%	89.6%	95.2%	99.3%	100.0%	89.7%	67.8%	47.7%
Fallfish	Adult	Year Round	2,000	437,958	41.4%	44.3%	49.3%	52.4%	49.9%	48.0%	45.9%	44.6%	45.2%	49.3%	63.5%	78.3%	85.2%	94.3%	100.0%	93.2%	77.5%	64.7%
Longnose Dace	Juvenile	Year Round	2,000	196,805	13.0%	14.5%	17.5%	22.5%	44.0%	43.4%	35.0%	31.2%	29.0%	31.0%	49.1%	68.0%	83.9%	95.4%	100.0%	46.2%	17.1%	5.4%
Longnose Dace	Adult	Year Round	2,000	462,096	9.5%	10.1%	12.5%	14.4%	28.5%	29.8%	27.3%	26.7%	25.6%	23.3%	41.7%	62.0%	79.8%	93.0%	100.0%	68.6%	29.4%	8.8%
White Sucker	Spawning/Incu	Apr-May	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
White Sucker	Fry	May-June	1,200	639,270	38.2%	38.7%	42.1%	49.0%	39.4%	47.3%	58.4%	70.1%	79.3%	96.8%	100.0%	91.8%	73.5%	52.8%	28.4%	6.5%	1.4%	1.1%
White Sucker	Adult/Juvenile	Year Round	1,600	202,982	87.2%	82.8%	77.1%	73.5%	58.0%	47.4%	40.0%	35.2%	32.9%	43.5%	70.4%	95.9%	100.0%	97.6%	79.0%	38.5%	10.9%	3.4%
Walleye	Spawning/Incu	April-May	3,000	151,950	8.8%	9.9%	11.3%	12.5%	18.9%	23.4%	28.2%	34.5%	40.9%	50.0%	55.8%	57.6%	68.0%	69.1%	69.2%	100.0%	95.4%	86.4%
Walleye	Fry	April-May	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Walleye	Juvenile	Year Round	150	179	71.4%	100.0%	100.0%	100.0%	71.4%	57.1%	57.1%	42.9%	28.6%	14.3%	5.7%	11.4%	8.6%	0.0%	0.0%	0.0%	0.0%	0.0%
Walleye	Adult	Year Round	3,000	6,289	38.2%	47.6%	53.3%	54.1%	47.6%	53.3%	58.2%	62.6%	65.9%	70.0%	74.7%	76.9%	77.7%	78.9%	83.4%	100.0%	39.0%	1.4%
Tessellated Darter	Adult/Juvenile	Year Round	2,000	169,159	8.6%	8.6%	11.5%	14.1%	32.9%	32.5%	21.5%	18.7%	19.4%	26.1%	47.4%	68.0%	85.3%	97.3%	100.0%	39.3%	5.5%	0.0%
Sea Lamprey	Spawning/Incu	May-June	800	8,809	15.0%	17.2%	23.3%	25.9%	68.7%	89.8%	92.6%	95.2%	100.0%	93.4%	59.5%	58.9%	57.5%	64.0%	68.0%	26.2%	12.4%	3.6%
Macroinvertebrates	Larva	Year Round	4,000	961,042	1.9%	3.0%	4.9%	6.6%	13.8%	18.0%	21.7%	24.7%	26.7%	28.7%	31.5%	37.0%	45.1%	55.4%	68.0%	91.8%	100.0%	98.0%
Shallow Slow	Shallow Slow	Year Round	1,200	789,695	22.3%	25.5%	31.7%	46.9%	58.3%	62.2%	68.3%	70.7%	78.5%	92.4%	100.0%	88.6%	78.8%	75.9%	71.6%	20.7%	0.0%	0.0%
Shallow Fast	Shallow Fast	Year Round	1,800	556,171	15.8%	18.5%	21.5%	23.5%	30.8%	30.3%	26.6%	21.7%	22.2%	33.4%	64.6%	85.2%	96.0%	100.0%	96.1%	43.8%	12.0%	3.0%
Deep Slow	Deep Slow	Year Round	1,400	385,669	49.4%	54.3%	60.7%	68.0%	37.5%	31.6%	25.5%	25.1%	37.3%	61.4%	83.7%	100.0%	84.7%	65.2%	54.3%	18.2%	3.5%	1.3%
Deep Fast	Deep Fast	Year Round	3,000	126,639	25.0%	33.7%	47.3%	57.5%	71.1%	63.4%	61.0%	56.0%	49.3%	53.7%	74.7%	87.8%	89.4%	91.4%	93.9%	100.0%	86.0%	69.2%

3.3.1-Instream Flow Study

Reach 2A (1-D) and Reach 2B (2-D): Station No.1 tailrace and Rock Dam



FirstLight Power Resources

3.3.1-Instream Flow Study

Reach 2- Reach 2A and 2B Steady State Habitat Results

Table 7.1.2-1: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 2

Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft^2)	120 (cfs) 0.02 (cfsm)	150 (cfs) 0.02 (cfsm)	200 (cfs) 0.03 (cfsm)	250 (cfs) 0.03 (cfsm)	400 (cfs) 0.06 (cfsm)	500 (cfs) 0.07 (cfsm)	600 (cfs) 0.08 (cfsm)	700 (cfs) 0.1 (cfsm)	800 (cfs) 0.11 (cfsm)	1000 (cfs) 0.14 (cfsm)	1200 (cfs) 017 (cfsm)	1400 (cfs) 0.2 (cfsm)	1600 (cfs) 0.22 (cfsm)	1800 (cfs) 0.25 (cfsm)	2000 (cfs) 0.28 (cfsm)	3000 (cfs) .42 (cfsm)	4000 (cfs) 0.56 (cfsm)	5000 (cfs) 0.7 (cfsm)
American Shad	Spawning/Incu	May-June	10,000	1,487,041	13.0%	14.1%	15.8%	17.4%	21.8%	24.1%	26.3%	28.4%	30.3%	34.0%	38.0%	41.9%	45.3%	48.6%	52.1%	62.8%	70.6%	78.0%
American Shad	Juvenile	June-Oct	3,000	1,094,797	26.0%	29.1%	33.9%	38.6%	49.3%	52.4%	55.3%	57.5%	59.5%	64.9%	73.5%	81.0%	86.4%	91.3%	95.7%	100.0%	97.6%	94.3%
American Shad	Adult	May-June	10,000	1,200,278	19.6%	20.7%	22.4%	24.0%	28.8%	31.3%	33.8%	35.9%	37.8%	41.4%	44.3%	47.0%	49.1%	51.2%	53.7%	60.4%	66.2%	74.6%
Shortnose Sturgeon	Spawning/Incu	April-May	10,000	950,854	2.7%	3.8%	5.4%	6.8%	10.6%	13.0%	15.0%	17.5%	19.9%	24.2%	29.2%	34.5%	39.3%	44.0%	48.9%	62.6%	74.2%	85.1%
Shortnose Sturgeon	Egg-Larvae	May	7,000	2,020,957	22.9%	25.2%	28.8%	32.2%	39.1%	41.6%	43.9%	45.9%	47.8%	54.9%	64.5%	71.7%	77.6%	83.2%	88.6%	95.5%	97.7%	99.2%
Shortnose Sturgeon	Fry	May	6,000	437,325	17.6%	21.5%	27.7%	33.8%	48.7%	52.8%	56.7%	59.2%	61.6%	65.7%	71.0%	76.7%	81.0%	85.0%	88.7%	94.9%	97.8%	99.6%
Fallfish	Spawning/Incu	May-June	3,000	44,809	28.8%	29.7%	31.3%	32.6%	33.8%	34.7%	36.2%	38.7%	41.3%	44.9%	53.7%	63.4%	73.1%	76.9%	81.3%	100.0%	94.4%	80.2%
Fallfish	Fry	May-June	1,600	107,763	61.8%	62.9%	64.7%	68.5%	73.8%	75.3%	76.2%	77.5%	80.3%	89.4%	95.3%	98.7%	92.1%	99.5%	98.0%	80.7%	59.9%	49.0%
Fallfish	Juvenile	Year Round	3,000	566,109	34.8%	38.4%	44.1%	49.4%	59.7%	61.4%	62.9%	64.5%	66.5%	69.3%	76.2%	85.3%	90.6%	95.4%	99.1%	100.0%	88.3%	74.2%
Fallfish	Adult	Year Round	1,800	822,519	45.4%	50.5%	57.4%	63.3%	71.6%	75.0%	77.8%	80.0%	81.8%	84.9%	90.7%	96.7%	92.1%	100.0%	99.0%	91.8%	82.5%	75.6%
Longnose Dace	Juvenile	Year Round	3,000	311,117	32.3%	33.0%	34.0%	35.6%	37.1%	37.5%	37.4%	36.7%	35.8%	38.3%	51.7%	66.0%	77.6%	88.8%	99.7%	100.0%	66.6%	40.6%
Longnose Dace	Adult	Year Round	3,000	615,175	22.3%	23.0%	24.1%	25.6%	29.0%	29.9%	30.3%	30.4%	30.6%	33.2%	46.3%	60.4%	71.9%	82.3%	92.2%	100.0%	89.3%	60.1%
White Sucker	Spawning/Incu	April-May	10,000	13,636	10.1%	8.0%	8.8%	10.1%	11.3%	12.1%	13.1%	15.3%	19.3%	27.4%	35.3%	41.9%	49.8%	56.6%	65.2%	86.4%	51.8%	43.5%
White Sucker	Fry	May-June	1,000	1,036,376	74.6%	75.4%	77.0%	79.5%	84.8%	87.4%	89.7%	91.9%	94.7%	100.0%	97.4%	89.7%	78.2%	65.6%	52.3%	34.9%	24.3%	19.1%
White Sucker	Adult/Juvenile	Year Round	1,400	436,799	42.9%	46.9%	52.4%	57.9%	71.2%	75.4%	80.2%	83.6%	85.8%	89.5%	95.6%	100.0%	98.2%	92.8%	85.0%	67.2%	49.7%	39.2%
Walleye	Spawning/Incu	April-May	8,000	482,932	6.4%	7.3%	9.0%	10.8%	16.8%	20.3%	24.4%	28.4%	31.6%	36.8%	39.0%	41.6%	45.3%	49.0%	52.4%	67.9%	80.5%	88.0%
Walleye	Fry	April-May	1,000	19,515	74.0%	77.0%	80.4%	82.8%	88.6%	91.1%	93.2%	95.5%	97.8%	100.0%	96.7%	92.5%	86.7%	79.6%	72.9%	61.8%	63.5%	61.4%
Walleye	Juvenile	Year Round	1,600	11,769	91.5%	91.4%	91.2%	91.1%	92.6%	93.8%	94.5%	94.0%	93.4%	94.2%	95.9%	98.2%	100.0%	99.5%	95.9%	79.1%	79.6%	77.7%
Walleye	Adult	Year Round	400	108,908	90.1%	91.4%	93.7%	96.0%	100.0%	95.4%	90.8%	83.5%	76.1%	62.8%	55.5%	51.5%	48.5%	46.1%	43.9%	37.5%	35.3%	35.2%
Tessellated Darter	Adult/Juvenile	Year Round	2,000	221,890	23.6%	23.2%	23.2%	23.9%	24.1%	24.3%	24.2%	24.0%	23.5%	26.5%	46.2%	66.6%	79.8%	90.9%	100.0%	93.7%	51.5%	25.5%
Sea Lamprey	Spawning/Incu	May-June	3,000	40,615	30.6%	36.5%	44.3%	49.8%	60.3%	61.9%	63.1%	62.4%	63.0%	63.3%	66.9%	71.4%	77.0%	81.3%	86.5%	100.0%	94.1%	72.0%
Macroinvertebrates	Larva	Year Round	6,000	1,343,516	5.9%	7.1%	9.0%	10.7%	15.1%	16.9%	18.5%	19.6%	20.7%	22.6%	25.9%	30.9%	37.6%	45.7%	55.5%	80.0%	93.5%	98.8%
Habitat Guild	Shallow Slow	Year Round	1,200	750,888	59.6%	59.0%	59.1%	63.4%	66.4%	66.7%	70.8%	75.8%	82.9%	95.8%	100.0%	99.0%	95.8%	90.0%	82.7%	50.4%	24.6%	15.6%
Habitat Guild	Shallow Fast	Year Round	2,000	618,960	28.2%	28.4%	29.4%	30.5%	32.4%	32.1%	32.2%	32.8%	33.4%	42.5%	64.5%	80.2%	89.7%	96.5%	100.0%	78.3%	49.5%	29.6%
Habitat Guild	Deep Slow	Year Round	1,400	822,968	72.4%	73.7%	75.7%	78.1%	83.6%	84.6%	86.8%	89.0%	90.6%	96.7%	98.9%	100.0%	95.2%	88.1%	78.6%	51.5%	40.2%	35.9%
Habitat Guild	Deep Fast	Year Round	7,000	456,895	2.8%	4.7%	8.8%	11.8%	17.2%	20.6%	24.7%	28.9%	32.1%	36.7%	40.6%	43.4%	46.8%	51.6%	57.4%	67.9%	75.8%	82.8%

FirstLight Power Resources

3.3.1-Instream Flow Study

Reach 3

Hydraulics in Reach 3 impacted by:

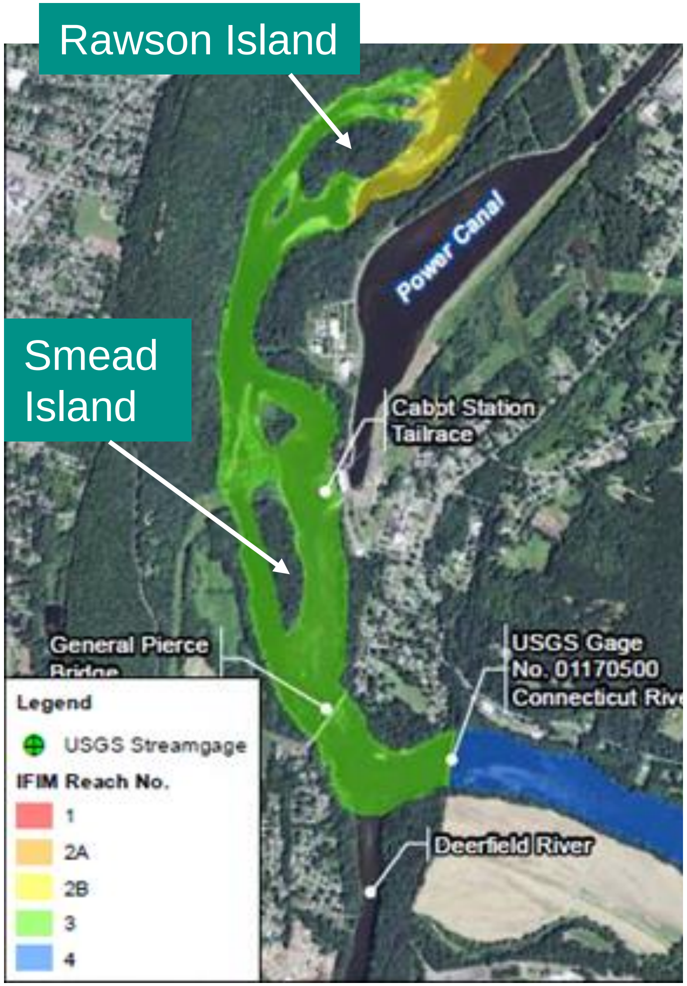
- Bypass Flow
- Cabot Operations
- Deerfield River Flow

Scenarios Evaluated for Steady State Habitat Assessment:

Scenario	Bypass Q	Cabot Q	Deerfield Q
1	120, 200, 300, 500, 700, 1,000, 2,000, 3,000, 5,000 cfs	2,500 cfs	200 cfs
2	Same as Scenario 1	7,000 cfs	200 cfs
3	Same as Scenario 1	14,000 cfs	200 cfs

Analyses

- Steady State Habitat Assessment
- Persistent Habitat Mapping
- Habitat Time Series (still needs to be completed)

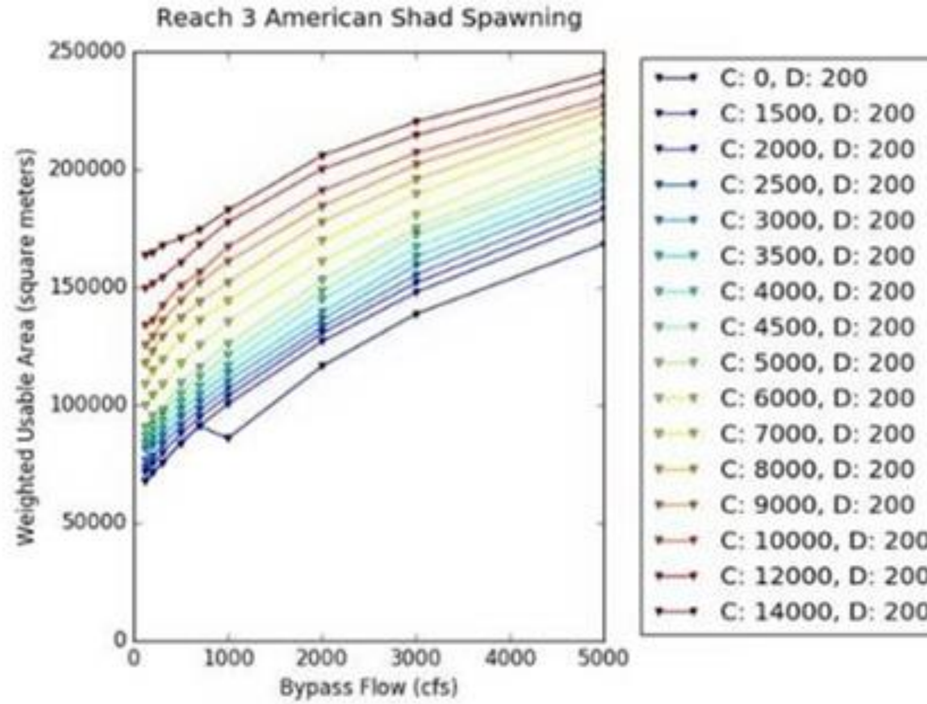


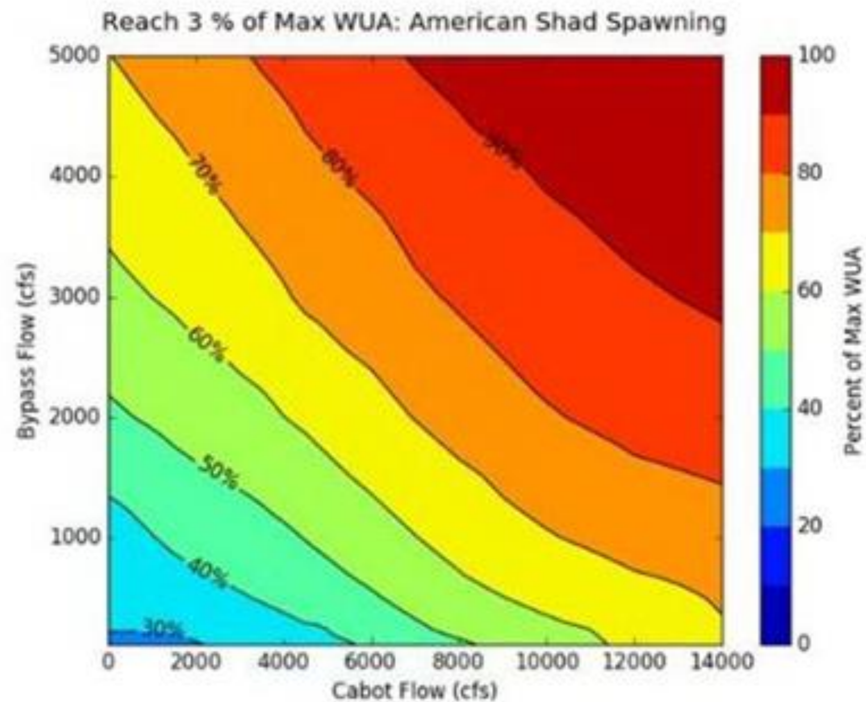
FirstLight Power Resources

3.3.1-Instream Flow Study

Reach 3

Example Output for Steady State Habitat Results for American Shad spawning and incubation under different bypass flows, and Cabot discharges, and Deerfield = 200 cfs



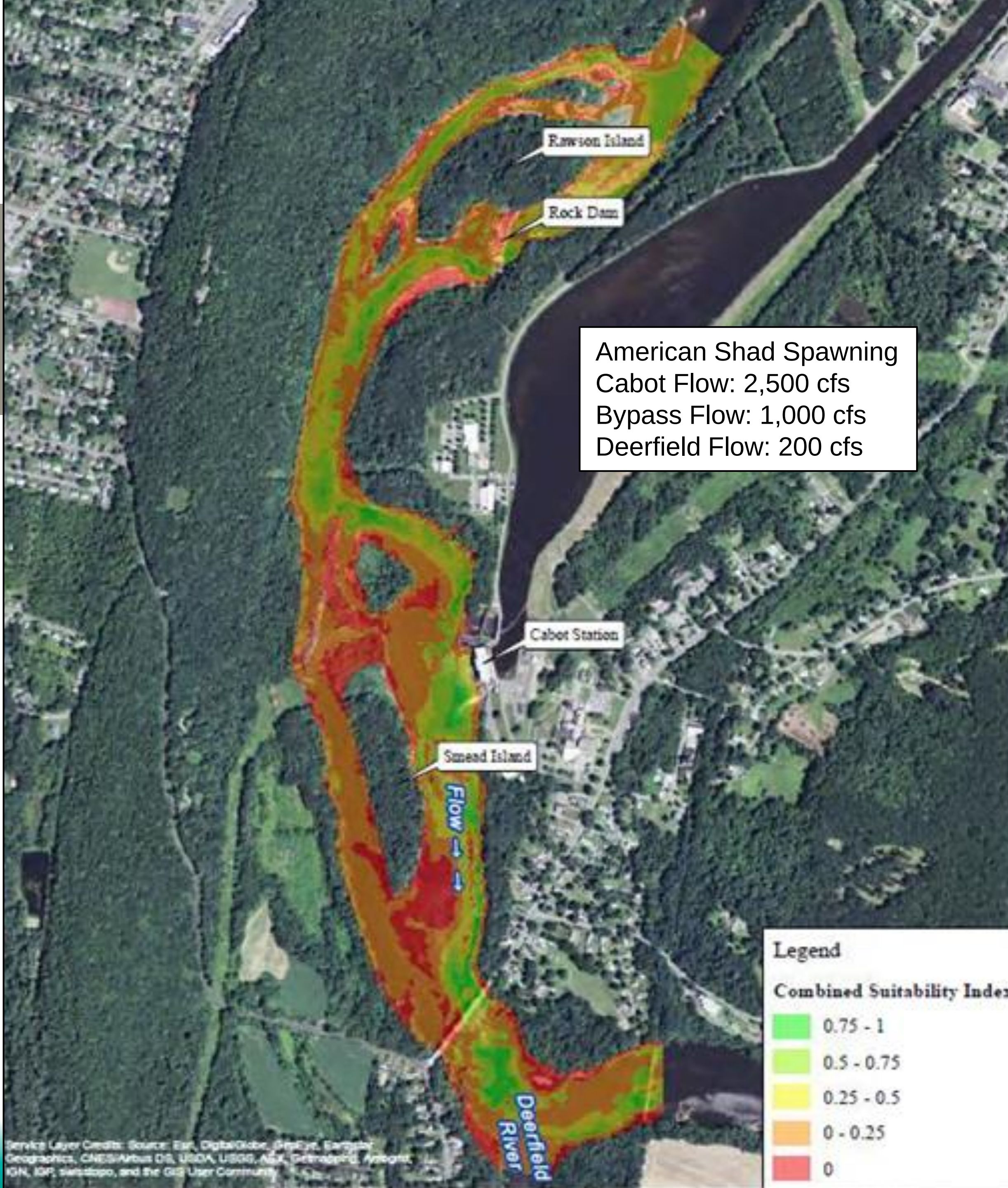


FirstLight Power Resources

3.3.1-Instream Flow Study

<u>Reach 3</u>

Example Output for Combined Suitability Index Results for American Shad spawning and incubation under Cabot discharge of 2,500 cfs, bypass flow of 1,000 cfs, and Deerfield flow of 200 cfs (steady state analysis)

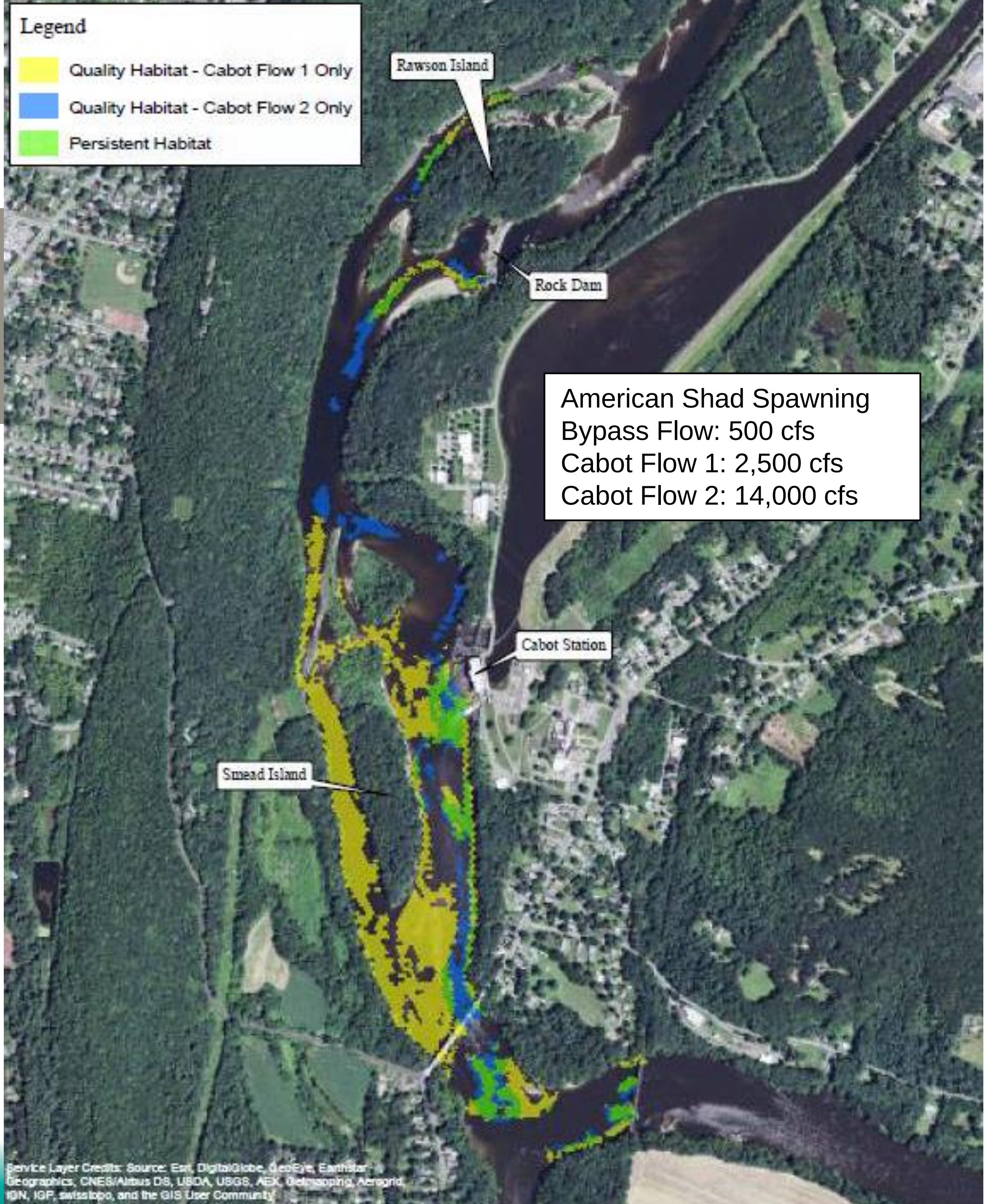


FirstLight Power Resources

3.3.1-Instream Flow Study

Reach 3

Example Output of Persistent Habitat Mapping for American Shad spawning and incubation under bypass flow of 500 cfs and Cabot discharges of 2,500 and 14,000 cfs

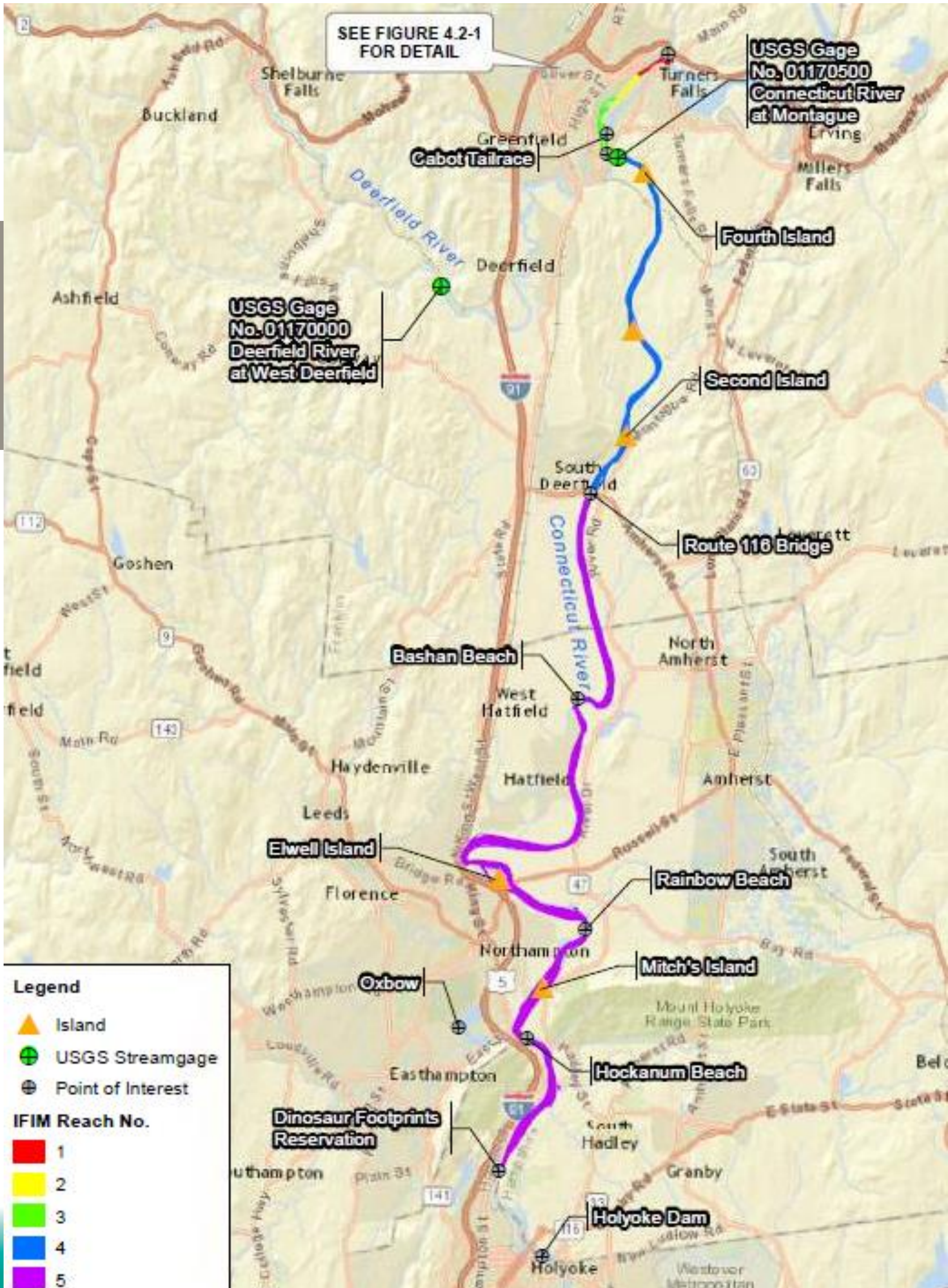


FirstLight Power Resources

3.3.1-Instream Flow Study

Reach 4

- Steady State Habitat Analysis
- Dual Flow Analysis
- Habitat Time Series Analysis



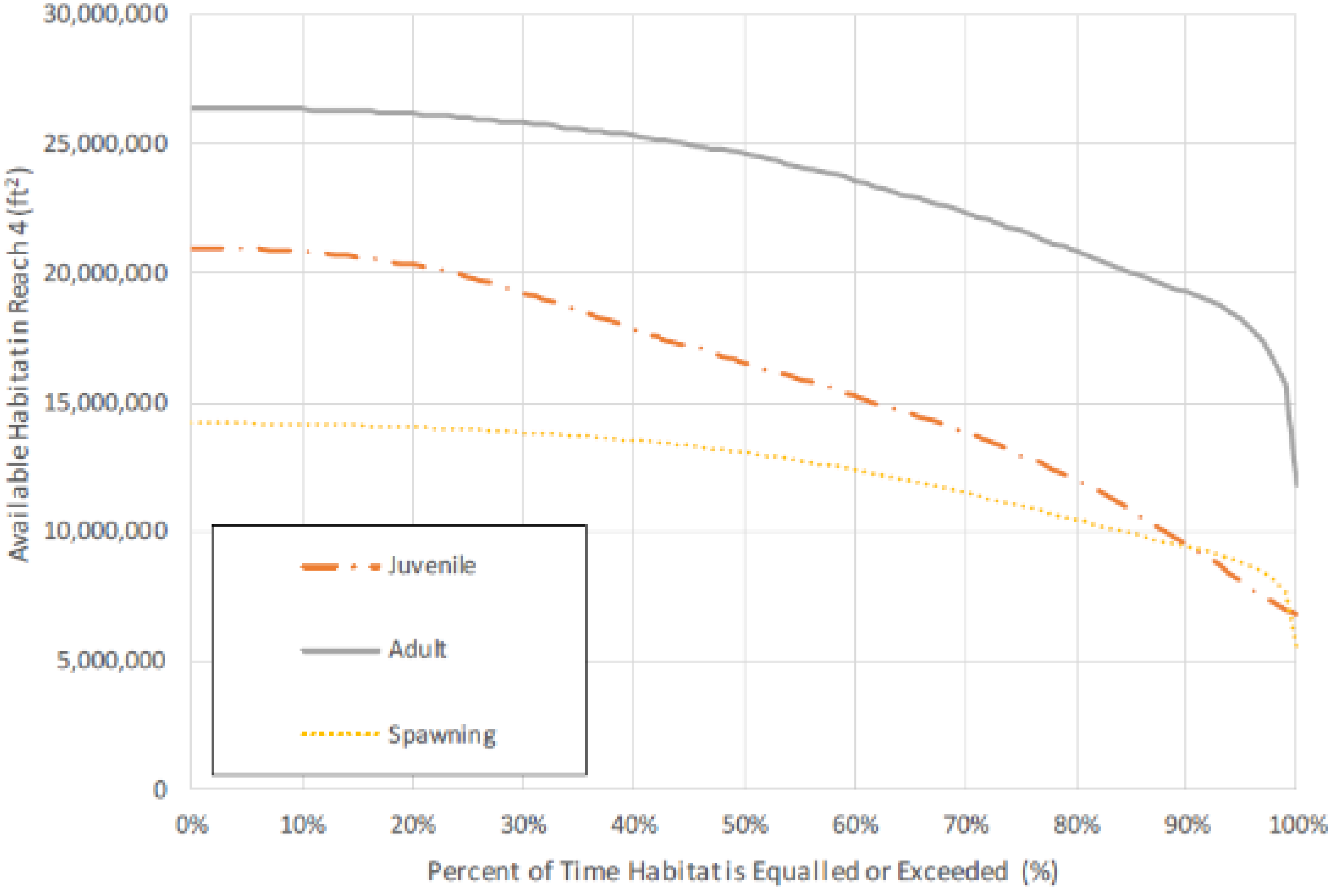
3.3.1-Instream Flow Study

Reach 4- Steady State Habitat Results

Table 7.1.4-1: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 4

Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft^2)	1200 (cfs)	1600 (cfs)	2000 (cfs)	2800 (cfs)	4000 (cfs)	5000 (cfs)	6000 (cfs)	8000 (cfs)	10000 (cfs)	12000 (cfs)	14000 (cfs)	15000 (cfs)	17500 (cfs)	20000 (cfs)	25000 (cfs)	30000 (cfs)	37500 (cfs)
					0.15 (cfsm)	0.2 (cfsm)	0.25 (cfsm)	0.36 (cfsm)	0.51 (cfsm)	0.64 (cfsm)	0.76 (cfsm)	1.02 (cfsm)	1.27 (cfsm)	1.53 (cfsm)	1.78 (cfsm)	1.91 (cfsm)	2.23 (cfsm)	2.54 (cfsm)	2.86 (cfsm)	3.82 (cfsm)	4.77 (cfsm)
American Shad	Spawning/Incu	May-June	12,000	14,182,397	46.8%	53.6%	59.3%	68.0%	77.4%	83.4%	88.2%	94.8%	98.5%	100.0%	99.6%	98.9%	96.0%	92.0%	82.3%	72.5%	59.4%
American Shad	Juvenile	June-Oct	4,000	20,970,703	87.3%	92.5%	95.8%	99.3%	100.0%	98.4%	95.7%	89.4%	83.2%	77.9%	72.1%	69.3%	62.9%	57.2%	47.4%	39.5%	32.2%
American Shad	Adult	May-June	12,000	26,411,552	52.7%	59.2%	64.9%	72.8%	80.6%	85.6%	89.7%	95.9%	99.1%	100.0%	99.3%	98.6%	96.0%	93.0%	86.6%	79.9%	70.8%
Shortnose Sturgeon	Fry	May	5,000	16,338,131	69.9%	79.8%	86.6%	95.3%	99.7%	100.0%	98.8%	95.1%	90.0%	84.7%	79.3%	76.7%	70.4%	64.7%	55.1%	47.8%	39.8%
Shortnose Sturgeon	Juveniles	June	5,000	20,325,318	78.8%	84.3%	88.9%	94.8%	98.8%	100.0%	99.8%	97.0%	92.2%	86.9%	81.8%	79.5%	73.8%	68.7%	59.8%	52.9%	45.3%
Shortnose Sturgeon	Adults	Year Round	5,000	20,657,503	79.8%	85.6%	90.1%	95.6%	99.3%	100.0%	99.3%	95.9%	90.9%	85.8%	80.8%	78.5%	72.8%	67.6%	58.9%	52.1%	44.6%
Fallfish	Spawning/Incu	May-June	800	5,014,615	88.5%	78.9%	73.1%	66.1%	55.6%	44.6%	34.3%	17.7%	10.8%	7.9%	6.6%	6.1%	4.4%	2.4%	0.2%	0.0%	2.2%
Fallfish	Fry	May-June	800	7,657,464	91.2%	82.0%	73.7%	61.9%	44.9%	35.4%	27.7%	18.3%	13.5%	11.7%	9.4%	8.0%	4.7%	2.9%	2.3%	2.6%	5.9%
Fallfish	Juvenile	Year Round	800	8,226,027	98.3%	95.0%	91.5%	88.5%	82.0%	73.0%	62.6%	43.3%	32.2%	27.2%	23.0%	21.4%	16.9%	13.1%	8.7%	7.1%	7.3%
Fallfish	Adult	Year Round	2,000	18,844,747	96.9%	99.3%	100.0%	98.2%	93.1%	87.7%	82.1%	71.3%	62.7%	57.4%	53.2%	51.5%	47.3%	43.3%	37.4%	33.5%	30.5%
Longnose Dace	Juvenile	Year Round	2,400	1,226,425	89.2%	98.7%	99.7%	96.4%	65.1%	38.4%	21.9%	9.4%	10.9%	11.8%	7.0%	4.7%	2.2%	1.2%	0.7%	1.3%	8.9%
Longnose Dace	Adult	Year Round	2,400	2,146,515	86.0%	92.9%	98.8%	96.0%	73.2%	49.3%	27.5%	9.2%	8.4%	10.3%	10.3%	8.3%	2.2%	1.3%	1.8%	2.2%	5.9%
White Sucker	Spawning/Incu	Apr-May	1,600	654,203	96.6%	100.0%	92.5%	91.4%	52.4%	23.9%	11.3%	8.9%	12.7%	12.1%	9.2%	6.7%	4.1%	3.3%	4.0%	5.8%	24.1%
White Sucker	Fry	May-June	800	17,311,497	93.3%	84.4%	76.9%	63.6%	49.6%	42.5%	38.2%	33.4%	31.1%	28.7%	26.4%	25.1%	22.7%	21.1%	19.0%	17.8%	17.8%
White Sucker	Adult/Juvenile	Year Round	1,000	11,466,039	98.6%	91.5%	83.1%	68.4%	52.9%	44.6%	38.2%	29.1%	24.3%	23.5%	22.2%	21.0%	17.6%	14.7%	10.8%	8.4%	7.0%
Walleye	Spawning	April-May	5,000	2,557,617	58.7%	68.1%	76.9%	89.4%	99.2%	100.0%	95.3%	84.4%	68.9%	49.4%	30.9%	24.1%	11.3%	7.1%	4.7%	2.4%	0.9%
Walleye	Fry	April-May	8,000	955,697	77.2%	85.4%	94.0%	93.6%	84.9%	77.5%	83.1%	100.0%	90.9%	67.5%	45.8%	39.9%	25.6%	11.6%	0.0%	0.0%	0.0%
Walleye	Juvenile	Year Round	800	1,789,966	88.8%	80.1%	74.1%	68.9%	64.7%	61.2%	58.0%	55.9%	59.0%	58.4%	55.2%	53.5%	47.4%	41.5%	30.8%	25.0%	21.4%
Walleye	Adult	Year Round	800	7,030,738	89.7%	80.0%	72.8%	61.3%	54.9%	53.9%	53.6%	52.8%	51.9%	53.3%	55.3%	54.7%	52.5%	50.0%	44.8%	41.0%	37.3%
Tessellated Darter	Adult/Juvenile	Year Round	1,600	1,097,027	92.5%	100.0%	86.3%	82.9%	51.8%	27.3%	15.2%	8.5%	13.8%	15.2%	8.8%	5.4%	4.3%	3.7%	3.7%	6.1%	25.8%
Sea Lamprey	Spawning/Incu	May-June	2,800	209,778	67.1%	83.7%	94.3%	100.0%	78.8%	44.0%	20.1%	3.4%	6.0%	8.3%	7.0%	6.9%	1.2%	0.5%	0.2%	0.3%	6.7%
Macroinvertebrates	Larva	Year Round	5,000	3,812,597	41.0%	54.5%	67.8%	87.3%	98.4%	100.0%	97.2%	87.2%	76.9%	67.9%	61.4%	59.1%	54.7%	51.7%	46.4%	42.6%	40.2%
Shallow Slow	Shallow Slow	Year Round	800	2,811,288	88.2%	89.5%	92.9%	84.6%	64.2%	60.6%	51.6%	34.2%	15.8%	12.3%	9.4%	7.8%	1.7%	1.3%	1.6%	0.2%	4.7%
Shallow Fast	Shallow Fast	Year Round	800	2,627,730	93.4%	94.6%	97.1%	89.2%	60.5%	41.8%	29.0%	16.3%	14.0%	12.7%	10.7%	6.8%	3.7%	2.4%	0.7%	0.5%	5.0%
Deep Slow	Deep Slow	Year Round	1,000	19,235,977	99.1%	96.4%	93.6%	87.4%	76.7%	66.8%	55.9%	43.6%	38.0%	36.0%	34.1%	33.1%	30.0%	27.4%	23.9%	21.7%	20.6%
Deep Fast	Deep Fast	Year Round	1,600	4,451,275	86.0%	100.0%	98.4%	90.7%	79.1%	72.0%	68.1%	62.3%	38.5%	19.4%	8.7%	6.2%	9.4%	8.4%	1.7%	0.5%	0.3%

Reach 4 – Example Habitat Time Series results for American Shad Based on hourly flow for period Jan 1, 2000 to Sep 30, 2015



Reach 4 – Results – Habitat Duration Exceedance Curves for various lifestages of American Shad

3.3.1-Instream Flow Study

Summary

- Work Completed
  - Reach 1- ZOP, steady state
  - Reach 2- steady state
  - Reach 3- steady state, persistent habitat mapping (for select flow combinations)
  - Reach 4- steady state, dual flow analysis, habitat time series analysis
  - Reach 5- steady state for mussels only

- Outstanding Work
  - Reach 3- persistent habitat mapping- need further input from stakeholders on flow combinations
  - Reach 3- habitat time series analysis

Variances

- None

3.3.16 State-Listed Mussels

Study Objectives

- **Conduct Field Surveys to delineate populations of state-listed mussels and suitable habitat downstream from Cabot Station and characterize the distribution, abundance, demographics, and habitat use of these populations. Identify and map potential habitat for state-listed mussel species based on habitat preferences.**

- **Develop a Binary Habitat Suitability Index for all state-listed mussel species found to occur in the 35-mile reach downstream from Cabot Station.**

3.3.16 State-Listed Mussels

Objective 1: Mussel Survey and Habitat Assessment (Completed in 2014)

- In June 2014, a habitat assessment and survey was completed throughout the 13-mile reach of the Connecticut River between Cabot Station and the Sunderland Bridge. A summary report of these findings was posted to the relicensing website in January 2015.

- The mussel community in the reach from Cabot Station to the Route 116 Bridge is dominated by a single species, Eastern Elliptio.

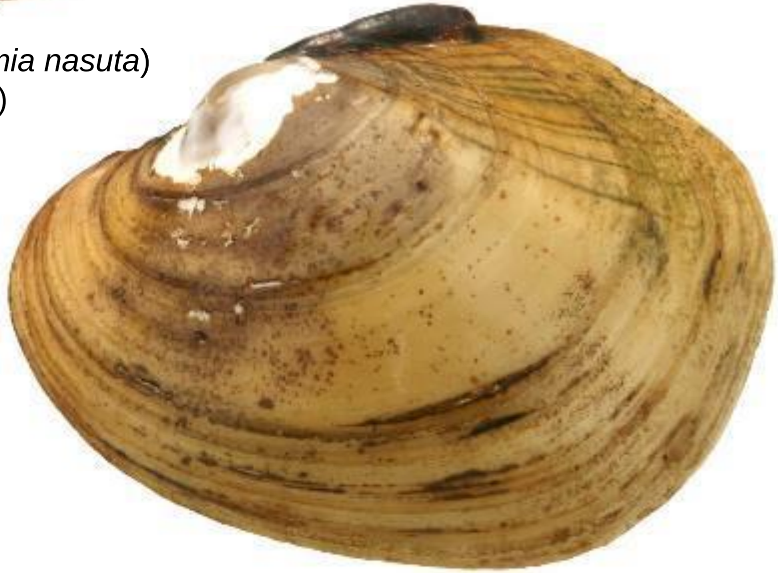
- No live state-listed mussels were found in the survey areas. One relic *Lampsilis cariosa* shell was found.

- As part of FERC-required studies for Holyoke Gas & Electric, three state-listed mussel species were documented in the lower end of Holyoke Dam impoundment (Reach 5 of FirstLight's study area).

3.3.16 State-Listed Mussels

Eastern Pondmussel (*Ligumia nasuta*)
(Special Concern)

Tidewater Mucket (*Leptodea ochracea*)
(Special Concern)



Yellow Lampmussel (*Lampsilis cariosa*)
(Endangered)

3.3.16 State-Listed Mussels

Objective 2: HSI Curve Development

- Delphi Panel
  - Developed from initial list of experts in conjunction with NHESP
- Panelists
- Instructions
- Process
  - Three Rounds
- Parameters
- HSI Results
- Application

FirstLight Power Resources

3.3.16 State-Listed Mussels

Delphi Panel

- Five Invitees, Four Participants
- Moderator

- Dr. David Strayer (Cary Institute of Ecosystem Studies)
- Dr. Barry Wicklow (St. Anselm's College)
- Dr. Cynthia Loftin (US Geological Survey/ME Cooperative Fish and Wildlife Research Unit)
- Ethan Nedeau (Biodrawversity)

3.3.16 State-Listed Mussels

Habitat Parameters

- **Depth** of water where individual mussels or mussel beds occur.
- **Flow velocity** refers to benthic (or "nose') velocity that mussels are subjected to.
- **Substrate** is specifically what mussels burrow in and generally where they spend their lives (recognizing limited mobility), and refers to dominant particle sizes in the top ~10cm of the river/lake bottom.
- **Cover** is any feature that can provide reduced lighting, reduced flow velocity, increased isolation; something that mussels can get under or behind. It may be important to host fish, which would in turn influence habitat suitability for mussels.
- **Shear stress** is the force exerted on the streambed by water per unit area of streambed, and is reflective of the stream’s flow intensity and its ability to entrain and transport sediment particles.
- **Relative shear stress** is the ratio of observed to critical shear stress; critical shear stress is the shear stress that is required to initiate movement for a given particle size.
- **Additional** as dictated by panelists

3.3.16 State-Listed Mussels

Round 1

- Panelists ranked suitability of parameters from 0.0, 0.1… to 1.0.
- Panelists provided a confidence in their scores based on personal level of certainty.
- References and data sources provided.

- Scores composited into a binary score as unsuitable “0” or suitable “1”
- Juvenile and adult life stages considered separately
- Anonymous scores, notes and references compiled for Round 2

3.3.16 State-Listed Mussels

Round 2

- Round 1 results summarized
  - Depth
  - Benthic Velocity
  - Substrate
  - Cover Type and %

- Shear Stress and Relative Shear Stress
  - Tentative scores compiled
  - Memo explaining SS/RSS considerations
  - RSS in Connecticut River under flood flows

3.3.16 State-Listed Mussels

Round 3

- Round 2 results provided
  - Depth
  - Benthic Velocity
  - Substrate
  - Cover – low importance

- Shear Stress and Relative Shear Stress
  - Memo updated
  - No HSI agreed upon for shear

3.3.16 State-Listed Mussels

Benthic Velocity

Parameter		Yellow Lampmussel		Eastern Pondmussel		Tidewater Mucket	
		Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Class	Benthic Velocity Range (ft/s)						
1	<0.16	1	1	1	1	1	1
2	0.16-0.34	1	1	1	1	1	1
3	0.35-0.67	1	1	1	1	1	1
4	0.68-0.99	1	1	1	1	1	1
5	1.00-1.32	1	1	1	1	1	1
6	1.33-1.65	1	1	1	1	1	1
7	1.66-2.47	0	1	0	0	0	1
8	2.48-3.29	0	0	0	0	0	0
9	3.30-4.93	0	0	0	0	0	0
10	4.94-6.56	0	0	0	0	0	0
11	>6.56	0	0	0	0	0	0

3.3.16 State-Listed Mussels

Water Depth

Parameter		Yellow Lampmussel		Eastern Pondmussel		Tidewater Mucket	
		Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Class	Water Depth Range (feet)						
1	0	0	0	0	0	0	0
2	0.03-0.34	0	0	0	0	0	0
3	0.35-0.83	1	1	1	1	1	1
4	0.84-1.65	1	1	1	1	1	1
5	1.66-2.47	1	1	1	1	1	1
6	2.48-3.29	1	1	1	1	1	1
7	3.30-4.93	1	1	1	1	1	1
8	4.94-6.56	1	1	1	1	1	1
9	6.57-9.85	1	1	1	1	1	1
10	9.86-13.12	1	1	1	1	1	1
11	>13.12	1	1	1	1	1	1

3.3.16 State-Listed Mussels

Substrate

Parameter		Yellow Lampmussel		Eastern Pondmussel		Tidewater Mucket	
		Juvenile	Adult	Juvenile	Adult	Juvenile	Adult
Class	**Particle Size**						
1	Organic Material	0	0	0	0	0	0
2	Clay	0	0	0	0	0	0
3	<0.002 in [mud/silt]	1	1	1	1	1	1
4	0.002 – 0.08 in. [sand]	1	1	1	1	1	1
5	0.08- 1.26 in. [fine gravel]	1	1	1	1	1	1
6	1.26 – 2.52 in. [coarse gravel]	1	1	0	1	1	1
7	2.52 – 5.90 in. [small cobble]	1	1	0	0	0	0
8	5.90 – 9.84 in. [large cobble]	0	0	0	0	0	0
9	9.84 – 157.5 in. [boulder]	0	0	0	0	0	0
10	Bedrock	0	0	0	0	0	0

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Application of 3.3.16 Mussel Criteria to Reach 5 IFIM

- HEC-RAS transects selected based on NHESP recommendations
  - Based on abundance of target species

- Benthic Velocity
  - HEC-RAS model calculated average water column velocity
  - Converted to benthic velocity using model/formula from literature

- Applied Velocity and Depth Criteria to Determine Suitability
  - Criteria 1: Yellow Lampmussel Juvenile; Eastern Pondmussel Juvenile and Adult; Tidewater Mucket Juvenile
  - Criteria 2: Yellow Lampmussel Adult; Tidewater Mucket Adult

- Limitations
  - Assumed sand substrate for modeling of velocity – No detailed substrate survey
    - Suitability of substrate was not a limiting factor for the modeling results

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

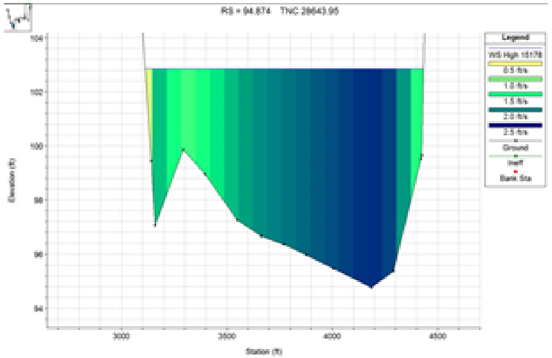
Scenario No.	Holyoke Dam Impoundment Elevation	Deerfield River Flow	Turners Falls Hydroelectric Project Flow	Total Flow
1	Min- 99.47 ft NGVD	Deerfield Hydroelectric Project Station No. 2 Min Flow 200 cfs	Turners Falls Project Min Flow 1,433 cfs	1,633 cfs
2	Max- 100.67 ft, NGVD	Deerfield Hydroelectric Project Station No. 2 Min Flow 200 cfs	Turners Falls Project Min Flow 1,433 cfs	1,633 cfs
3	Min- 99.47 ft NGVD	Deerfield Hydroelectric Project Station No. 2 Max Hydraulic Capacity 1,450 cfs	Cabot Station Hydraulic Capacity 13,728 cfs	15,178 cfs
4	Max- 100.67 ft, NGVD	Deerfield Hydroelectric Project Station No. 2 Max Hydraulic Capacity 1,450 cfs	Cabot Station Hydraulic Capacity 13,728 cfs	15,178 cfs
5	Min- 99.47 ft NGVD	Mean April Flow at the Montague USGS Gage		38,600 cfs

- **Scenarios 1-4 were used to examine “operational effects” that are within Project Capacity – Plus effects of Holyoke**
- **Scenario 5 was used to evaluate suitability during typical higher river flow conditions**

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

FirstLight Power Resources

HEC-RAS Model Output (Provides Depths and Mean Water Column Velocities for 20 Equally-Spaced Intervals)



Converted Mean Water Column Velocities to Benthic Velocities (Logarithmic Functions)

Matrix of Parameters by Cross-Section Interval

Interval	Depth (ft)	Benthic Velocity (ft/s)
1	2.09	0.57
2	5.17	1.41
3	3.92	1.20
4	3.23	1.08
5	3.81	1.19
6	4.54	1.31
7	5.29	1.43
8	5.81	1.51
9	6.16	1.56
10	6.38	1.59
11	6.6	1.62
12	6.85	1.65
13	7.11	1.70
14	7.37	1.73
15	7.64	1.76
16	7.9	1.80
17	7.98	1.81
18	7.57	1.76
19	5.94	1.52
20	3.72	1.16

Evaluated Binary Suitability using Depth and Benthic Velocity (Substrate was Assumed Medium Sand)

Matrix of Suitability by Cross-Section Interval

Species/Life Stage Criteria 1

Interval	Depth	Benthic Velocity	Substrate	Suitable
1	1	1	1	YES
2	1	1	1	YES
3	1	1	1	YES
4	1	1	1	YES
5	1	1	1	YES
6	1	1	1	YES
7	1	1	1	YES
8	1	1	1	YES
9	1	1	1	YES
10	1	1	1	YES
11	1	1	1	YES
12	1	0	1	NO
13	1	0	1	NO
14	1	0	1	NO
15	1	0	1	NO
16	1	0	1	NO
17	1	0	1	NO
18	1	0	1	NO
19	1	1	1	YES
20	1	1	1	YES

Calculated Cross-Section Suitability

13/20 Intervals Suitable = 65% of Cross-Section for this Species/Life Stage

Calculated Suitability for All Species/Life Stages

Transect	94.874	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	65.00%	100.00%

Calculated Suitability for All Modeling Scenarios

Transect	94.874	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	65.00%	100.00%
15,178	Low	45.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		13.64%	100.00%

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Qualitative Categorization

- None (No effect) – 0%
- Minimal – up to 10%
- Low – 10-20%
- Moderate – 20-40%
- Moderate-High – 40-60%
- High – 60-80%
- Severe – 80-100%

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

100 – 81.25 = 18.75% Lower Habitat Due to Increased Flow from 1,633 to 15,178:
"Low" Operational Effect on Criteria 1

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

93.75 – 81.25 = 12.5% Lower Habitat Due to Decreased Backwater during 15,178 cfs
"Low" Backwater Effect on Criteria 1

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

100 – 18.75 = 81.25% Lower Habitat Due to Mean April River Flow:
"Severe" High River Flow Effect on Criteria 1

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

No Operational or Backwater Effects on Criteria 2

Moderate High River Flow Effect on Criteria 2

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Modeling Results

- High suitability for most model runs
- Criteria 1 more sensitive to increases in flow
- Limited effects of backwatering
- Mean April Flows (High River Flow) most limiting
- No longitudinal pattern

Transect	88.5988	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	90.91%	100.00%
1,633	High	90.91%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.18%	100.00%

Transect	92.69	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		19.05%	100.00%

Transect	96.461	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	36.36%	63.64%
15,178	Low	40.00%	60.00%
1,633	High	100.00%	100.00%
1,633	Low	71.43%	100.00%
38,600		40.91%	72.73%

Transect	89.5413	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	95.45%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		31.82%	100.00%

Transect	92.9704	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	95.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	89.47%	100.00%
38,600		31.82%	100.00%

Transect	96.837	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		52.17%	86.96%

Transect	90.653	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	90.48%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		4.76%	52.38%

Transect	94.298	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	93.75%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		39.13%	73.91%

Transect	100.169	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	95.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		27.27%	81.82%

Transect	91.8435	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	95.00%	100.00%
38,600		85.71%	100.00%

Transect	94.874	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	65.00%	100.00%
15,178	Low	45.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		13.64%	100.00%

Transect	100.917	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	100.00%	100.00%
15,178	Low	100.00%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	95.00%	100.00%
38,600		18.18%	100.00%

Transect	92.257	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	93.75%	100.00%
15,178	Low	81.25%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	100.00%	100.00%
38,600		18.75%	68.75%

Transect	96.347	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	52.94%	100.00%
15,178	Low	52.94%	100.00%
1,633	High	84.62%	100.00%
1,633	Low	90.91%	100.00%
38,600		35.00%	60.00%

Transect	106.344	Channel Suitability	
Flow (cfs)	Backwater	Criteria 1	Criteria 2
15,178	High	9.09%	100.00%
15,178	Low	9.09%	100.00%
1,633	High	100.00%	100.00%
1,633	Low	73.68%	100.00%
38,600		9.09%	9.09%

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Yellow Lampmussel Abundance	Number of Transects	Criteria 1 (Includes Yellow Lampmussel Juveniles)		Criteria 2 (Includes Yellow Lampmussel Adults)	
		Operational Effect Range	High River Flow Effect Range	Operational Effect Range	High River Flow Effect Range
Absent (n = 0)	4	Minimal - Severe[1]	High - Severe	None	None - Severe[2]
Low (n = 1-4)	1	Minimal	High	None	Moderate
Medium (n = 5-50)	4	None - Moderate/High	Moderate/High - Severe	None - Moderate/High	None - Moderate/High
Medium-High*	3	Minimal - Low	Low - Severe	None	None - Moderate
High (n > 50)	3	None - Minimal	High - Severe	None	None - Moderate/High

*Medium-High was included for transects where values from 2009/2013 varied between medium and high
[1]Only one Severe value, the remaining three were Minimal
[2]Only one Severe value, the remaining three were None/Low

Abundance and presence/absence of Yellow Lampmussel was not correlated to the effects on suitability from the models

3.3.16 State-Listed Mussels to 3.3.1 Instream Flow Study (Reach 5)

Conclusions

- Flow conditions within operational parameters at Turners Falls Dam do not appear to be correlated with State-Listed mussel presence/absence or abundance
  - Mussels absent from seemingly suitable areas under a variety of flows
  - Mussels present in areas where typical spring (April) river flows can result in low suitability
- Other factors independent of operations at Turners Falls Dam are likely the primary driver of State-Listed mussel distribution in Reach 5. Potential other factors include:
  - Dispersal and successful colonization
  - Shear Stress during high flow events (scouring of habitat and displacement of mussels)
  - Distribution of suitable substrate

3.3.2- Upstream/Downstream Passage of Adult American Shad

Study Objectives

Our analysis methods were designed to assess each objective using appropriate statistical methods that return an estimate of the parameter of interest (e.g. proportion of successful passage) while also providing an estimate of precision with 95% confidence intervals.

- Describe the effectiveness of the **Cabot fish ladder**;
- Evaluate attraction, entrance efficiency and internal efficiency of the **Gatehouse ladder**;
- Identify **migration delays** resulting from operation of the Turners Falls Project;
- Determine **route selection** and behavior of upstream migrating shad at the Turners Falls Project under **various spill** flow levels;
- Evaluate attraction, entrance efficiency and internal efficiency of the **Spillway ladder** for shad reaching the dam spillway, under a range of spill conditions;
- Evaluate **migration** through the Turners Falls Impoundment (**TFI**);
- Identify **impacts of** Northfield Mountain, Cabot Station and Station No. 1 **operations** on upstream and downstream adult shad migration, including delays, entrainment, behavioral changes and migration direction shifts.
- Estimate **downstream passage route selection**, timing/delay, and survival at Turners Falls Dam; and
- Estimate passage rates and routes taken by shad **migrating downstream through the canal**, and evaluate Cabot Station fish bypass effectiveness.

3.3.2- Upstream/Downstream Passage of Adult American Shad

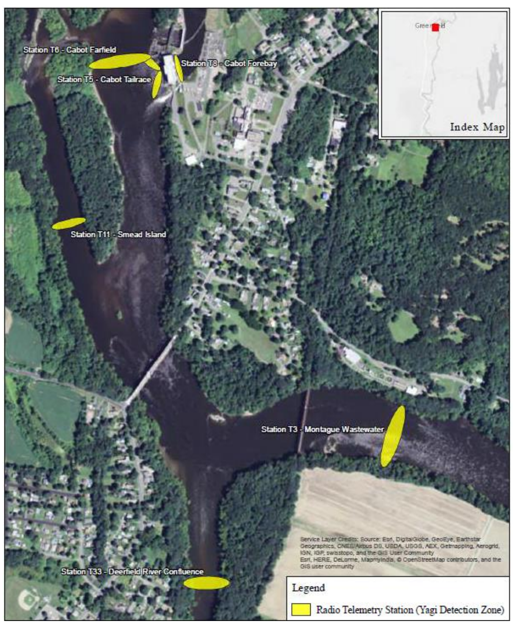
Work Completed

- Beginning in March 2015, FirstLight designed, installed and tested a fixed telemetry network (29 radio telemetry and 14 PIT) consisting of both passive and active radio telemetry monitoring equipment within the study area to answer specific questions related to the study objectives.
- Additional monitoring was conducted during mobile surveys throughout the entire study area, with the exception of the Power Canal and bypass reach to inform on migration and mortality events between fixed stations.
- A total of 33 mobile tracking surveys were conducted over 9 weeks between May 15, and July 7, 2015.

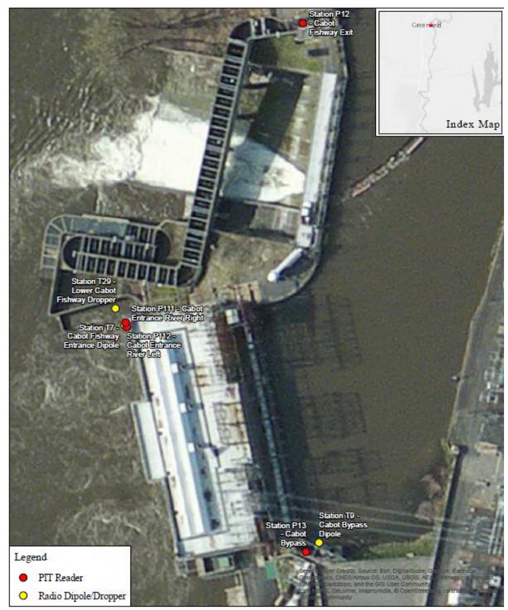
3.3.2- Upstream/Downstream Passage of Adult American Shad

Red Cliff Canoe Club

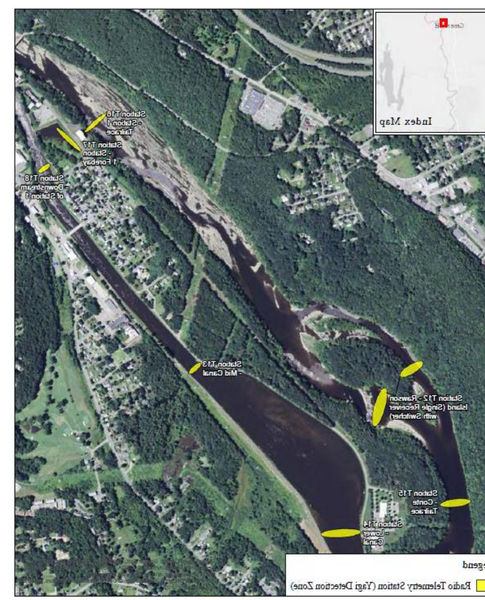
Sunderland Bridge



Montague Spoke

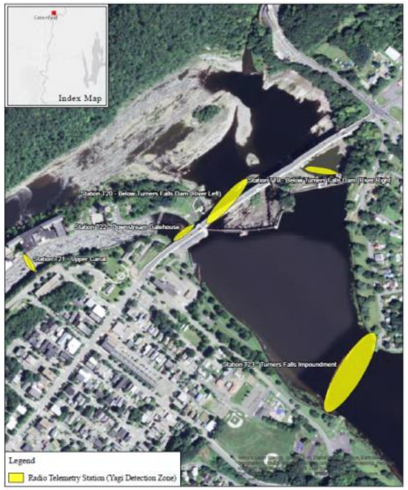


Cabot Ladder

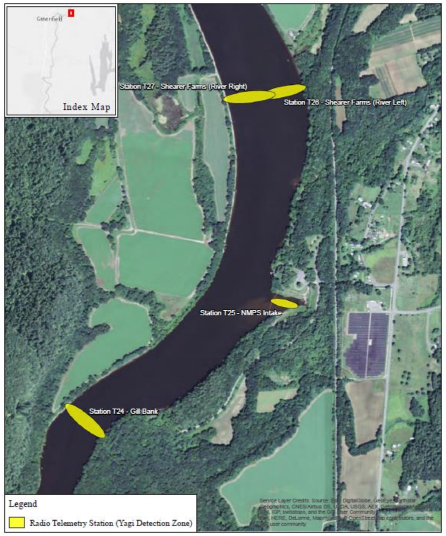


Bypass Reach

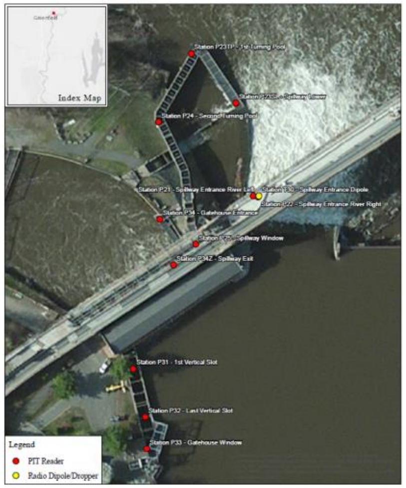
3.3.2- Upstream/Downstream Passage of Adult American Shad



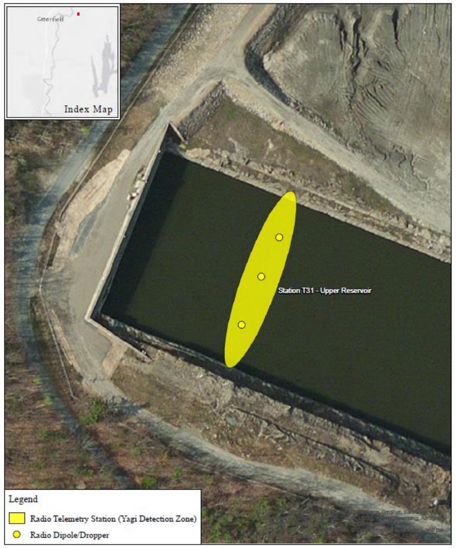
TFI



Northfield Area

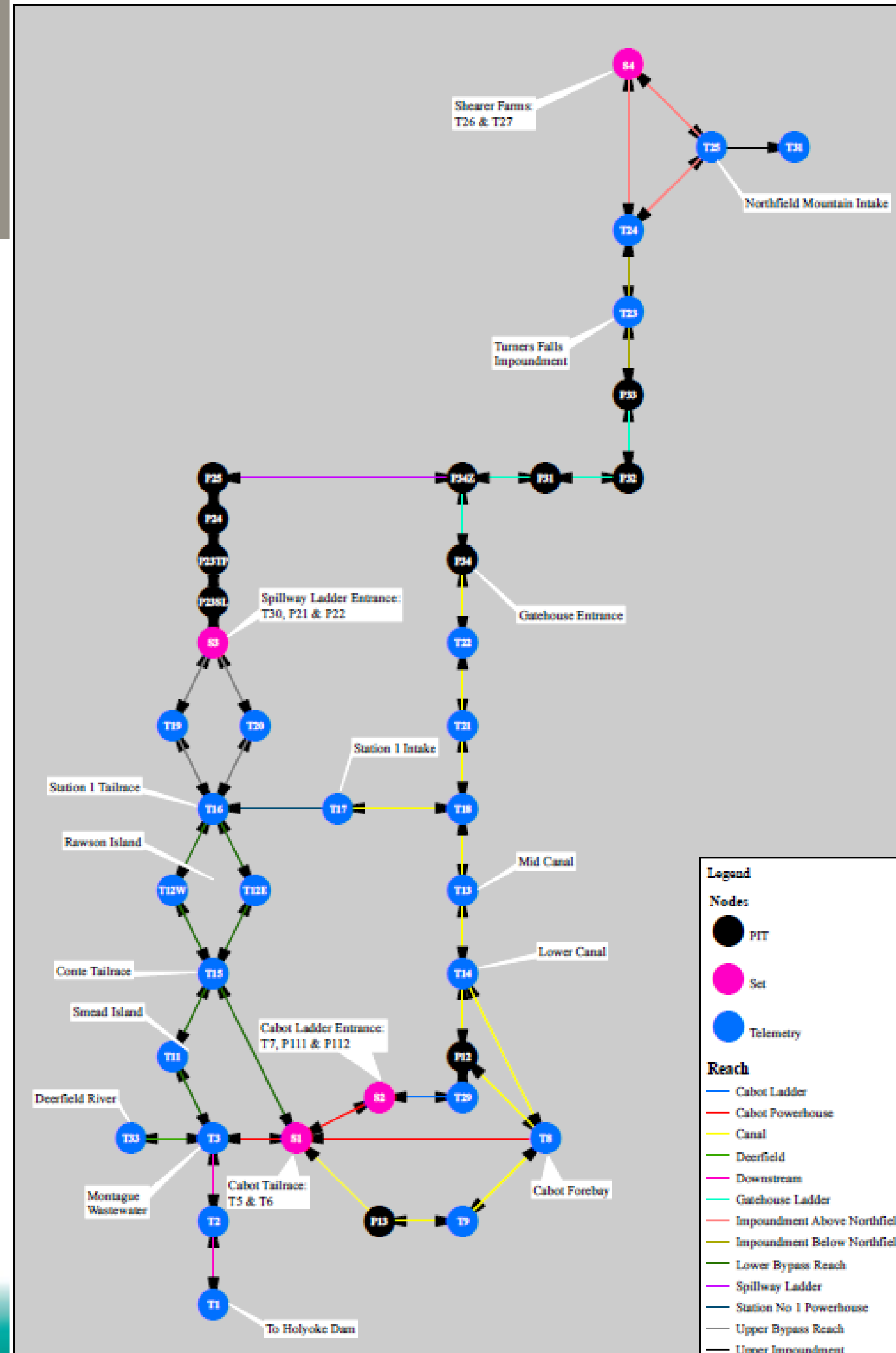


Spillway Ladder



Upper Reservoir

Telemetry Network Model



3.3.2- Upstream/Downstream Passage of Adult American Shad

Tagging occurred over 12 days from the period beginning on May 6, and ending on June 8, 2015. Approximately half of the shad were tagged with radio and PIT tags (double tagged) (n=397) and half tagged with PIT only (n=396).

Fishway Passage Peak

- Cabot – 5,066 on 5/12/15
- Spillway – 4,414 on 5/13/15
- Gatehouse – 6,395 on 5/13/15
- Holyoke - ~42,000 on 5/10/15
- Vernon - ~4,013 on 5/18/2015.

Table 4.2-1. FirstLight shad collection, tagging and release summary.

Date of Collection/Release	Collection Location	Release Location	Number of Double Tagged Shad	Number of PIT only Shad	Total Tagged and Released
5/6/15	Holyoke	Holyoke	72	1	73
5/7/15	Holyoke	Holyoke	0	72	72
5/12/15	Holyoke	Holyoke	48	1	49
5/13/15	Holyoke	Holyoke	0	47	47
	Cabot	Canal	25	25	50
5/15/15	Holyoke	TFI	33	29	62
5/16/15	Cabot	TFI	33	33	66
5/18/15	Cabot	Canal	0	25	25
5/19/15	Holyoke	Holyoke	48	48	96
	Cabot	Canal	25	0	25
5/22/15	Holyoke	TFI	33	33	66
5/23/15	Cabot	TFI	33	33	66
5/26/15	Holyoke	Holyoke	24	24	48
6/8/15	Holyoke	Holyoke	23	25	48
Totals			**397**	**396**	**793**

3.3.2- Upstream/Downstream Passage of Adult American Shad

TransCanada collected, tagged and released 154 Shad over six days in May, 2015 beginning on the 10th and ending on the 30th.

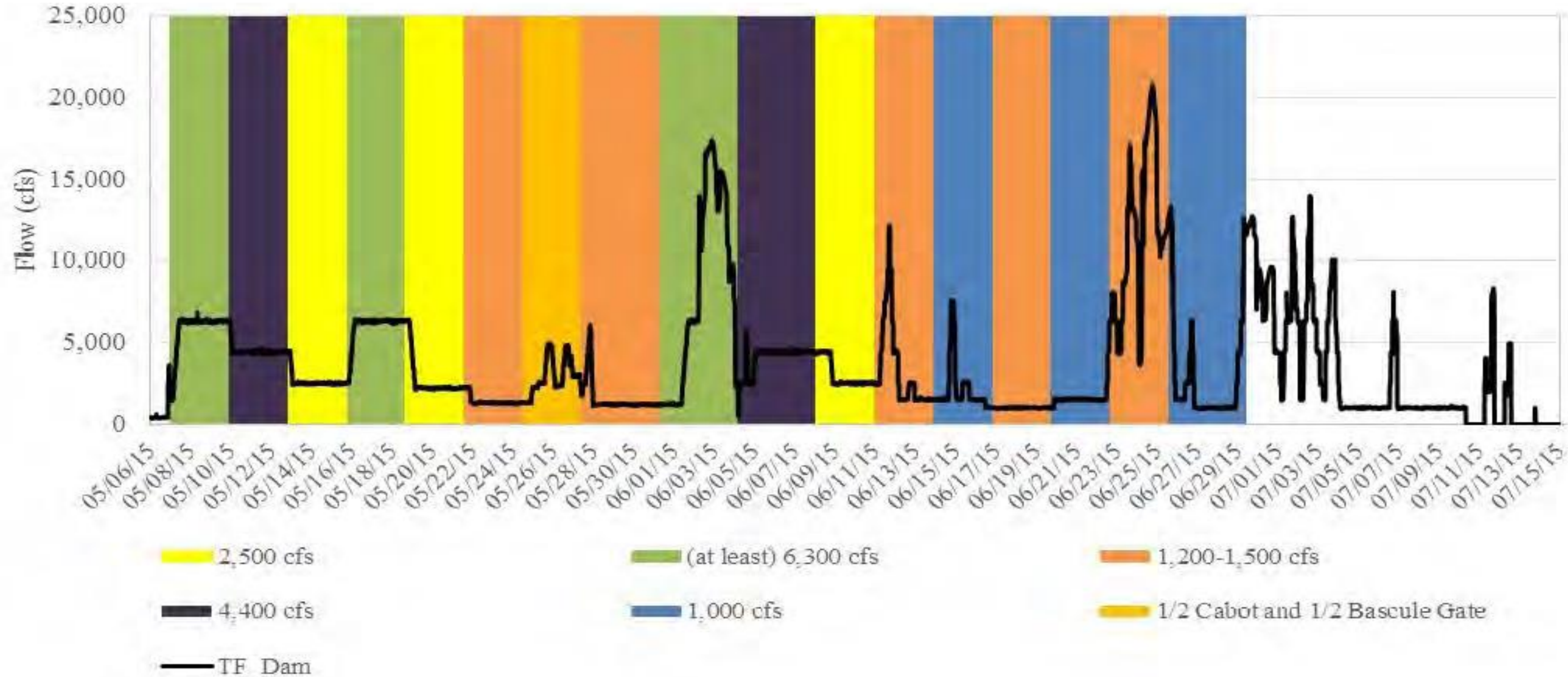
Table 4.2-2. Shad collection, tagging and release by TransCanada.

Date of Collection/ Release	Collection Location	Release Location	Number of Double Tagged Shad	Number of Radio Only Tagged Shad	Number of PIT only Shad	Total Tagged and Released
5/10/15	Holyoke	Pauchaug Brook Boat Launch	20	0	20	40
5/14/15	Holyoke	Pauchaug Brook Boat Launch	20	0	20	40
5/17/15	Vernon	Old Ferry Boat Ramp Brattleboro, VT	0	20	0	20
5/24/15	Vernon	Old Ferry Boat Ramp Brattleboro, VT	0	23	0	23
5/28/15	Holyoke	Pauchaug Brook Boat Launch	12	0	8	20
5/30/15	Vernon	Old Ferry Boat Ramp Brattleboro, VT	0	11	0	11
Totals			**52**	**54**	**48**	**154**

3.3.2- Upstream/Downstream Passage of Adult American Shad

- Relevant operations and environmental data were collected including river flow, generation (MW), water temperature and dissolved oxygen. These parameters were monitored continuously at fifteen-minute intervals throughout the study period.

- A series of test flows were released in the Turners Falls bypass reach during this study to investigate how bypass flows may affect shad migration into and through the bypass reach.
    - Flows ranged between 1,000 and 6,300 cfs



3.3.2- Upstream/Downstream Passage of Adult American Shad

Methods

- 5 main statistical procedures on top of basic ratios were used to understand adult American Shad migration.

- Hot spot analyses identified spatial clusters in mobile tracking data
  - Where did most of the fish turn around and where did they die?

- Multi-state Markov models (MSM) identified routes of passage, attraction towards receivers, and enumerated the expected number of visits (forays) to receivers of interest
  - Our understanding of movement is limited to the joint probability of an animal surviving, transitioning from and being detected at the next receiver
  - Further, it is the probability of movement between locations for each foray, not the overall probability of movement between two locations. If the number of forays are small than this probability is very close to the overall probability of movement.
  - MSM is descriptive of the study results, but it provides us with confidence intervals

- Cox proportional hazards (CoxPH) assessed the delay incurred by changing operations
  - Do fish take longer to migrate through a stretch of the project if flows increase?

- Cormack-Jolly-Seber (CJS) open population mark recapture model assessed the internal and overall efficiencies of the Project's ladders and provided <u>unbiased</u> efficiencies with respect to receiver detection.

- Catch curve analysis developed rates of mortality by day and by river mile.

3.3.2- Upstream/Downstream Passage of Adult American Shad

Analysis Matrix

Our analysis took a geographic approach and followed shad as they passed Holyoke, migrated up to the Deerfield confluence, navigated through the maze of choices at the Project, arrived in the TF impoundment, and how they reacted to NMPS and turned back downstream after spawning. On their return approach, we follow fish as they make an emigration route choice at TF, navigate their way through the canal and to their eventual downstream passage at Cabot Station.

(Table 3.2.1-2)

Subnetwork Model	Analysis Objective	Analytical Method
Holyoke to Project	To understand bi-directional movement and residence time within the downstream portion of the project from the Holyoke Dam upstream to Montague Wastewater.	• MSM • CoxPH
Montague Spoke	To understand route selection as shad migrate upstream from the Montague area to the Cabot tailwater area and how discharge effects route selection and time-to-event.	• MSM

FirstLight Power Resources

3.3.2- Upstream/Downstream Passage of Adult American Shad

Analysis Matrix cont'd

Subnetwork Model	Analysis Objective	Analytical Method
Cabot Ladder Attraction	To understand attraction and delay to the Cabot Ladder under varying bypass flows with competing routes to the lower bypass reach and downstream locations.	• MSM • CoxPH
Cabot Ladder Internal Efficiency and Delay	To understand the internal efficiency of the ladder and ladder entrance.	• CJS • CoxPH
Rawson Island	To understand passage around and delay at Rawson Island and Station No. 1 under varying bypass flows.	• MSM
Spillway Ladder Attraction	To understand attraction to the spillway ladder and delay under varying bypass flows.	• MSM • CoxPH
Spillway Ladder Internal Efficiency	To understand the internal efficiency of the ladder.	• CJS
Spillway Ladder Passage and Delay	To understand overall ladder passage efficiency and delay.	• MSM • CoxPH

3.3.2- Upstream/Downstream Passage of Adult American Shad

Analysis Matrix cont'd

Subnetwork Model	Analysis Objective	Analytical Method
Cabot Forebay and Downstream bypass	To understand migration delay in the Cabot forebay area and the risk of entrainment.	• MSM • CoxPH
Power Canal	To understand migration routes and delay within the canal and the risk of entrainment at Station No. 1. Separate models created for migration and emigration	• MSM • CoxPH
Gatehouse Internal Efficiency	To understand the internal efficiency of the ladder.	• CJS
Gatehouse Ladder Passage and Delay	To understand overall ladder passage efficiency and delay.	• MSM • CoxPH
TF Impoundment	To understand migration and delay in the TFI and investigate the risk of entrainment at the NMPS intake.	• MSM • CoxPH
TF Dam Spoke	To understand route selection during emigration.	• MSM

3.3.2- Upstream/Downstream Passage of Adult American Shad

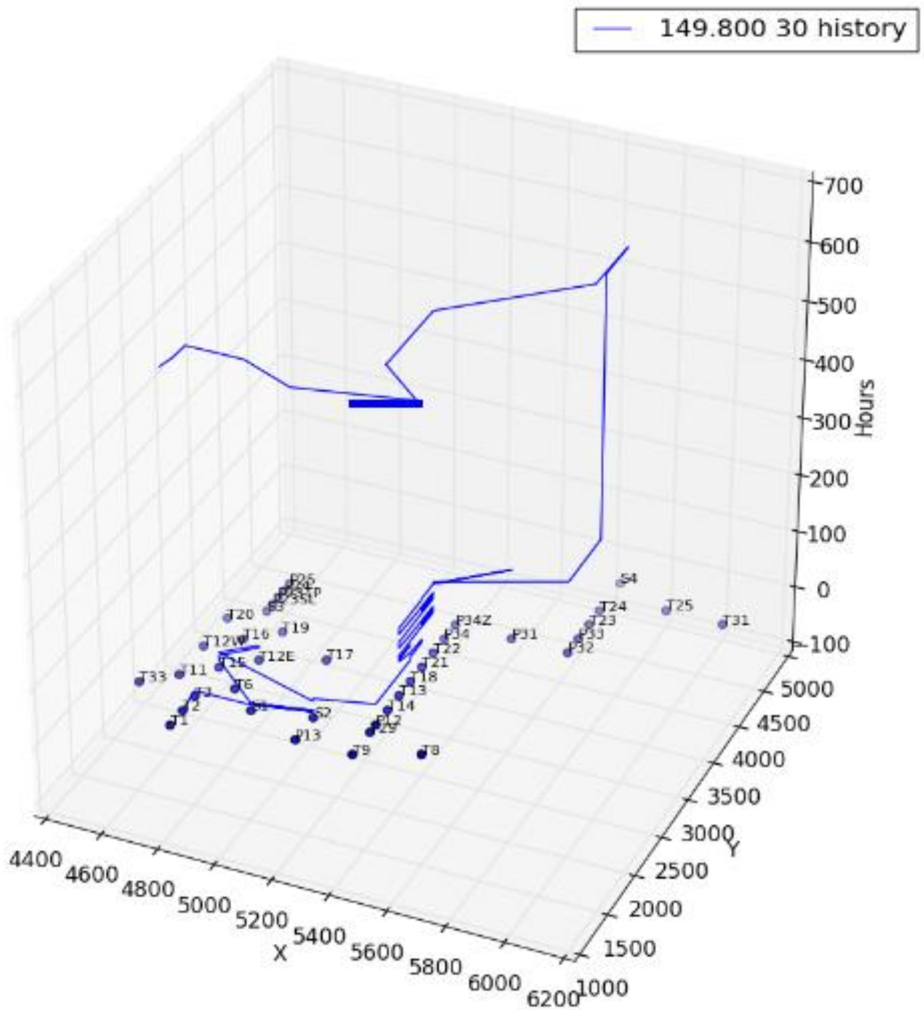
Work Completed

- Study work conducted in spring/summer 2015

- 3 Step data reduction & false positive removal – fall 2015 through spring 2016
  1. Naïve Bayes classifier algorithm
  2. SQL data reduction (MS Access)
  3. Visual Inspection

- Data dissemination meeting held in July 2016 for interested parties

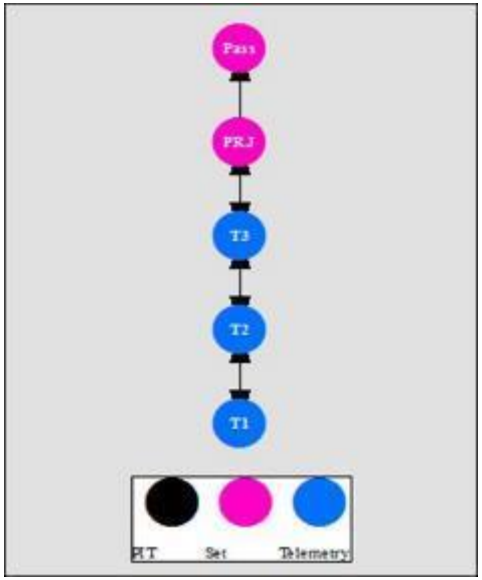
- Record Stats:
  - 1034 tagged fish in river during spring 2015
  - Initial record length: 19,177,280
  - Reduced record length : 16,784,468

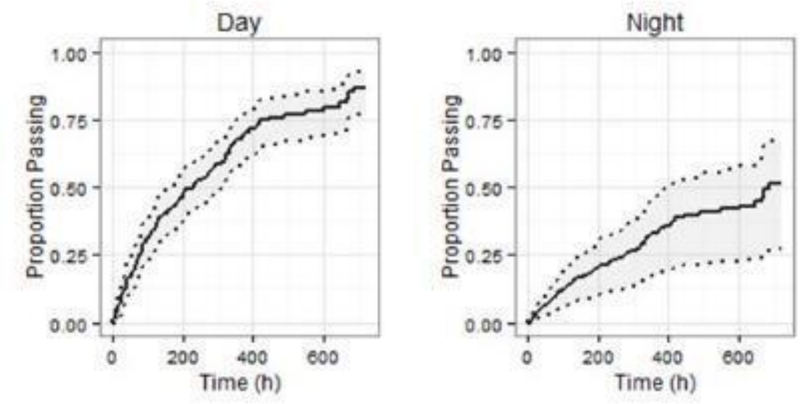


3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions
Holyoke to Montague

- Released 215 dual tagged shad at Holyoke
- Detection histories from 164 adult shad used in MSM analysis, 162 in CoxPH
- Once a fish reached Montague, the probability of a fish surviving, transitioning and being detected next at the "Project" site was 72% at 7,070 cfs. At 17,100 cfs this probability was 65%. Fish naturally move upstream through this reach seeking passage and or spawning (see Study No. 3.3.6), but seem to be affected by increasing flow.
- CoxPH found that animals marked experienced the event 2.8 times faster during the day than at night, we achieved 50% arrival at the project within 232 hours

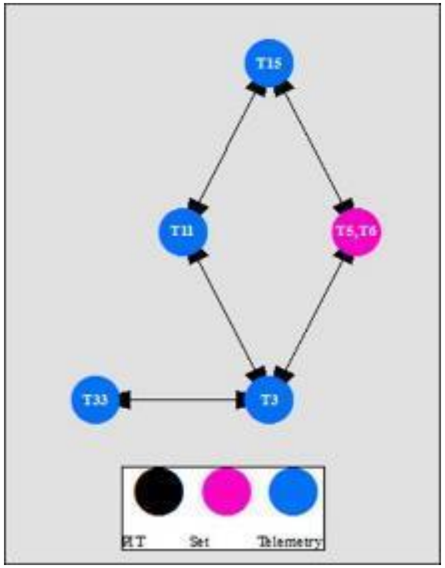


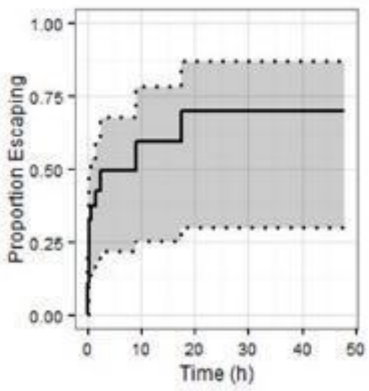


3.3.2- Upstream/Downstream Passage of Adult American Shad

<u>Conclusions</u>
Montague Spoke

- Released 215 dual tagged shad at Holyoke
- Detection histories from 105 adult shad used in MSM analysis
- Probability that a fish will survive, transition from Montague and be detected next within Cabot Tailrace decreased from 74% to 44% as flow increases from 2,327 cfs at Cabot and 2,500 cfs Bypass to 11,375 cfs Cabot and 5,275 cfs Bypass
- Probability that a fish survives, transitions from Montague and is detected next at the West Channel of Smead Isl. Increases from 7% at low flow to 26% at high flow.



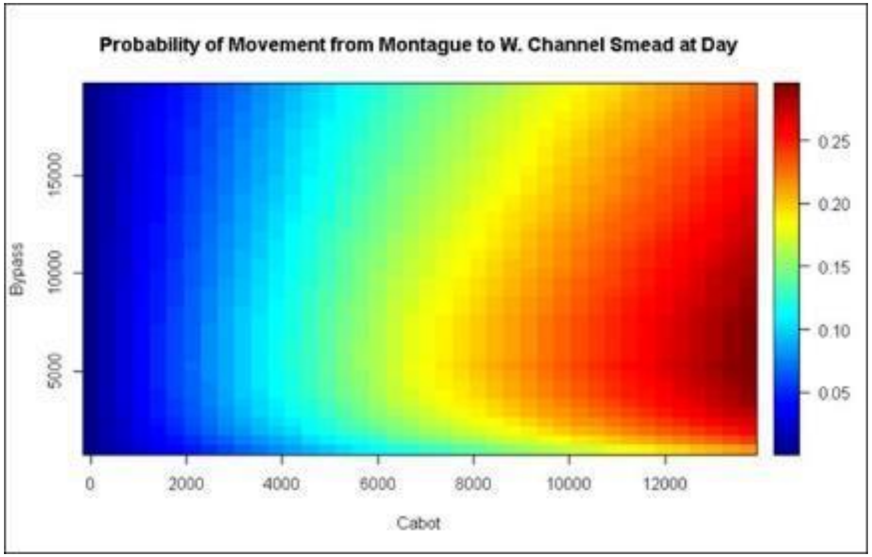


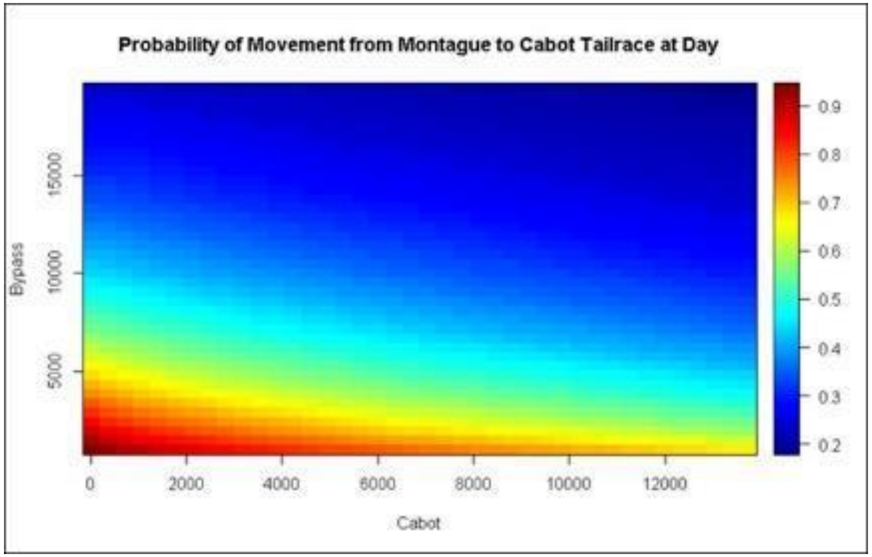
Kaplan Meier curve of time to escape the Deerfield River

3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Montague Spoke cont'd





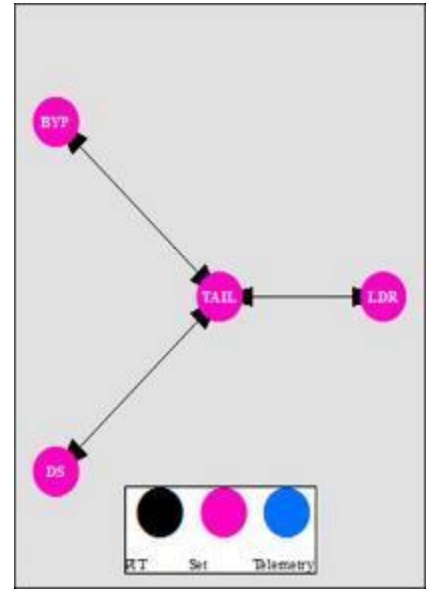
FirstLight Power Resources

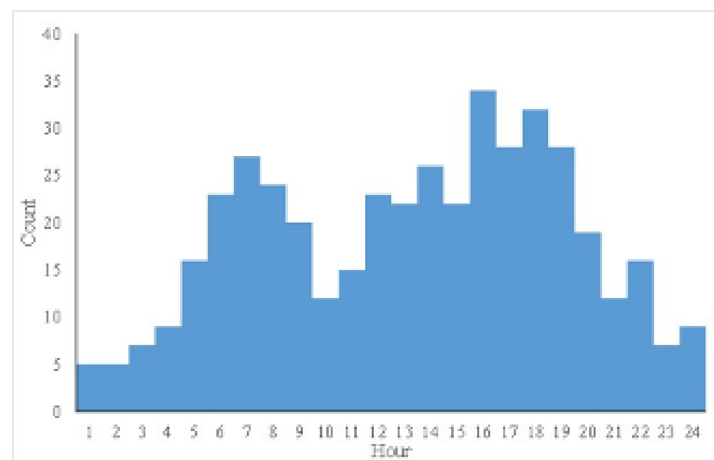
3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Cabot Ladder Attraction

- Released 215 dual tagged shad at Holyoke
- Detection histories from 107 adult shad used in MSM analysis
- State table counts 137 forays into Cabot Ladder with 120 of those coming from the tailrace
- Highest probability (60%) of a fish surviving, transitioning from the tailrace and being detected next at the ladder was when Cabot discharge high and bypass flow low (11,380 and 2,500 respectively)
- Best CoxPH model incorporated bypass flow and diurnal cues
    - Fish are 10.9 x more likely to experience event during the day, however as bypass flow increases by 1000 cfs, 0.7 times less likely to experience the event



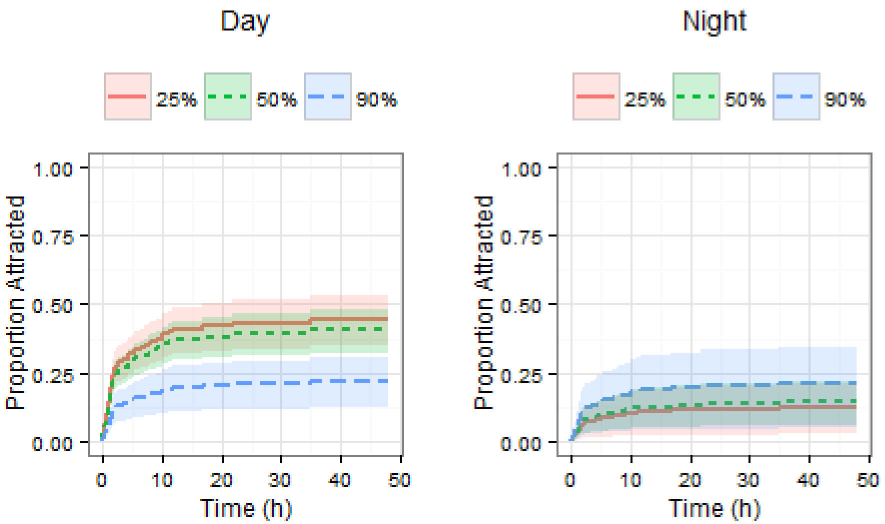


3.3.2- Upstream/Downstream Passage of Adult American Shad

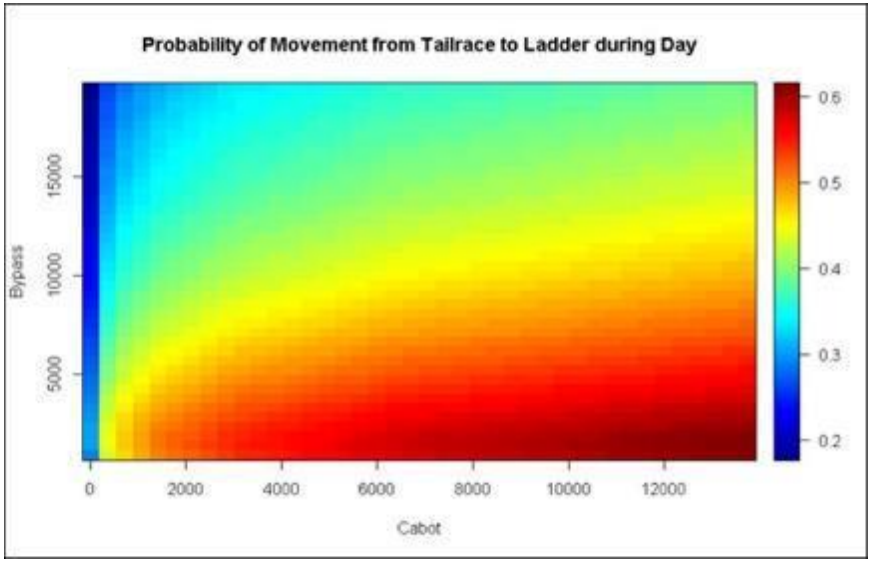
Conclusions

Cabot Ladder Attraction cont'd

- Time-to-first foray found that 50% completed their first foray in only 7.55 hours from Montague



Time-to-Cabot Ladder Attraction from tailrace. Note, fish incur delay as flow is increased



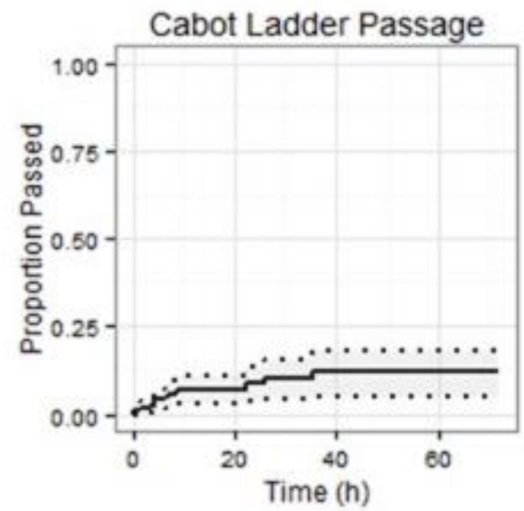
Probability of movement from tailrace to ladder during day and under various bypass flow and Cabot discharge. Note that the probability of movement is greater the higher the flow, however we see with time-to-event that as flows increase so does time to Cabot Ladder entrance.

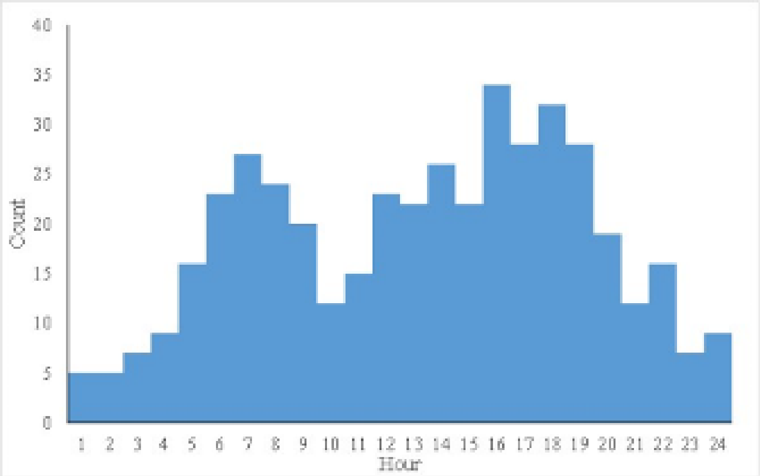
3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Cabot Ladder Efficiency

- Of the 103 dual and PIT tagged fish known to use the ladder, 16 made successful events
- Best CJS model fully time dependent
- Entrance efficiency: 68%
- Internal efficiency: 15.3%
- Overall: 10.2%
- Time-to-event analysis showed that all fish to pass did so within 40 hours





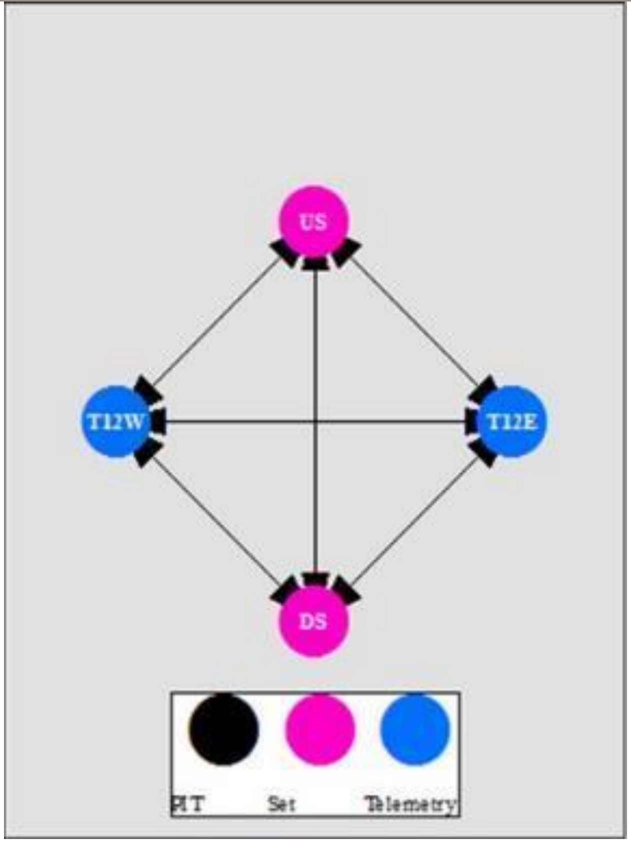
3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Bypass Reach

- Rawson Island MSM model incorporated recaptures from 95 dual tagged fish released at Holyoke
- The eastern channel (rock dam) appears to be a natural migratory barrier with little upstream passage success (i.e. probability that a fish will survive, transition from rock dam and be detected next within the spillway) is only 2%
  - State table only shows 1 successful transition

	To			
From	Downstream	T12W	T12E	Upstream
Downstream	2,160	21	22	17
T12W	16	57	23	9
T12E	19	24	240	1
Upstream	19	3	0	767

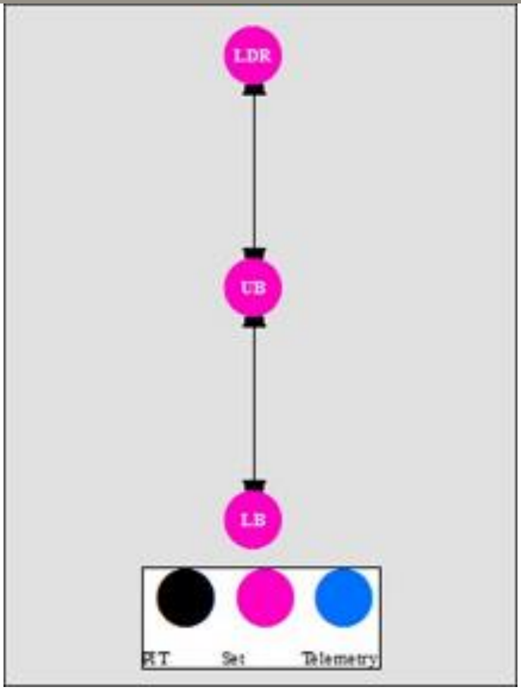


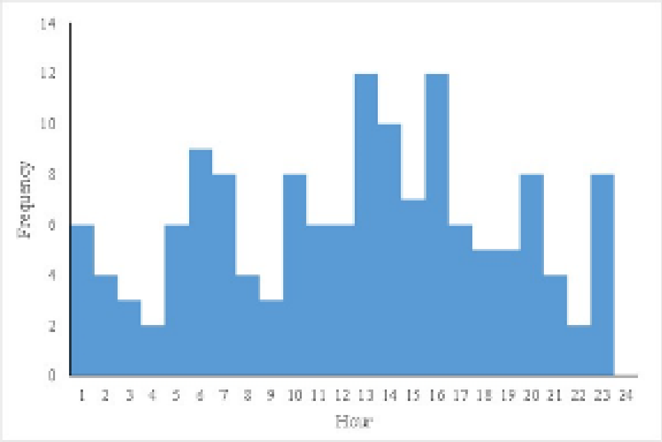
3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Spillway Ladder Attraction

- MSM model incorporated 57 dual tagged fish released at Holyoke known to be within the upper bypass reach
- Probability that a fish survives, transitions from the spillway and is detected next within the spillway ladder is 65% at low flow (2,569 cfs) and drops to 41% at high flow (6,226 cfs)
- Forays (msm: envisits) decrease from 3.47 at low flow to 2.47 at high flow
- Time to first foray – 50% experienced event after migrating from Montague within 94.4 hours.
- Time to attraction from spillway:
  - 7.3 x more likely to enter spillway ladder during day than at night

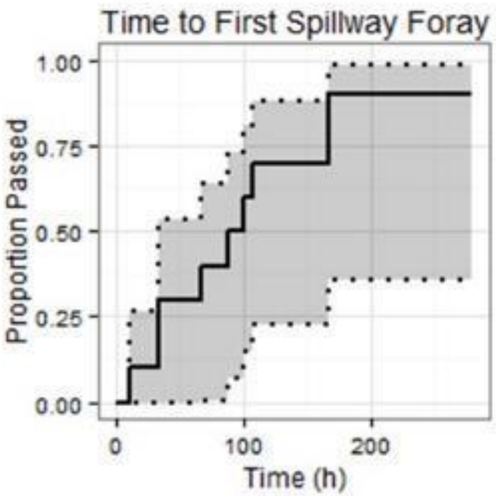




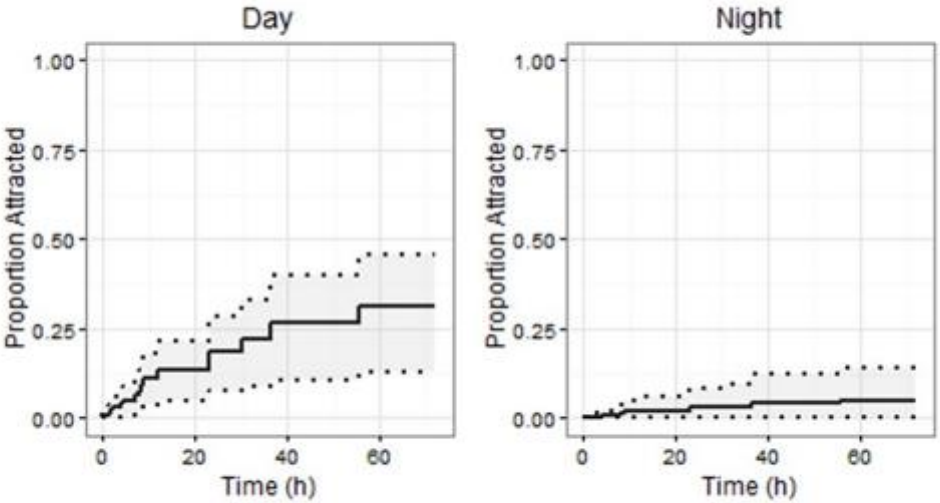
3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Spillway Ladder Attraction cont'd



Time-to-first foray
Montague -> Spillway

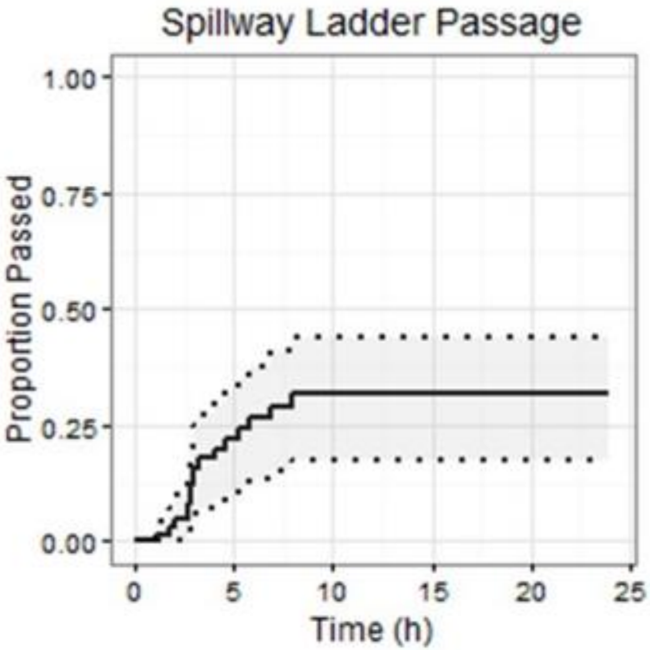


Time to spillway ladder attraction – spillway - > ladder

3.3.2- Upstream/Downstream Passage of Adult American Shad

<u>Conclusions</u>
Spillway Ladder Efficiency

- Best CJS model was fully time dependent
- Spillway entrance efficiency was 91.5%
- Overall ladder efficiency was 32.7%
- Time-to-event:
  - Of the 35 dual and PIT tagged only fish released at Holyoke that attempted Spillway Ladder, 16 successful attempts out of 87 tries
  - Fish take between 1.1 and 7.9 hours to pass spillway ladder .



3.3.2- Upstream/Downstream Passage of Adult American Shad

<u>Conclusions</u>

Overall

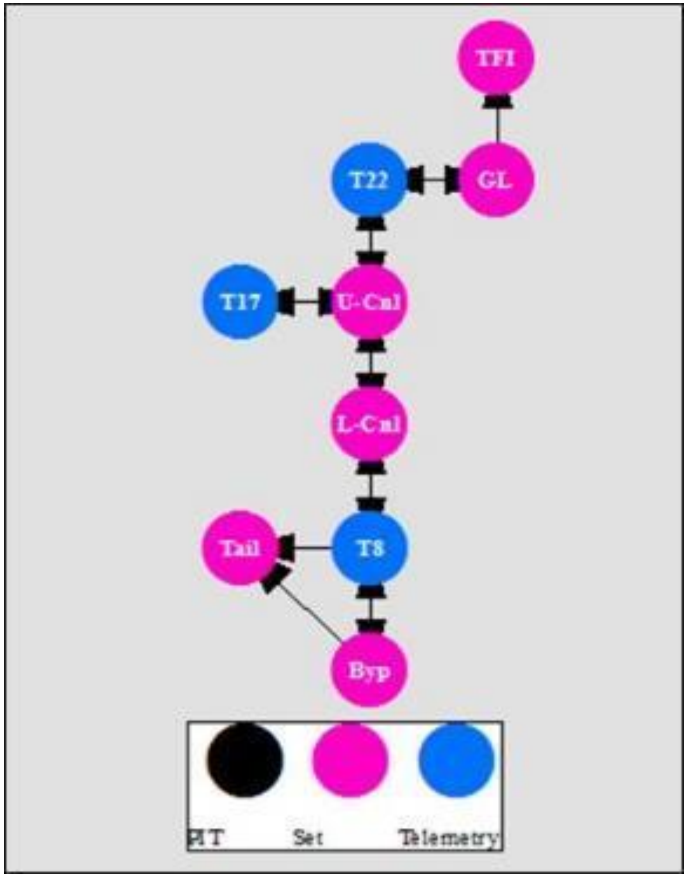
- Of 50 canal released fish, all were recaptured in Forebay, 9 within the Gatehouse Ladder and 7 within TFI Impoundment

Upstream Migration Through Canal (MSM)

- MSM and CoxPH incorporated recaptures from the 60 dual tagged fish released into the canal or at Holyoke that passed Cabot Ladder

- State table indicates considerable milling forebay (T8) and downstream bypass (T9, P13)
  - 866 transitions from forebay to bypass
  - 813 transitions from bypass back to forebay

- Probability that a fish survives, transitions from the Gatehouse Yagi (T22) and into Gatehouse Ladder increases with increasing canal flow from 11% (25th: 3,340 cfs) to 15% (75th:12,016 cfs)



3.3.2- Upstream/Downstream Passage of Adult American Shad

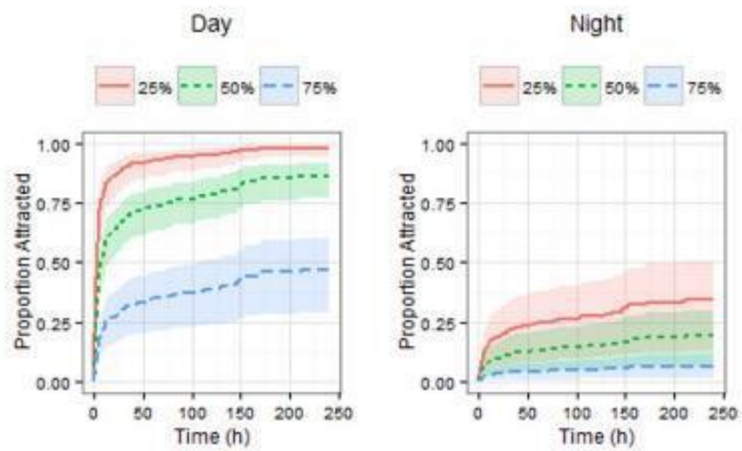
Conclusions

Upstream Migration Through Canal (CoxPH)

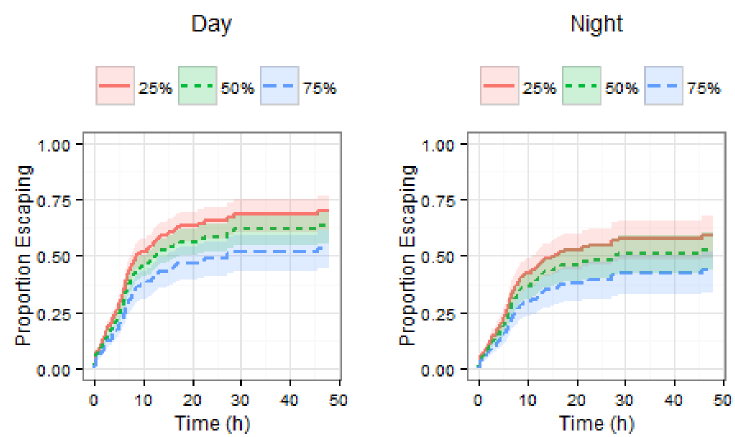
- Time-to-upper canal (first recapture to Gatehouse Yagi (T22)
  - 60 fish, 122 successful forays
  - As flows increase the rate at which fish experience the event decreases

- Time-to-escape Station No. 1 Forebay
  - 6 fish made 7 successful attempts
  - Fish attracted to forebay leave within 15 hours

- Time-to-escape Cabot Forebay
  - As flows increase, the rate at which fish experience the event decreases
    - 50% escape within 8.84 hours at 25th
    - 50% escape within 27.2 hours at 75th



Time to overall upstream canal passage under different flow regimes.



Time to escape Cabot Forebay under different flow regimes.

3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Gatehouse Ladder Efficiency

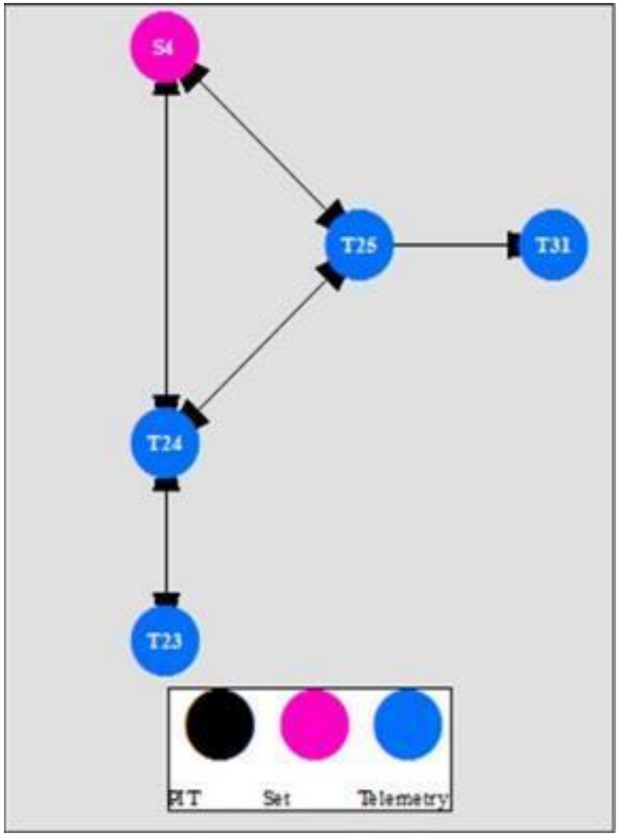
- Overall the entrance efficiency was high passing 84.8% of the fish that attempt the ladder, however there was evidence of milling between the gatehouse yagi (T22) and the ladder because only 11 – 15% of the individual forays from T22 are successful– meaning that a fish must make more than 1 transition from T22
- Internal efficiency was very high 91%
- Overall efficiency: 76.9%
- Time-to-Gatehouse Ladder passage not computed considering issues at P34Z – we never have a start time

3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Upstream directed impoundment migration

- We only received a list of fish making it to Vernon and not time of arrival or exit, therefore we could not include time-to-Vernon in our assessments
- No fish detected in upper reservoir
- MSM model incorporated 204 dual tagged fish from the Impoundment release, Cabot release, Holyoke release and those fish released at TC
- Pumping:
  - Fish downstream of intake have 60% chance of transitioning to Shearer Farms next at - 3,346 cfs to 53% at (- 9,887 cfs) –
  - Probability of fish transitioning into the intake as pumping rates increase: -3,346 cfs = 9%, -9,887 cfs = 33%
- Idle:
  - fish downstream of the intake (T24) had a 68% chance of transitioning to Shearer Farm and a 24% chance of transitioning into the intake next
- Generation:
  - Fish downstream of intake had a 72% chance of transitioning to Shearer Farms and only 19% chance of transitioning towards the intake (25th discharge, 2,360 cfs) with little change through 75th discharge (5,301 cfs)



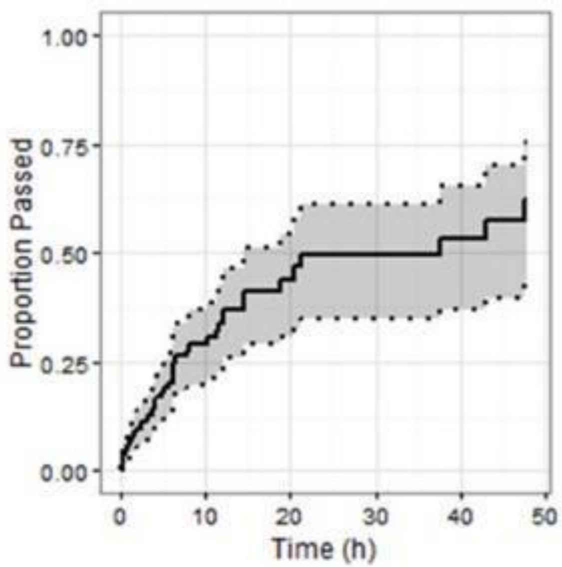
3.3.2- Upstream/Downstream Passage of Adult American Shad

<u>**Conclusions**</u>

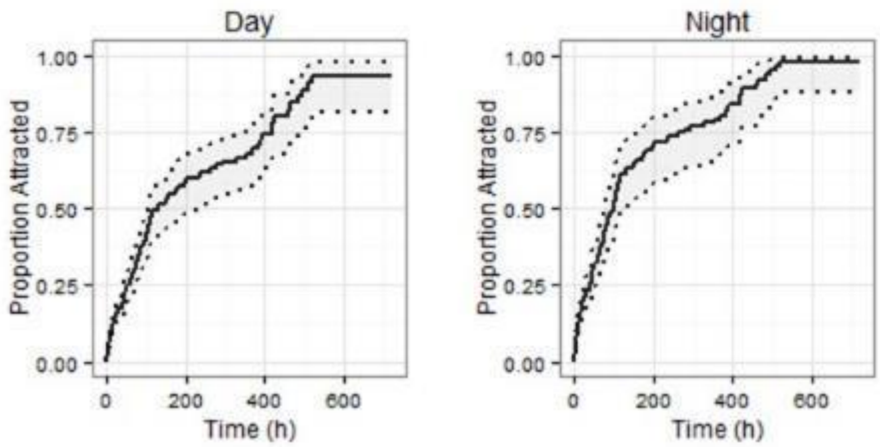
Upstream directed impoundment migration

- Time-to-escape NFM Intake
  - 32 fish made 52 successful escape attempts

- Time-to-Shearer Farms from d/s Intake
  - 142 fish made 228 attempts at Shearer Farms
  - Fish were 1.2 times more likely to experience event during day than at night



Time to escape NMPS intake

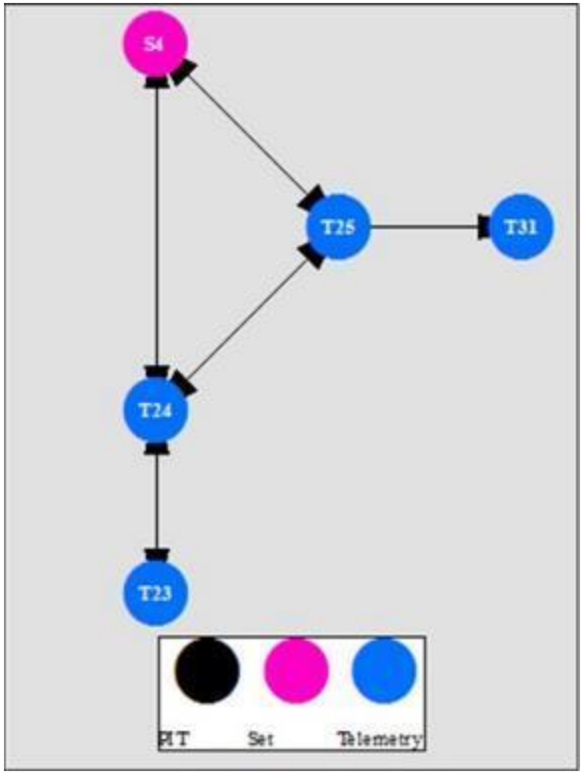


3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Downstream directed impoundment migration

- MSM model incorporated 204 dual tagged fish from the Impoundment release, Cabot release, Holyoke release and those fish released at TC
- Pumping:
  - Probability that fish transition from Shearer Farm to downstream of the Intake (T24) was 95% at -3,346 cfs and 69% at -9,887
  - Transition to intake increased from 5% to 30% over this range
- Idle:
  - Probability that fish transition downstream during day 88%
  - Transition to intake during day 12%
- Generation:
  - Probability that fish transition downstream increased from 93% to 97% (25th : 2,360 cfs to 75th: 5,301 cfs)
  - Transition to intake decreased from 7% to 3%

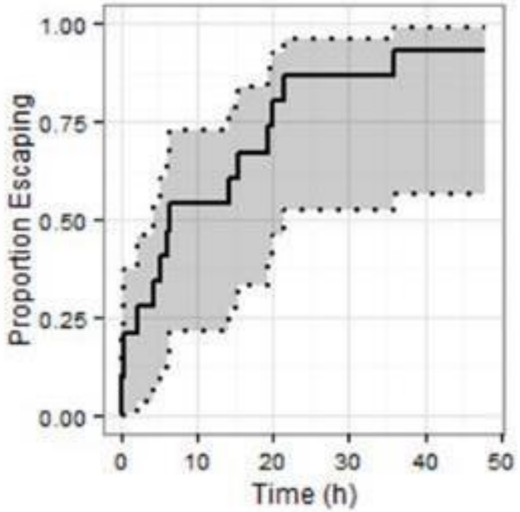


3.3.2- Upstream/Downstream Passage of Adult American Shad

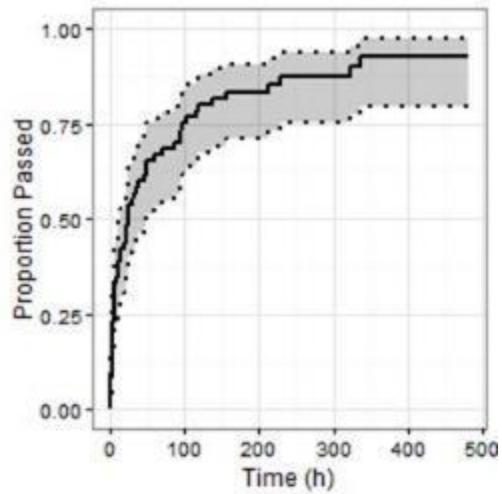
Conclusions

Downstream directed impoundment migration

- Time-to-escape NFM Intake
  - 10 fish made 15 successful events with 50% escaping within 6.42 hours and 75% escaping within 20 hours
- Time-to-downstream of the NFM intake from Shearer Farms
  - Downstream obligated (TC only fish)
  - 50% reach the lower TFI Impoundment (T23/T24) within 25 hours, 75% within 100 hours



Time to escape intake



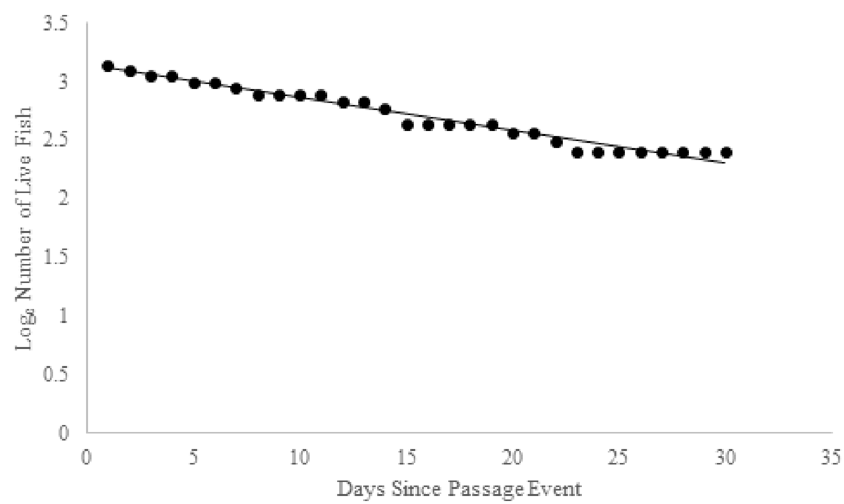
Time to migrate past intake

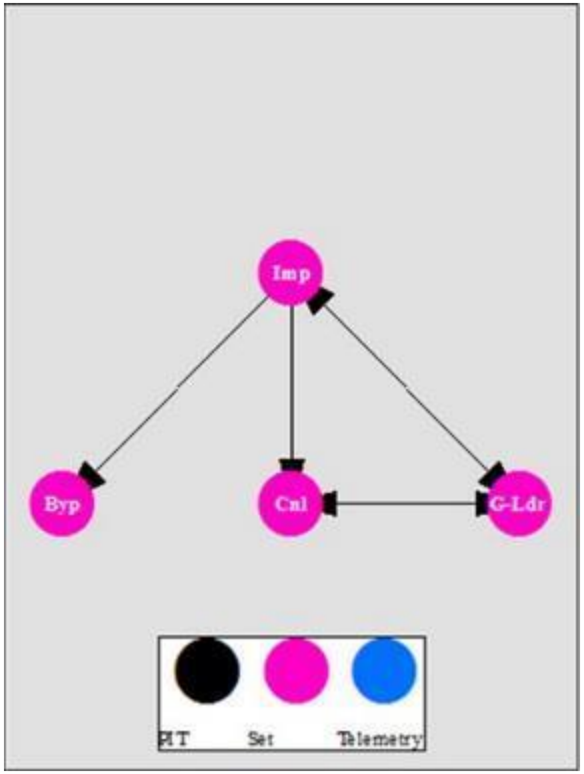
3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Turners Falls Route Selection

- MSM incorporated recaptures from 165 fish
  - Probability that a fish will survive, transition from the TFI and be detected next within the bypass reach (aka spill) 26%, while 74% will transition into canal
- Catch curve mortality estimates were 3% per day
  - Fish that died after passing via spill travelled an average of 13 miles over an average of 21 days before mortality signals emitted from the tags were detected.
- Catch curve analysis for 'natural mortality' aka those fish that do not pass any structure found a 1% mortality per day



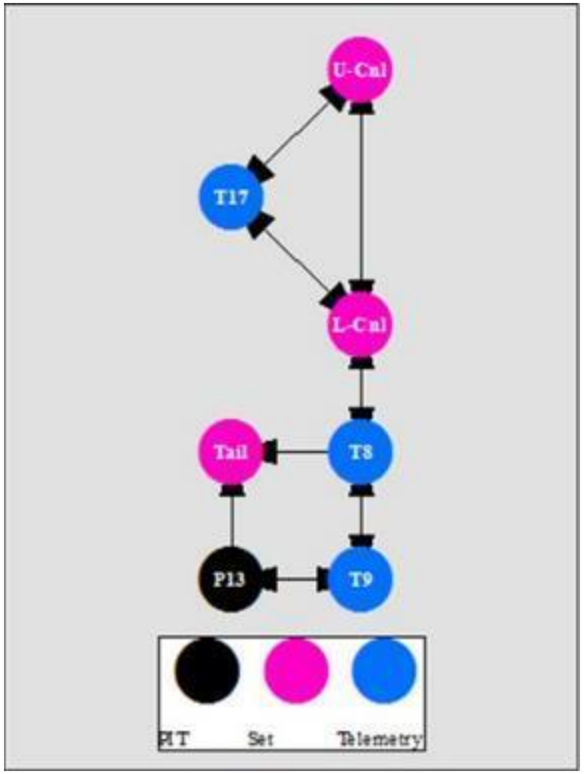


3.3.2- Upstream/Downstream Passage of Adult American Shad

Conclusions

Downstream Migration through Canal

- MSM included recaptures from 86 fish
- Overall 71 fish escaped canal (82%) with 39 passing via bypass (45%) and 28 via powerhouse (32%) – remaining fish passed undetected
- Of the 76 fish that attempted the bypass, 39 were successful
- State tables indicate considerable milling within forebay area with 599 forays from the forebay into the bypass and 547 from the bypass into the forebay
- Probability of transitioning from the forebay to the tailrace (entrainment) next increased from 2% at 3,340 cfs to 5% at 12,016 cfs
- Probability of transitioning from the bypass to the tailrace next increased from 4% at low flow to 11% at high flow

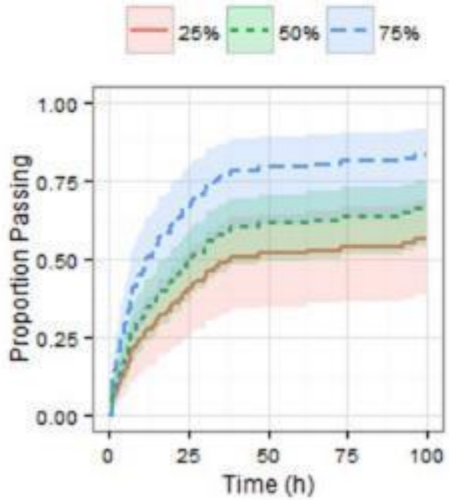


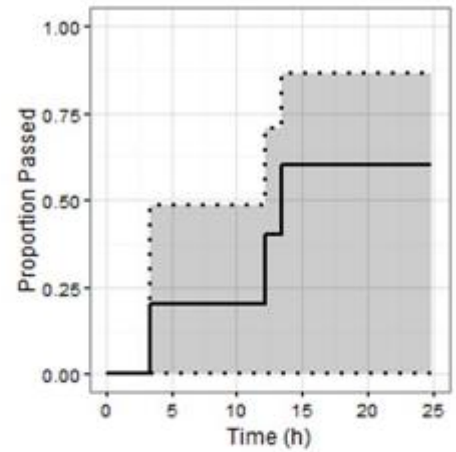
3.3.2- Upstream/Downstream Passage of Adult American Shad

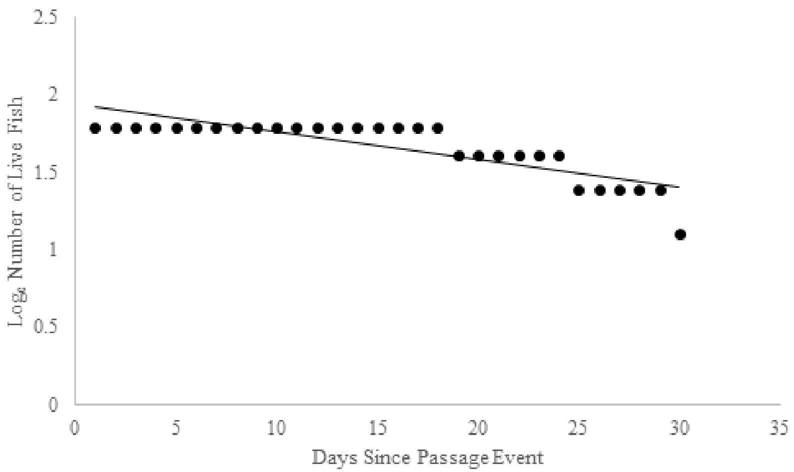
Conclusions

Downstream Migration through Canal

- Overall delay in the canal is reduced with increasing flow
  - 50% pass downstream within 23 hours (75th percentile), however a portion remains in the canal after 10 days
- 50% of the shad attracted to the Station No. 1 Forebay escape within 14 hours
- We were able to track 9 fish known to have passed via the powerhouse, and 5 died.
- Catch-curve estimate of mortality rate = 0.02 per day







3.3.2- Upstream/Downstream Passage of Adult American Shad

Variances

- An additional radio telemetry monitoring station was established within the Cabot fish ladder approximately 40 ft upstream of the entrance at the request of the USGS and U.S. Fish and Wildlife Service (USFWS). The monitoring location employed an Orion receiver and a dropper antenna. The noise floor was set and tested such that only those fish entering the fishway were detected to differentiate from those fish that were attracted to the attraction jet but did not enter the fishway.

- Per the RSP and the SPDL, a total of 100 shad were to be collected at the Cabot fish ladder and released into the TFI. However, due to a miscommunication within the study team a total of 132 shad were collected at the Cabot ladder and released into the TFI. This deviation to the study resulted in a greater number of shad collected at Cabot and released in the TFI and fewer fish collected and released at Holyoke than was planned. However since a large number of fish were tagged and released at Holyoke this reduction represented only 6% of all the fish released at Holyoke.

3.3.3- Downstream Passage of Juvenile American Shad

Study Objectives

The goal of this study is to assess the effects of Project operations on juvenile shad emigration success. The specific objectives are as follows:

- Assess the effects of the Projects on the timing, orientation, routes, migration rates, and survival of juvenile shad;
- Determine the proportion of juvenile shad that pass downstream through the power canal versus over the dam under varied operational conditions, including a range of spill conditions;
- Determine the rate of downstream movement within the impoundment, over the dam and through the bypass reach, or through the power canal;
- Determine survival rates for juveniles spilled over/through dam gates, under varied operation conditions, including up to full spill during the annual fall power canal outage period;
- Determine downstream passage timing, route selection, and rate of movement of juvenile shad through the power canal to Station No. 1, Cabot Station and the Cabot Station bypass;
- Determine the rate of entrainment at the Northfield Mountain Project;
- Determine the survival rate for juvenile shad entrained into Station No.1; and
- Determine the survival rates for juvenile shad entrained at Cabot Station.

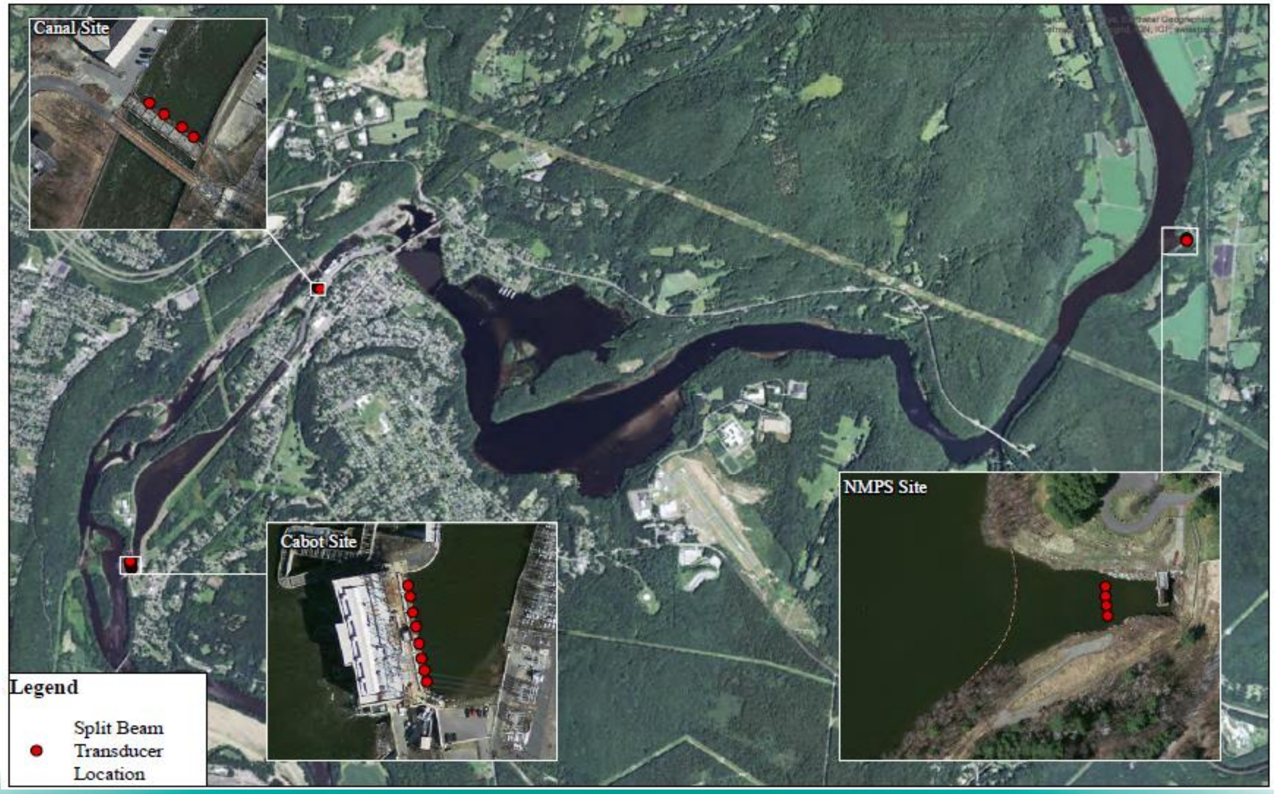
3.3.3- Downstream Passage of Juvenile American Shad

Work Completed

The impact of Projects operations on juvenile shad emigration was assessed using a combination of techniques, including hydroacoustics, radio telemetry, and HI-Z Turb'N tags.

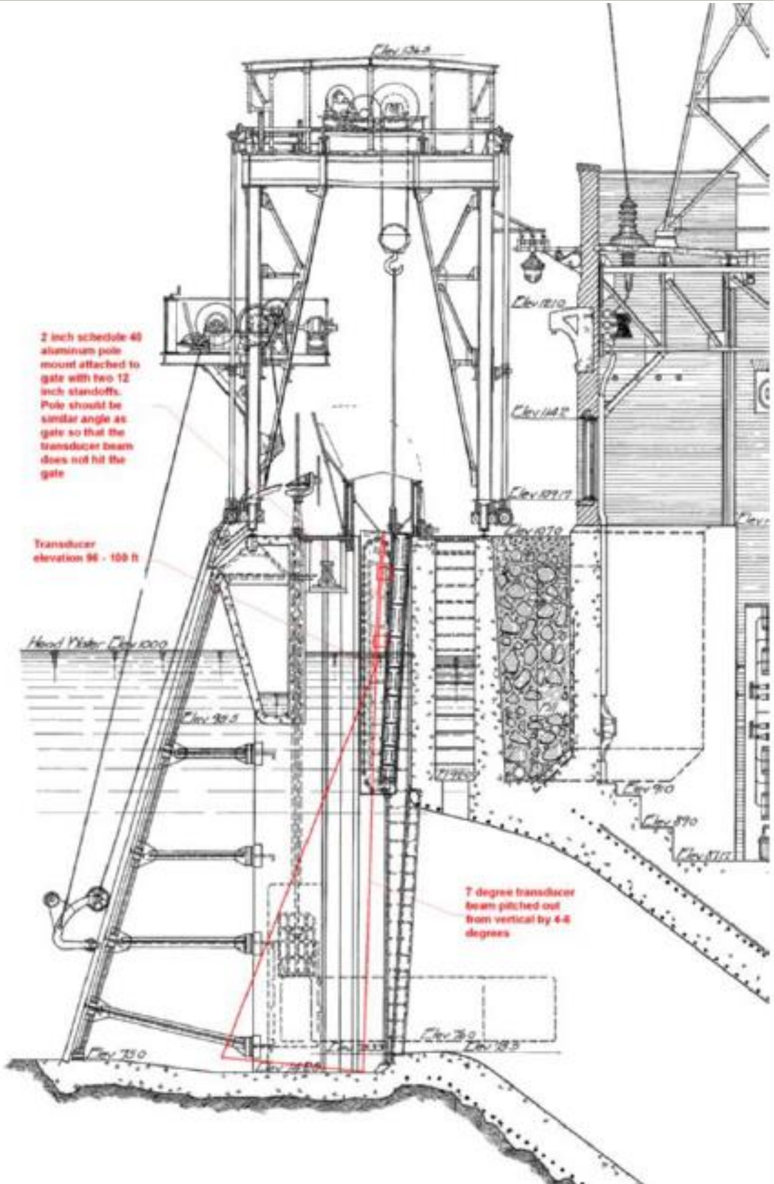
The run timing, duration, magnitude and entrainment of juvenile American Shad were evaluated through the use of hydroacoustics at Cabot Station, the Turners Falls power canal and at NMPS.

- Monitoring was conducted using a Simrad 333-kHz frequency multiplexing sonar, each with four 7° circular split beam transducers.



3.3.3- Downstream Passage of Juvenile American Shad

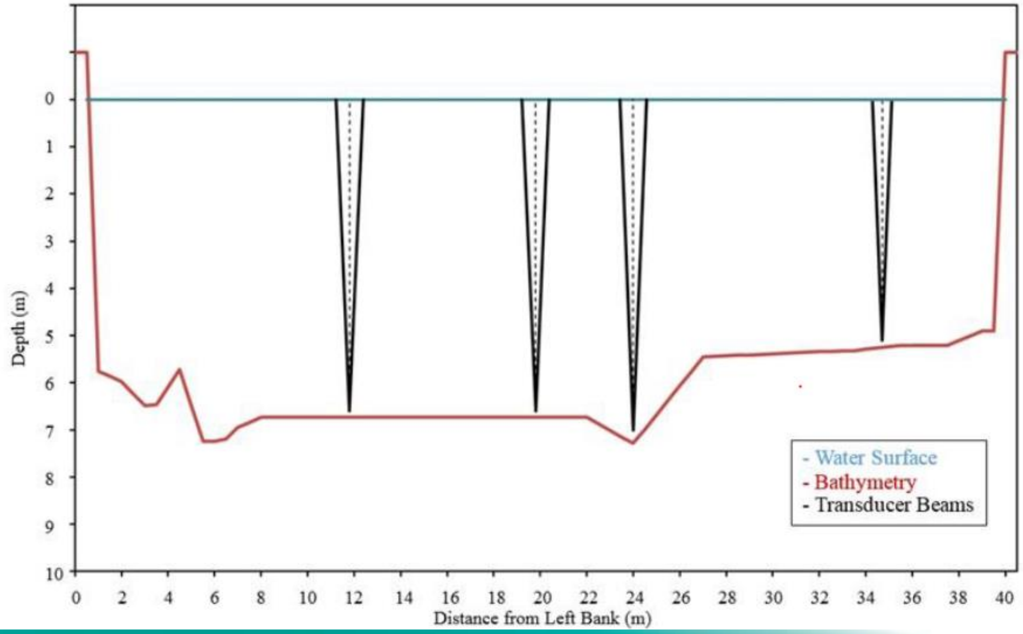
Sampled ~10% of the intake



3.3.3- Downstream Passage of Juvenile American Shad

Turners Falls Canal

Sampled ~9% of the canal



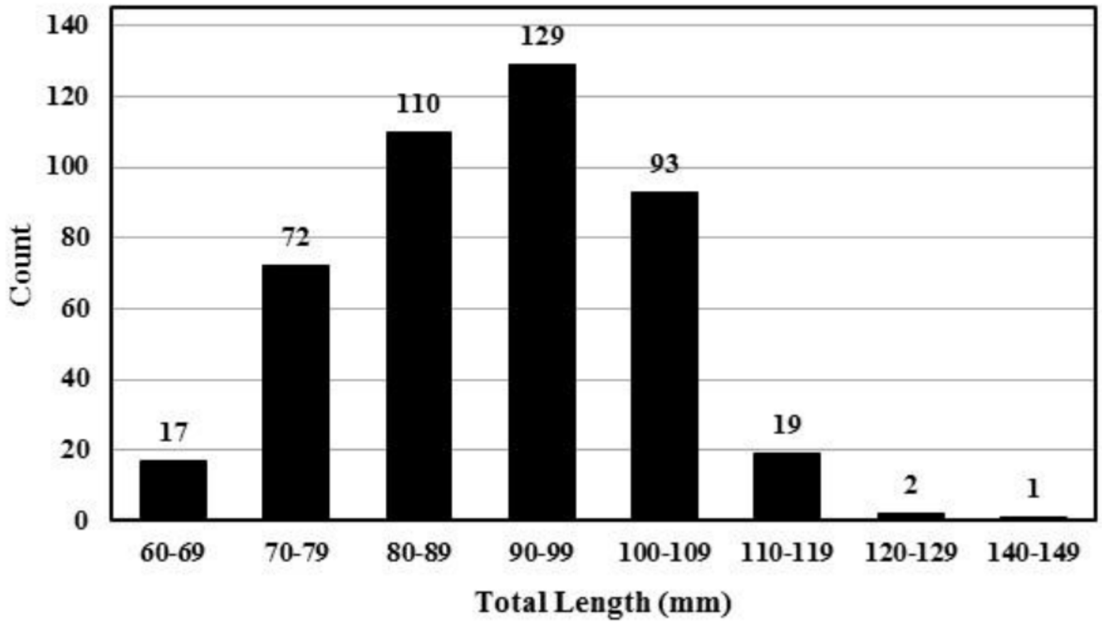
3.3.3- Downstream Passage of Juvenile American Shad

Sampled ~24% of the intake

3.3.3- Downstream Passage of Juvenile American Shad

Verification Sampling

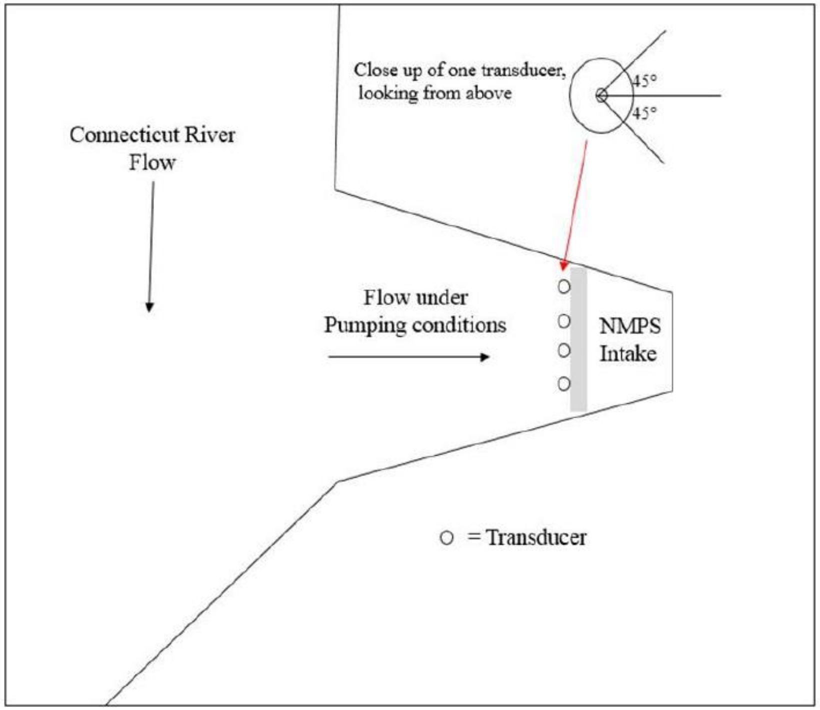
- Concurrent with the hydroacoustic study, sampling was performed at the Cabot Station bypass sampler over several discrete events (15) to determine the species identity of targets observed in the hydroacoustic data and compare the proportion of juvenile shad passing via the downstream bypass (in the Turners Falls Power Canal) and Cabot Station.
- Sampling was conducted during evening hours (generally between 16:00-22:00 hrs) beginning on September 9, 2015 and continuing through October 28, 2015.
- Nearly all fish collected were juvenile American Shad, 50 of which were randomly selected and measured for total length per event. These length data were used to set the ranges for targets detected by hydroacoustic transducers at Cabot Station and Northfield Mountain to be identified as juvenile shad .



3.3.3- Downstream Passage of Juvenile American Shad

Results

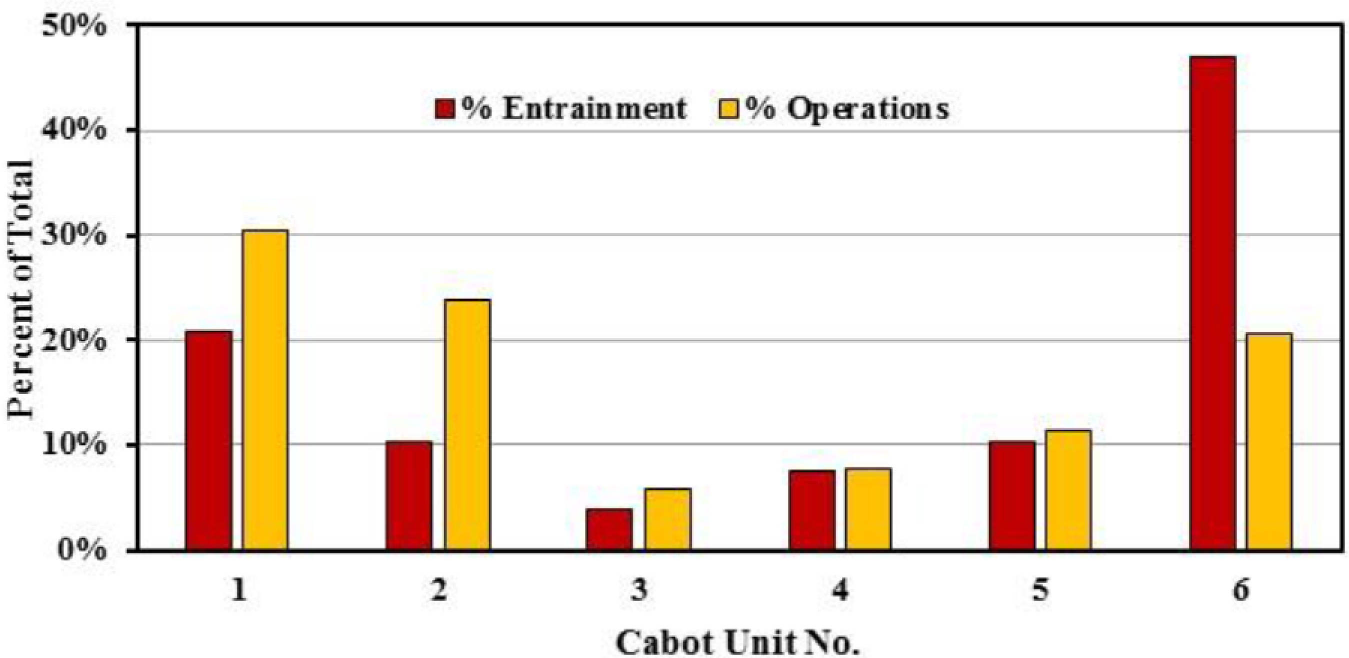
- The locations of the transducers at the Northfield Mountain intake area and in the Turners Falls Power Canal did not allow for data reduction to accurately estimate the run timing, duration, magnitude or entrainment of juvenile shad outmigration, thus rendering some objectives unattainable as scoped in the Revised Study Plan (RSP).
  - Analysis of the data for these two locations revealed a substantial number of targets in these locations engaging in a milling behavior, rather than simply moving in a downstream direction. This behavior reduces the ability of the split beam system to enumerate individual targets and would lead to overestimates, as targets moving in and out of the beam are subject to being counted multiple times.



3.3.3- Downstream Passage of Juvenile American Shad

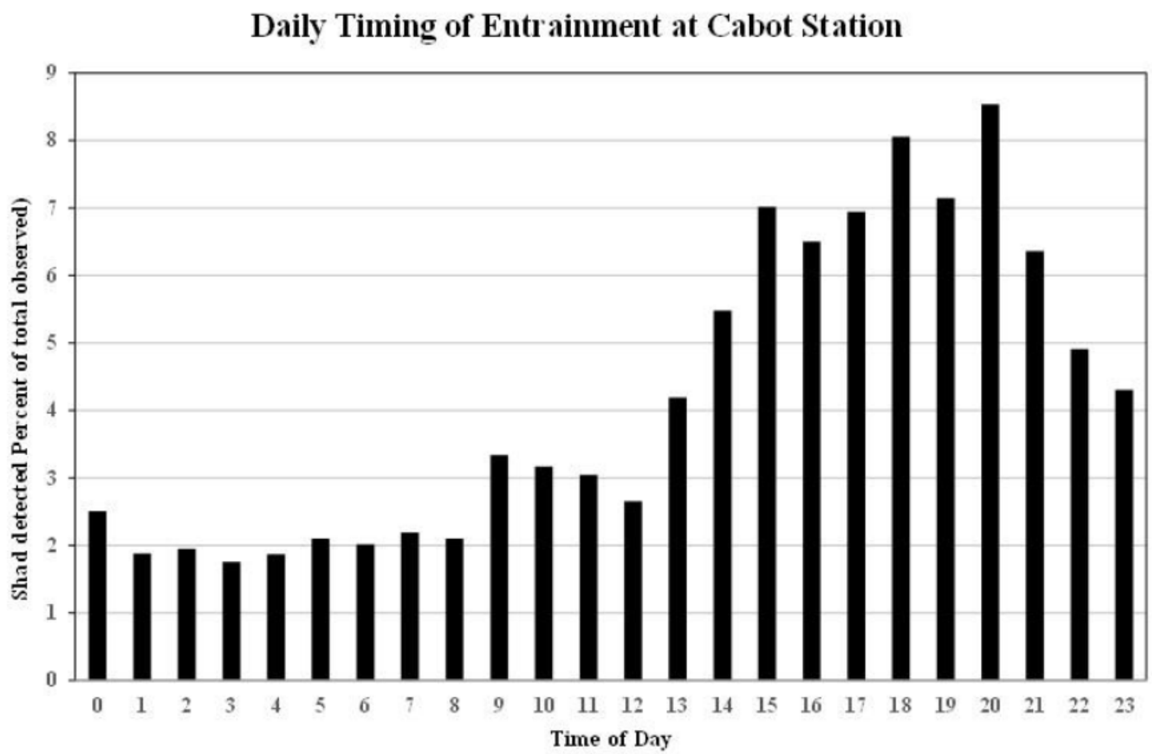
Cabot Station

- Review of the split beam sonar data indicated juvenile shad-sized targets were present in the vicinity of Cabot Station throughout the monitoring period spanning August 1 to November 14, 2015.
- About 1,660,166 shad-sized targets (62-120 mm in length) were estimated to be entrained at Cabot Station between August 1 and November 14, 2015.
- The distribution of entrainment by unit was such that almost half (46%) of the overall entrainment was attributable to Unit 6, despite the more frequent operation of Unit 1.



3.3.3- Downstream Passage of Juvenile American Shad

- Based on concurrent observations at the bypass sampler and Cabot Station intake, it was estimated that an average of approximately 43% of juvenile shad exit the canal via the downstream bypass and 57% are subject to entrainment at Cabot Station.
- Diel movement was investigated at the Cabot Station intake using hydroacoustics methods. Shad size targets were observed to be entrained during each hour of the day at Cabot station but were most prevalent during the afternoon and evening hours, with a peak at 20:00.



3.3.3- Downstream Passage of Juvenile American Shad

Conclusions

- The evaluation of run timing, duration, magnitude and entrainment using split beam hydroacoustics was not possible at NMPS due to high levels of milling.
- Entrainment occurred at Cabot Station and had a significant relationship with daily volume of water that passed through Cabot Station.
- Daily entrainment at Cabot Station was most prevalent during the afternoon and evening hours (75%), with a peak at 20:00.
- Unit 6 exhibits the highest rate of entrainment at Cabot Station.

3.3.3- Downstream Passage of Juvenile American Shad

Evaluation of Passage Routes (Radio Telemetry)

Radio telemetry techniques were used to evaluate route selection and rate of movement of emigrating juvenile shad as they passed through the Northfield Mountain and Turners Falls Projects.

- Tagged juvenile shad were monitored at 13 locations within the study area in accordance with the RSP and FERC's SPDL using a combination of Orion receiver, Lotek SRX 400 receiver or Lotek SRX 800 receiver.
- Both aerial yagi and in-water dropper antennas were used.
- Stations with Lotek SRX 400 or 800 receivers were set up with two receivers to reduce the scan time (2.2 seconds per channel).
- The radio telemetry monitoring system was tested and calibrated in the field prior to tagging and release of test fish

3.3.3- Downstream Passage of Juvenile American Shad

Variances

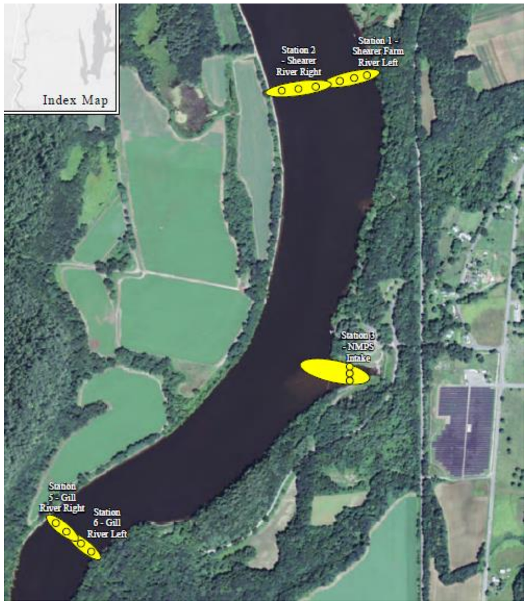
- The RSP envisioned the use of hatchery raised juvenile shad to ensure that they are large enough to tag. This approach will be used for the survival studies but not the route selection studies. Feasibility testing conducted by the TransCanada study team in 2014 showed that the hatchery raised fish did not behave similarly to wild stock. Therefore, while hatchery fish are suitable for survival studies they are not suitable for behavioral studies like route selection.

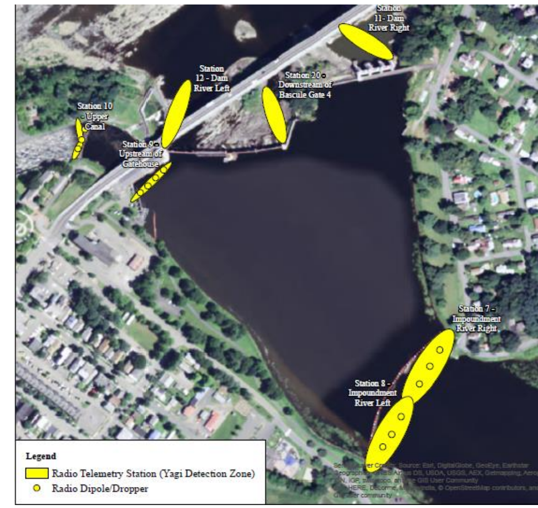
- The specification for the radio tags have been changed as defined herein.

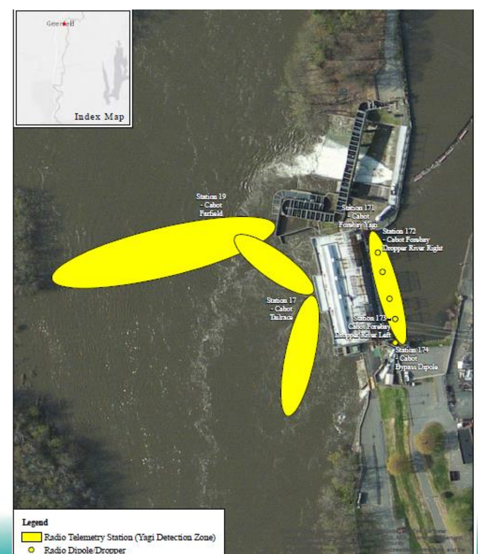
- A Gatehouse monitoring station was added.

- A Cabot Station tailrace monitoring station was added.

3.3.3- Downstream Passage of Juvenile American Shad

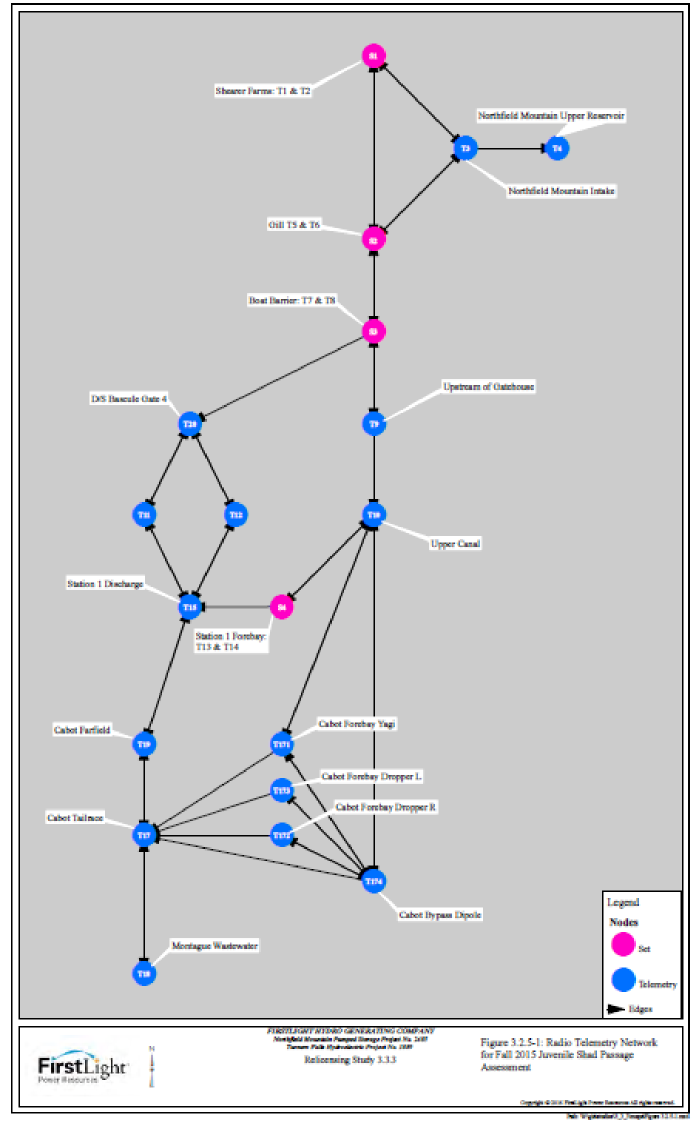






3.3.3- Downstream Passage of Juvenile American Shad

Telemetry Network Model



3.3.3- Downstream Passage of Juvenile American Shad

Tagging and Release

- Juvenile shad were collected in the evenings (generally between 16:00-22:00) and transported in an aerated live well (90 gallons) by truck to the TF Gatehouse where they were divided into three 1,000 gallon circular holding tanks with flow-through ambient river water supplied from the impoundment.
- Juvenile shad from the holding tanks were transported in small groups (~80) to the release location by boat in a live well (90 gallons).
- A Lotek NanoTag Series Model NTQ–1 was externally affixed to 218 juvenile shad.
  - 5 mm wide
  - 3 mm high
  - 10 mm long
  - 0.26 g weight in air
  - A tag life of 10 days at a 2 second burst rate
  - Three frequencies; 150.340, 150.360, and 150.380 MHz.

- Large shad, free from scale loss and observable injuries were selected for tagging. Juvenile shad were transferred from the holding tank by brail and placed in a 5 gallon bath of carbonated water (~1 liter) and ambient river water (~19 liters) for approximately 1 minute, or until anesthetized. Tags were affixed to barbed No. 16 dry fly hooks.
- The fish were kept in the water while the hooks were inserted into the dorsal musculature just below the dorsal fin.
- Once tagged, the fish were held in a small circular recovery tank (~8 gallons) for observation (approximately 15 minutes) to verify initial survival and tag retention.

3.3.3- Downstream Passage of Juvenile American Shad

- Tagged shad were released at two sites in the TFI. The first was approximately 1.5 miles upstream of the Northfield Mountain Project intake/tailrace and the other was in the lower impoundment, about 1.25 miles upstream of the TFD.
- The releases upstream of the Northfield Mountain Project occurred on six days between October 12 and 20, 2015 and on three days between October 12 and 15, 2015 at the lower impoundment site upstream of the TFD (Table 3.2.3-1).
- Upstream releases were scheduled such that cohorts of test fish would experience a range of NMPS Project pumping scenarios (i.e. 1, 2 and 3 pumps). Unit 4 was in an outage during the study period and did not operate.

Release Location	Release Date	Release Time	Count	Cumulative Total	No. Units Pumping at NMPS
Upper Canal	October 4, 2015	20:45	8	8	1
Lower Canal	October 4, 2015	22:25	9	17	1
Upstream of TFD	October 12, 2015	19:20	20	37	2
Upstream of NMPS	October 12, 2015	20:45	20	57	2
Upstream of TFD	October 13, 2015	20:45	20	77	3
Upstream of NMPS	October 13, 2015	20:05	24	101	3
Upstream of TFD	October 15, 2015	19:45	23	124	3
Upstream of NMPS	October 15, 2015	20:10	24	148	3
Upstream of NMPS	October 16, 2015	20:55	24	172	2
Upstream of NMPS	October 19, 2015	19:10	24	196	3
Upstream of NMPS	October 20, 2015	20:10	22	218	2

3.3.3- Downstream Passage of Juvenile American Shad

- Fifty (50) juvenile shad were placed in a 90-gallon tank and tagged with mock tags that consisted of tin BB weights attached to dry fly hooks to serve as controls.
- The weight and approximate size of the control tag (~0.3 grams) was similar to the Lotek NanoTag.

3.3.3- Downstream Passage of Juvenile American Shad

Rate of Movement

- The amount of time that each fish spent within the impoundment was determined by using the time from release and last known detection at any given fixed telemetry station within the impoundment.

- Distance from the release location to the last known fixed telemetry station detection was determined in RMs. These data were used to calculate migration rate, distance per hour (RM/h).

- If a fish passed through the Turners Falls Project, the time of release to the time of the last detection closest to the dam and/or Gatehouse was used. The same procedure was used for the bypass reach and the power canal.

FirstLight Power Resources

3.3.3- Downstream Passage of Juvenile American Shad

Canal Escapement during Drawdown

- Prior to the drawdown of the Turners Falls Power Canal juvenile shad were tagged and released into the canal the evening of October 4, 2015.
- 8 tagged juvenile shad were released in the upper portion of the canal just downstream of Gatehouse and 9 were released in the lower portion of the canal where it begins to widen along Migratory Way.
- Subsequent to release, mobile tracking was performed on October 5, 2015 in an attempt to locate the tagged fish and determine escape routes.

An objective of Study 3.3.18 *Impacts of the Turners Falls Canal Drawdown on Fish Migration and Aquatic Organisms* was to assess whether juvenile shad and American Eel abundance in the canal increases leading up to the time of its closure, due to delays in downstream passage (e.g., is fish accumulation occurring).

- Shad were monitored at the Cabot intake leading up to the canal drawdown using split beam hydroacoustics.
- These data were used to estimate entrainment at Cabot Station, which has an assumed positive relationship to shad abundance within the power canal such that as the entrainment rate increases so must the abundance in the canal.
- Entrainment rate at Cabot Station was plotted over time and used to investigate the potential for shad accumulation within the power canal leading up to the drawdown.

3.3.3- Downstream Passage of Juvenile American Shad

NMPS Area

- A total of 129 tagged juvenile Shad were released upstream of the NMPS intake/tailrace area. Of those 77 Shad (60% of release) were detected at Shearer Farms fixed telemetry monitoring station (T1 and T2) located approximately 1.2 river miles downstream of the release point and approximately 0.5 miles upstream of the NMPS intake/tailrace. These fish represent the cohort of emigrating fish that entered the NMPS area.
  - Thirty two of these fish emigrated past the NMPS intake/tailrace area and continued downstream approximately 0.66 miles downstream, where they were detected at the Gill Banks monitoring station (T5 and T6) for a passage rate of 41.6% through this reach of the TFI.
  - Of the fish that entered this reach 72.7% were either detected in the NMPS intake/tailrace area, the upper reservoir or downstream of the NMPS intake/tailrace; leaving 27.3% undetected.
  - Three fish were entrained and detected in the Upper Reservoir of Northfield Mountain, suggesting an entrainment rate of 3.9%.
  - Twenty-one (21) additional fish were last detected at the Northfield Mountain intake/tailrace and were never detected again at any of the telemetry receiver stations.
    - Of those 21 fish, 14 were last detected at the Northfield Mountain intake/tailrace during pumping operations.

3.3.3- Downstream Passage of Juvenile American Shad

TFD and Powerhouse

- Only two juvenile shad (1% of releases) passed over the TFD and 16 (9% of releases) passed through the Gate House and into the power canal.

Rate of Movement

- Juvenile shad (n=113, 61.7% of releases) detected at the impoundment receiver stations exhibited a mean rate of downstream movement of 0.31 RM/h.
- Two fish passed over the TFD, one of which continued through the bypass reach to the Station No.1 tailrace at a rate of 1.45 RM/h.
- Three fish were detected in the Cabot Station tailrace. Based on these fish, the mean rate of movement through the canal was 0.03 RM/h.

3.3.3- Downstream Passage of Juvenile American Shad

Canal Release Group

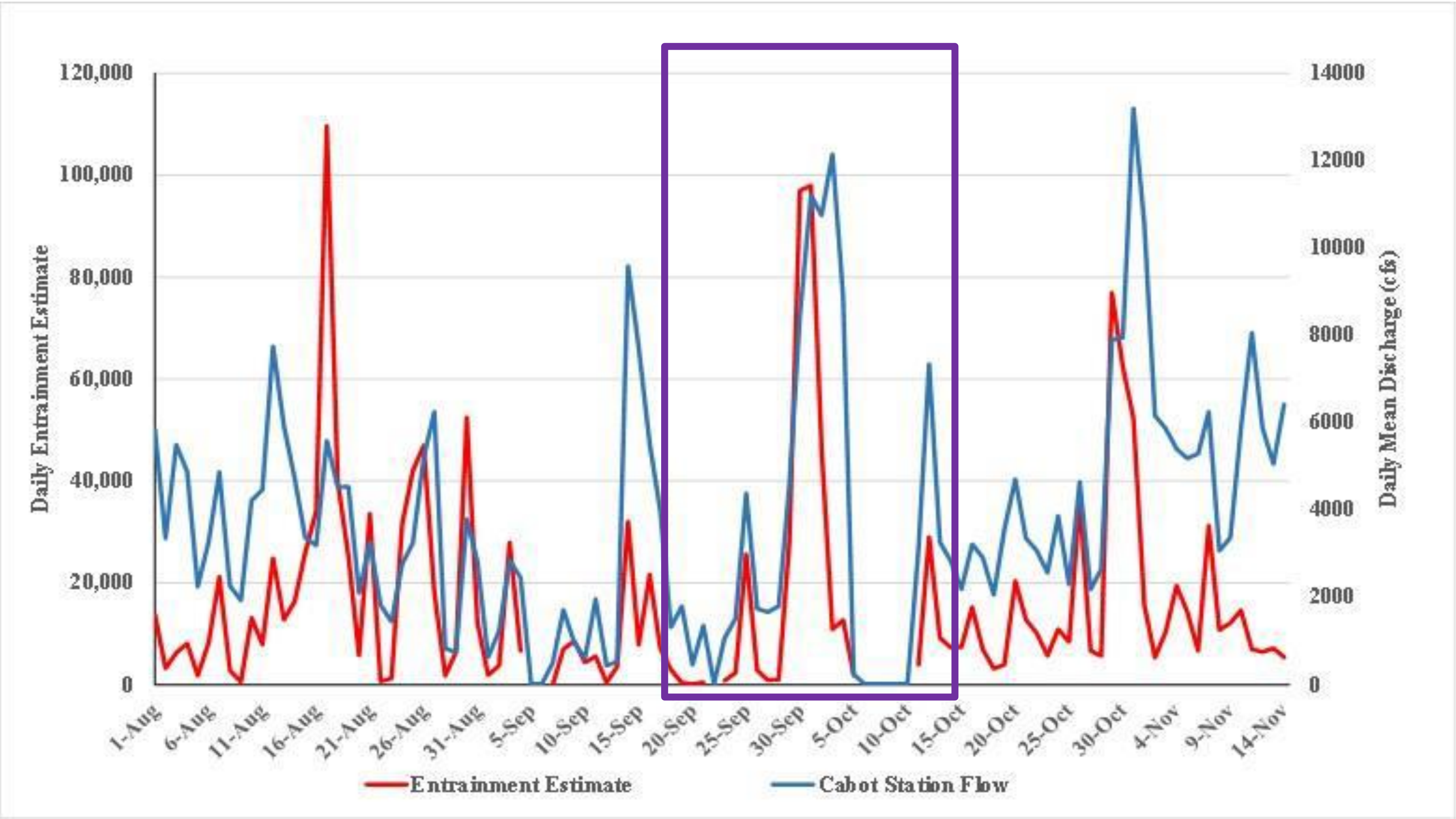
- A separate group of 17 tagged juvenile shad were released into the Turners Falls Power Canal the evening before the annual drawdown on October 5, 2015.
  - Five fish were detected in the area of release; two at the upper canal release site and three at the lower canal release site.
  - One fish released in the upper canal was detected at the Station No. 1 forebay, although passage was not confirmed as Station No. 1 was not operating.
  - Similarly, one fish released in the lower canal was detected in the vicinity of the Cabot Station forebay; however, Cabot Station was not operating at the time of detection and this individual was not detected at any station downstream of Cabot Station.

3.3.3- Downstream Passage of Juvenile American Shad

Fish accumulation - Turners Falls Power Canal

- Split beam hydroacoustics data collected at the Cabot Station intake indicated an increase in entrainment rate during the week leading up to the canal drawdown beginning on September 28, 2015 with a rate of 1,100 shad sized targets per day to a peak of approximately 98,000 entrained per day on October 1.
- This increase in entrainment coincided with an increase in river flow and discharge at Cabot Station, which has a positive relationship with an increase in canal flow and intake velocity.
- The highest river flows experienced during the study (~39,000 cfs) occurred on October 2 and 3, 2015 the days before the start of the drawdown.
- The daily entrainment rate had declined to approximately 13,000 per day on October 4 immediately before the drawdown.
- Entrainment decreased prior to the decrease in discharge at Cabot Station suggesting that an accumulation of shad occurred during the relatively low flow period (9/17/15 – 9/30/15) in the canal leading up to the drawdown but shad were conveyed downstream during the increase in canal flow/discharge at Cabot Station prior to the drawdown.
- Escapement of tagged shad from the canal during the drawdown was poor but tagging and handling mortality may have confounded the results.

3.3.3- Downstream Passage of Juvenile American Shad



3.3.3- Downstream Passage of Juvenile American Shad

Conclusions

- The control experiment revealed significant mortality, tag loss and irregular swimming behavior of tagged shad. These observations leave the reliability of the study results in question.
- The study did not effectively estimate the run timing, duration, or magnitude of juvenile shad entrainment at NMPS rendering these objectives unattainable as scoped in the Revised Study Plan (RSP).
- Of the fish released upstream of NMPS (129) a large proportion (60%) emigrated and were detected at the Shearer farms monitoring Site. Of those 41.6 % emigrated past NMPS and were detected downstream at Gill Banks.
- Three fish were entrained and detected in the Upper Reservoir of Northfield Mountain, suggesting an entrainment rate of 3.9%.
- Passage over the dam and into the Turners Falls power canal was low, 1% and 9% of released, respectively.
- Rate of emigration was highest in the bypass reach (1.45 RM/h) followed by the impoundment (0.31 RM/h) and the slowest rate of emigration was observed in the canal (0.03 RM/h).
- Entrainment rate and thus shad abundance in the canal increased leading up to the canal drawdown and corresponded to increased flows and Cabot Station discharge. However, entrainment rate declined prior to flow and was at a relatively low level at the time of the drawdown.

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Background

Study involved qualitative and quantitative approach to characterizing and estimating fish entrainment for the NMPS and TF Projects. Entrainment magnitude and turbine mortality were evaluated. A qualitative desktop entrainment analysis was conducted for resident fish; adult and juvenile American Shad and adult American Eel were quantitatively assessed.

Study Objectives

- Estimate the potential risk of entrainment, impingement, and turbine passage mortality to resident fish species at the Northfield Mountain Project and Turners Falls Project by developing a qualitative scale of risk for resident and migratory fish species.
- Conduct a quantitative assessment of the potential impact of entrainment and turbine passage mortality on American Shad and American Eel.

Work Completed

- Qualitative assessment of entrainment and impingement of resident species.
- Estimation of turbine passage mortality rates for juvenile American Shad and adult American Eel.

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Conclusions

- Entrainment of resident species was ranked as low to moderate risk; no population wide impacts are expected.
- Turbine passage survival rates for juvenile shad ranged from 95% at Cabot Station to 68% at Station 1 Units 2/3.
- Survival of shad passing the dam via the Bascule Gates ranged from 48% (1,500 cfs) to 76% (5,000 cfs) at BG1 and from 59% (2,500 cfs) to 74% (5,000 cfs) at BG4. Survival rates were highest under the 5,000 cfs discharge scenario .
- Turbine passage survival rates for adult eels ranged from 96% (48 h) at Cabot Station to 62% (48 h) at Station 1 Units 2/3. Survival at Station 1 Unit 1 was 90% (48 h).
- Bascule Gate survival of adult eels ranged from 85.7% (2,500 cfs) to 88.8% (1,500 cfs) at BG1 and from 82.9% (1,500 cfs) to 93% (5,000 cfs) at BG4 .

Variances

- Due to safety concerns regarding access to the gates, survival testing at the dam occurred at Bascule Gates 1 and 4 only.
- Estimates of 48 hour survival for juvenile shad was deemed unreliable because of high control mortality.

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Resident Species

- Species assessed based on observations in TFI during 2015 Fish Assemblage Assessment (Study No. 3.3.11)
- Traits Based Assessment used to evaluate risk of entrainment and/or impingement at Northfield, Station No. 1 and Cabot Station
- Susceptibility to entrainment/impingement based on habitat preferences, life history strategies, behavior, and morphology
- Degree of entrainment/impingement depends on swimming capabilities
- For entrainment, if sustained swim speed < mean intake velocity, then entrainment assumed
- For impingement, smaller fish with body widths < trashrack spacing were assumed not to be susceptible to impingement. If body width > trashrack spacing, then potential for impingement based on swimming performance as compared to mean intake velocity
- Turbine passage mortality estimates for resident species were extrapolated from an empirical dataset of more than 30 hydro projects with similar characteristics (head, peripheral runner velocity, and hydraulic capacity) as Cabot Station and Station No. 1

FirstLight Power Resources

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Resident Species - NMPS

Species	Habitat & Biology	Swim Speed	Survival	Likelihood	Population Impact	Risk Score
Banded Killifish	1	2	3	1	0	7
Black Crappie	1	2	3	1	0	7
Bluegill	1	2	3	1	0	7
Brown Bullhead	1	2	3	1	0	7
Chain Pickerel	1	2	3	1	0	7
Channel Catfish	1	2	3	1	0	7
Common Carp	1	2	3	1	0	7
Common Shiner	1	2	3	1	0	7
Fallfish	1	2	3	1	0	7
Golden Shiner	1	2	3	1	0	7
Largemouth Bass	1	2	3	1	0	7
Longnose Dace	1	2	3	1	0	7
Mimic Shiner	1	2	3	1	0	7
Northern Pike	1	2	3	1	0	7
Pumpkinseed	1	2	3	1	0	7
Rock Bass	2	2	3	1	0	8
Rosyface Shiner	1	2	3	1	0	7
Smallmouth Bass	2	2	3	1	0	8
Spottail Shiner	1	2	3	1	0	7
Tessellated Darter	1	2	3	1	0	7
Walleye	1	2	3	1	0	7
White Perch	2	2	3	1	0	8
White Sucker	2	2	3	1	0	8
Yellow Perch	1	2	3	1	0	7

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Resident Species - Station No. 1

Species	Habitat & Biology	Swim Speed	Survival	Likelihood	Population Impact	Risk Score
Banded Killifish	1	2	1	1	0	5
Black Crappie	2	2	1	2	0	7
Bluegill	1	0	1	1	0	3
Brown Bullhead	1	0	2	1	0	4
Chain Pickerel	1	2	1	1	0	5
Channel Catfish	1	0	3	1	0	5
Common Carp	2	0	2	1	0	5
Common Shiner	1	0	2	1	0	4
Fallfish	1	0	2	1	0	4
Golden Shiner	1	0	2	1	0	4
Largemouth Bass	1	1	1	1	0	4
Longnose Dace	1	2	2	1	0	6
Mimic Shiner	1	2	2	1	0	6
Northern Pike	1	0	0	1	0	2
Pumpkinseed	1	0	1	1	0	3
Rock Bass	1	2	1	1	0	5
Rosyface Shiner	1	2	2	1	0	6
Smallmouth Bass	1	1	1	1	0	4
Spottail Shiner	1	0	2	1	0	4
Tessellated Darter	1	2	2	1	0	6
Walleye	1	0	2	1	0	4
White Perch	1	0	1	1	0	3
White Sucker	2	0	1	1	0	4
Yellow Perch	1	0	2	1	0	4

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Resident Species - Cabot Station

Species	Habitat & Biology	Swim Speed	Survival	Likelihood	Population Impact	Risk Score
Banded Killifish	1	2	2	1	0	6
Black Crappie	1	2	1	2	0	6
Bluegill	1	2	1	1	0	5
Brown Bullhead	1	2	3	2	0	8
Chain Pickerel	1	2	1	2	0	6
Channel Catfish	1	0	3	2	0	6
Common Carp	3	2	2	2	0	9
Common Shiner	1	2	2	2	0	7
Fallfish	1	2	2	1	0	6
Golden Shiner	2	2	2	2	0	8
Largemouth Bass	1	2	1	1	0	5
Longnose Dace	1	2	2	2	0	7
Mimic Shiner	1	2	2	2	0	7
Northern Pike	1	0	0	2	0	3
Pumpkinseed	1	2	1	1	0	5
Rock Bass	1	2	1	2	0	6
Rosyface Shiner	1	2	2	2	0	7
Smallmouth Bass	1	2	1	1	0	5
Spottail Shiner	1	2	2	2	0	7
Tessellated Darter	1	2	2	1	0	6
Walleye	1	2	2	2	0	7
White Perch	2	2	1	2	0	7
White Sucker	2	0	1	2	0	5
Yellow Perch	1	2	2	1	0	6

3.3.7 - Fish Entrainment and Turbine Passage Mortality
Migratory Species

Adult American Shad
- No adults were confirmed to be entrained at NMPS or Station No. 1 (Study No. 3.3.2).
- A total of 86 double tagged shad emigrated through the canal, of those 24 were entrained through Cabot (9 of those detected further downstream) and 39 adult shad exited the area via the sluiceway.

Juvenile American Shad
- Hydroacoustics set-up at NMPS did not allow for reliable entrainment estimate. Based on radio telemetry methods, 3.9% of those that passed the intake were entrained.
- Of the 16 juveniles that migrated through the Power Canal, only one was detected at Station No. 1, but no entrainment confirmed.
- Hydroacoustics data suggested over 1.6M juveniles entrained at Cabot; however, turbine passage survival of 95% suggests the majority survive entrainment at Cabot.

Adult American Eel
- Data analysis remains ongoing and entrainment potential will be discussed in report for Study No. 3.3.5 due to FERC in March 2017.

3.3.7- Fish Entrainment and Turbine Passage Mortality

Migratory Species

- The goal of these studies was to assess turbine survival (1 and 48 h) at Cabot Station Unit 2, Station No. 1 (Units 1 and 2/3) and over the Bascule Gates (1 and 4) of emigrating juvenile American Shad and adult silver-phase American Eels.
- The results were obtained using the HI-Z Tags recapture techniques.
- Juvenile shad collected in the Connecticut River and adult silver-phase eels imported from Newfoundland were released into the intakes of designated Francis units at Cabot Station, Station No. 1, and over Bascule Gates 1 & 4 at three discharge scenarios (1,500, 2,500, and 5,000 cfs).

- After passage, live and dead fish were captured and the condition of each was examined.
- At the end of the 48 h holding period, all live and uninjured shad were released to the river.
- Survival rates were estimated for each passage location and descriptions of the observed injuries were recorded to help assess the probable causal mechanisms for injury/mortality.

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Tag-Recapture Data and 1 hour Survival Rates for Juvenile Shad, October 14-24, 2015.

Juvenile Shad	Cabot	Station No. 1		Bascule Gate 1 (cfs)			Bascule Gate 4 (cfs)			Controls	
	Unit 2	Units 2/3	Unit 1	1,500	2,500	5,000	1,500	2,500	5,000	Cabot & Station 1	Bascule Gates
Number released	120	90	90	60	60	62	60	60	60	71	75
Number recaptured Alive	113	59	59	38	27	45	37	34	41	67	72
Number recaptured Dead	2	6	9	4	7	4	4	6	0	0	3
1 hour survival rate	0.95	0.68	0.77	0.69	0.48	0.76	0.64	0.59	0.74		
Number Held	113	59	59	38	27	45	37	34	41	67	72
Number Alive at 48 hours	86	48	31	28	4	9	4	6	7	45	48
Number Dead at 48 hours	27	11	28	10	23	36	33	28	34	22	24

*48 hour survival not reliable because of high control mortality

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Tag-Recapture Data and 1 and 48 hour Survival Rates for Adult Eels, November 4-9, 2015.

Adult Eels	Cabot	Station No. 1		Bascule Gate 1 (cfs)			Bascule Gate 4 (cfs)			Controls
	Unit 2	Units 2/3	Unit 1	1,500	2,500	5,000	1,500	2,500	5,000	Combined
Number released	50	30	30	35	30	30	35	30	30	25
Number recaptured Alive	49	18	27	30	24	25	31	27	28	25
Number recaptured Dead	0	1	0	0	0	0	0	1	0	0
1 hour survival rate	0.98	0.62	0.90	0.88	0.86	0.86	0.89	0.9	0.93	
Number Held	49	18	27	30	24	25	29	27	28	25
Number Alive at 48 hours	48	18	27	30	24	25	29	27	28	25
Number Dead at 48 hours	1	0	0	0	0	0	2	0	0	0
48 hour survival rate	0.96	0.62	0.90	0.88	0.86	0.87	0.83	0.90	0.93	0

3.3.7 - Fish Entrainment and Turbine Passage Mortality

Juvenile Shad

Survival rate (1 h) was 95.0% for juvenile shad passed through Cabot Station Unit 2.

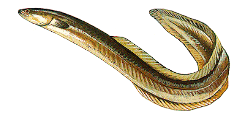
Survival rate (1 h) was about 68% at Unit 1 of Station No. 1 and 77% for fish passed through the common penstock of Units 2 and 3 .

Cabot Station turbines are larger and rotate slower than Station No. 1 turbines.

Juvenile shad are more likely to survive turbine passage than passage via the dam. Combined (for three flows tested) survival at Bascule Gate 1 was about 63% and about 65% at Bascule Gate 4.

The boulder and concrete sill structures directly below the discharge of Bascule Gates 1 and 4 likely impacted survival of juvenile American Shad passed via the dam .

Adult Eels



Adult eels incur minor mortality (≤4%) passing the large Francis units at Cabot Station.

Eels exhibited 90% survival (48 h) and little injury passing the larger of the Francis units (Unit 1) at Station No. 1.

Station 1 Units 2/3 with a common penstock inflict up to about 38% mortality.

Testing at 3 discharges (1,500, 2,500, and 5,000 cfs) through Bascule Gates 1 and 4 indicated survival estimates of 86-88% at Bascule Gate 1 and 83-93% at Bascule Gate 4.

Very few injuries were observed with recaptured fish.

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Background

The goal of this study is to collect information to determine if Project operations negatively impact fish species so that appropriate mitigation measures may be developed, if warranted, to protect and conserve the species utilizing project waters.

Study Objectives

- Assess timing and location of fish spawning in the littoral zone.
- Delineate, qualitatively describe (*e.g.* substrate composition, vegetation type and relative abundance),and map shallow water habitat types subject to inundation and exposure due to project operations.
- Evaluate potential impacts of impoundment fluctuation on nest abandonment, spawning fish displacement and egg dewatering.

Work Completed

- Field data collected during 2015 field season
- Draft report prepared June 2016

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Field crew systematically traversed the littoral zone (depth < 6 feet) of the entire TFI to visually identify any fish nests, egg masses/deposits, and/or spawning habitat.

Used an RTK-GPS unit to determine:

- Position and elevation of nests and/or potential habitat surveyed to the NGVD29 datum.
- Prevailing water surface elevation at each site

Early Spring - Broadcasted adhesive eggs. Gravel shoals, point bars etc. At locations where eggs could be embedded in gravel interstices, substrates were inspected using underwater surveillance. Aquatic and riparian vegetation also examined

Late Spring -   Nearshore shoal areas where nest construction could occur searched for evidence of either nest construction, redd formation, or spawning aggregations of adult fish.

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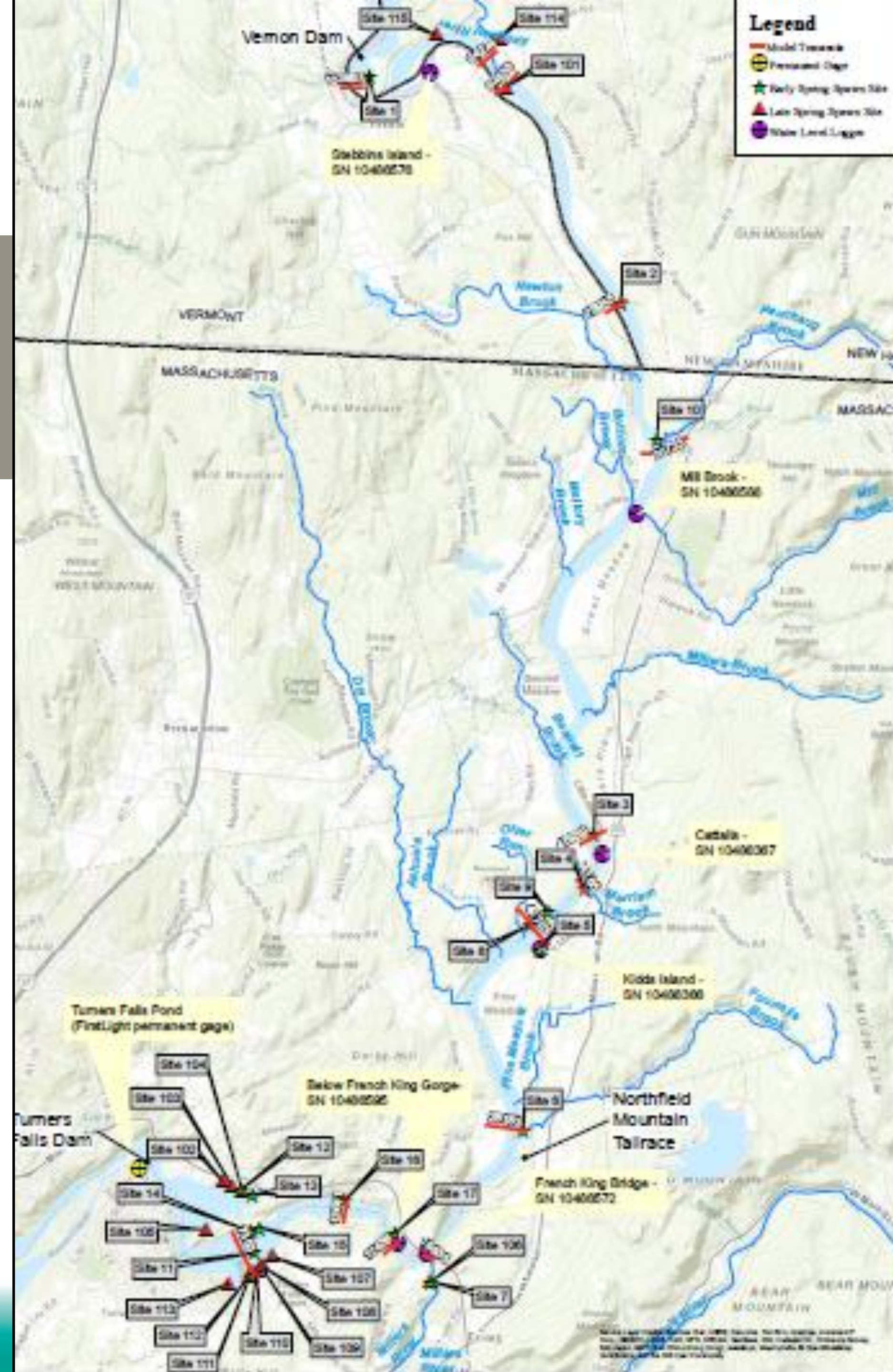
3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

- To supplement the WSEL data collected, used the hydraulic model of the TFI (part of Study No. 3.2.*2 Hydraulic Study of Turners Falls Impoundment, Bypass Reach and below Cabot)*.

- Location of each spawning site was mapped and compared against hydraulic model transects. The transect in closest proximity to each spawning location was used to determine whether spawning sites could have been dewatered.

- 32 spawning sites (17 in the early spring and 15 in the late spring) were discovered throughout the survey



3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

TFI WSELs during the course of early spring surveys were relatively close to the long-term median (181.3 ft). Thus fish selected spawning sites under relatively "typical" TFI water levels in 2015.

Early spring spawning:
Early May 2015
Areas where either evidence of spawning was observed, or habitat and substrates suitable to such spawning, were limited to isolated patches.

- Several gravel-rubble beds in the upper TFI appear to provide suitable spawning conditions for walleye; it was assumed that spawning could occur at these sites given the availability of suitable substrates, however direct observation of spawning was not possible due to relatively high flows and turbid water

- SAV or emergent vegetation beds were concentrated in the section below French King Gorge to Barton Cove. A few were scattered throughout the middle and lower reaches of the TFI

- All life stages (including young of year, YOY) of walleye and yellow perch were detected in the fish assemblage study(Study No. 3.3.11), indicating that reproduction using these habitats was successful in 2015 and earlier years.

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

TFI WSEL recorded between 180.5 and 181.1(in Barton Cove); an elevation of 184.6 ft was recorded at the upstream extent of the TFI near Stebbins Island instrument during late spring surveys; therefore fish selected spawning sites under relatively “typical” TFI water levels.

Late spring spawning:

Early-late June

- The vicinity of Barton Cove, and the boat club had the greatest concentrations of nests
- Scattered spawning was observed in the upper TFI between Stebbins Island and the vicinity of the Ashuelot River mouth
- Spawning nests were not detected in the middle reaches of the TFI, although YOY centrarchids were collected in all reaches of the TFI during the late summer fish assemblage survey
- Sea lamprey spawning was observed in areas such as riffles in the Millers River (*discussed in detail in the report for Study No. 3.3.15*)
- YOY lifestages of lamprey and centrarchids were detected in the fish assemblage study (Study No. 3.3.11), in reasonably close proximity to where nesting was observed

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Shallow water habitat types subject to inundation and exposure were mapped and profiled in detail in the report for Study No. 3.3.14 (Aquatic Habitat Mapping of Turners Falls Impoundment).

- Littoral areas were characterized by lotic riverine areas in the upstream most two-thirds of the TFI (approximately 13 miles), and a lacustrine embayed section of the TFI downstream from French King Gorge.
- *Upstream reach* is relatively uniform and located within a broad floodplain. There are a few narrow islands comprised of alluvial materials such as gravel, cobble and fines.
- The reach between the Northfield Mountain tailwater downstream through the gorge is comprised of steep, vertical bedrock walls and lacks significant littoral habitat.
- The *downstream reach* extends from the outlet of French King Gorge to the Turners Falls Dam, defined by both bedrock and depositional features, includes a complex of embayment, points, coves, islands and a wide range of substrates, and includes shallow lacustrine littoral habitat.
- Fines and cobble collectively accounted for about 50% of all littoral substrate. Coarser materials are more common in the upper reach, and fines, muck and organic sediments are common in the lower reach.

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Potential impacts of impoundment fluctuation on fish spawning

Early Spring Spawning

White sucker and walleye

- Depths greater than 1 ft up to 9.8 ft provide at least a suitability rating of 0.5 or greater for white sucker; and depths from approximately 1.2 ft up to 6 ft also meet or exceed a habitat suitability rating of 0.5.

- TFI WSELs are frequently met at Site 2; however, Site 1, and Site 10 (in Pauchaug Brook) are only submerged about 50% or less of the time during April and May.

  - Site 1 is directly in the Vernon tailwater and at times directly influenced by Vernon discharges;

  - Site 10 is a cattail bank near the edge of the riparian zone and is inherently shallow.

  - Although walleye likely use shoals such as that at Site 2, they also undergo migrations to find suitable riffles for spawning (McMahon, 1984) and it is possible that additional spawning areas exist in tributaries outside of the study area.

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3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Northern Pike

- SAV bed spawning sites for pike were very limited in the upper TFI.
- Site 10 is submerged about 50% of the time in April (the month most likely for pike spawning), therefore not consistently usable.

Yellow Perch

- Spawning suitability conditions in the **upper TFI** would be marginally available under any circumstances. Yellow perch spawning would potentially occur on cattail stubs and other emergent vegetation submerged from approximately 3 to 12 ft in areas of extremely low velocity (less than .075 ft/sec)
- Spawning habitat in the **lower TFI:** Median operating conditions create water levels generally suitable for spawning conditions at most, but not all, SAV beds.
  - (*sites 11&12*) submerged adequately about 75% of the time
  - (*sites 13 - 17*) submerged adequately about 50-70% of the time

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Late spring spawning

- Dominated by nest building species such as centrarchids.
- Confined to the upper (limited) and lower (very abundant) extremities of the TFI.
- Embayment's and coves below French King Gorge and throughout the Barton Cove area.
- Nests built at the shallowest observed elevations generally remain adequately deep 90-95% of the time at most spawning locations and nests built at the deeper elevations remain adequately submerged nearly 100% of the time.
- Under median conditions most nest depths ranged between 2 and 4 ft and would be considered optimal.
- Nests constructed under approximately median conditions at sites 1.8 ft depth or shallower may become abandoned if the TFI WSEL falls below 179.8 ft.
- Should TFI elevation rise following nest construction, the increased depth did not appear to prohibit spawning and nesting success would not be affected.

3.3.13- Littoral Zone Fish Habitat and Spawning Habitat

Summary

Early Spring spawning

Upper impoundment

- spawning sites are scattered
- Some upstream sites affected by inflow from Vernon
- Emergent vegetation bed habitat adequately submerged 50%
- Gravel redds adequately submerged most of the time

Lower impoundment

- Median operating conditions create water levels generally suitable for spawning conditions at most SAV beds

Late Spring spawning

- spawning sites are scattered in upper impoundment, abundant in lower impoundment
- remains above179.8 ft, few nests established under median conditions would be abandoned
- If the TFI water level rises following nest construction, nesting success would not be affected.

3.3.15 Sea Lamprey Spawning

Study Objectives

- Identify areas within the Project area where suitable spawning habitat may exist for adult Sea Lamprey

- Conduct spawning surveys to confirm use of areas identified as containing suitable spawning habitat

- Describe spawning mound characteristics, including location, size, substrate, water depth, and velocity

- Collect the information to assess whether operations of the Turners Falls Project and Northfield Mountain Project are adversely affecting spawning areas (*e.g.,* if flow alterations are causing dewatering and scouring of lamprey area)

3.3.15 Sea Lamprey Spawning

Tagging:

- In total 40 adult Sea Lamprey were tagged for this study
- 20 released in the early portion of the run (5/21/15), and 20 in the later portion of the run (5/28/15) at two locations

Mobile Tracking:

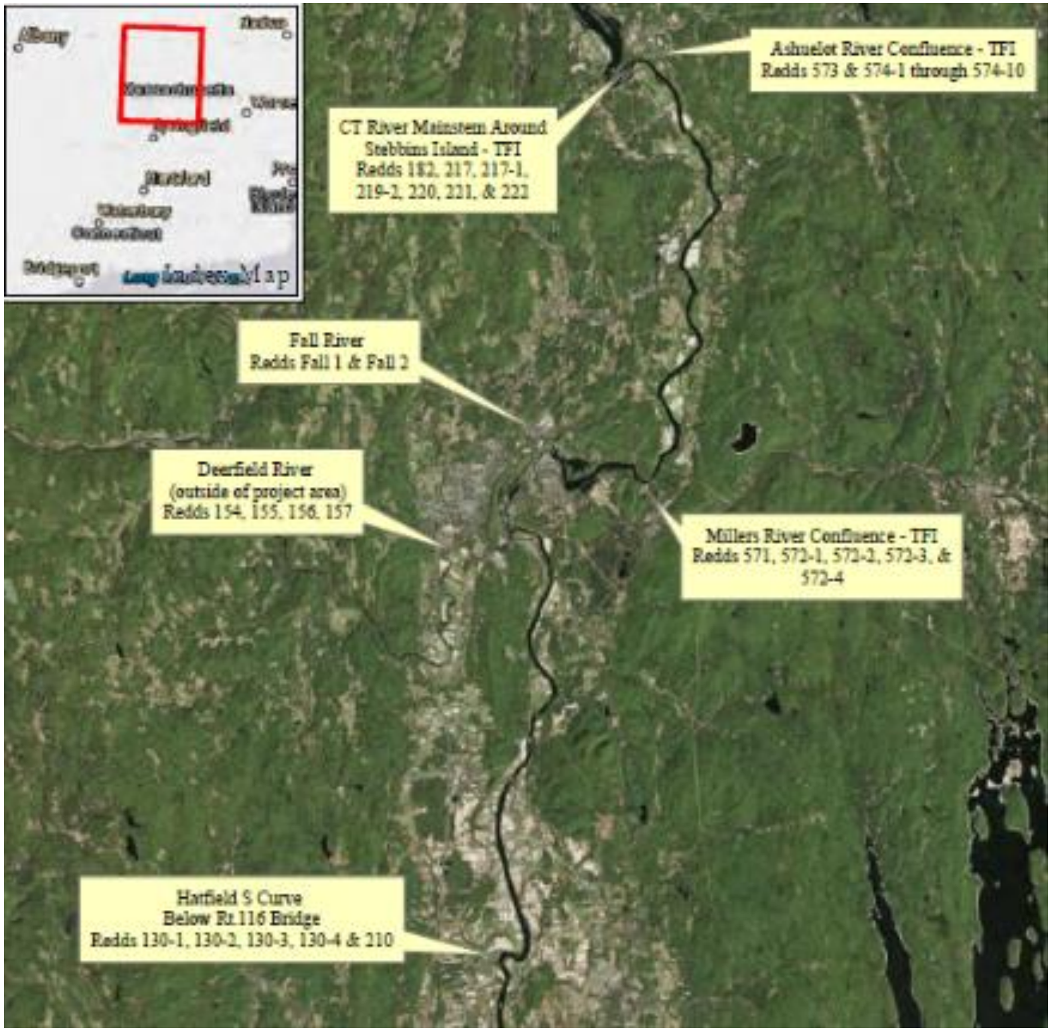
- Seventeen days of mobile tracking occurred between June 3 and July 17, 2015
- During tracking potential spawning habitats and/or redds were inspected along the CT River and its confluences

Date of Collection/Release	Collection Location	Number tagged and release location	Number tagged and release location	Total Tagged and Released
5/21/2015 (Early)	Holyoke Dam	10 – Rt. 116 Bridge	10 – Turners Falls Gatehouse	20
5/28/2015 (Late)	Holyoke Dam	10 – Rt. 116 Bridge	10 – Turners Falls Gatehouse	20

3.3.15 Sea Lamprey Spawning

Spawning Grounds and Habitat Assessment:

- 29 redds were GPS located in 5 spawning sites
- Marked redds were routinely monitored for:
  - *Depth, velocity, temperature, substrate characteristics, damage and general observations*
- 5 redds were capped using 4x4 ft, weighted PVC framed collection net (1 mm Mesh) to collect any emerging larvae (*Ammocoetes*)

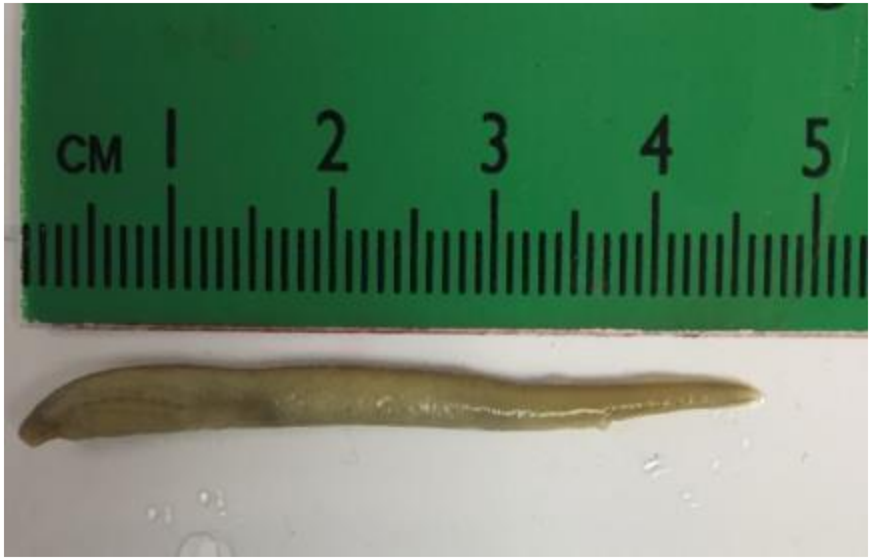


3.3.15 Sea Lamprey Spawning

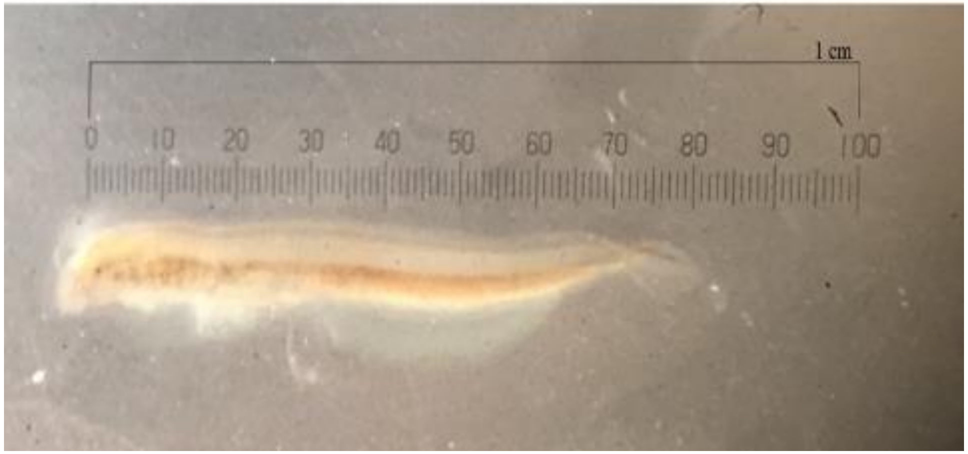
Spawning:

- Caps were left in place for 2 to 3 weeks
- There were 2 caps that successfully captured ammocoetes
- It is difficult to determine the age of these ammocoetes based on length but they are clearly in different stages of development and/or metamorphosis

Hatfield S Curve



Fall River



3.3.15 Sea Lamprey Spawning

Site Specific Habitat Measurements:

Site	Dates Surveyed	Depth (ft)		Velocity (fps)		Dominant Substrate
		Range	Mean	Range	Mean	
Millers River	6/12/15-7/6/15	1.1-2.9	1.91	0.21-4.25	1.98	Cobble
Ashuelot River	6/12/15-7/6/15	0.6-5.8	2.94	0.06-3.02	1.24	Gravel/Cobble
Hatfield S Curve	6/16/15-7/7/15	2.8-7.9	3.96	1.41-2.84	1.77	Cobble
Stebbins Island	6/19/15-7/10/15	1.3-8.8	4.59	0.11-6.08	2.99	Cobble
Fall River	6/17/15-7/31/15	0.6-4.8	1.53	0.02-2.38	0.82	Gravel/Cobble

- The 7 redds around Stebbins Island recorded the highest mean velocity (4.64 fps) and the highest mean depth (7.96 ft) of any spawning sites on June 24, 2015
- The 2 redds in the Fall River recorded the lowest mean velocities (0.44, 0.14 fps) on June 24, 2015 and July 2, 2015, respectively

3.3.15 Sea Lamprey Spawning

Habitat Suitability Mapping:

Turners Falls Impoundment:

- A map of suitable lamprey habitat within the TFI was created based on the HSI criteria developed for FirstLight's IFIM Study No. 3.3.1. Each transect in the TFI hydraulic model was divided into 20 equally sized cells.

- Within in each cell, the hydraulic model produced the mean velocity and depth. These variables, coupled with the substrate data obtained from Study No. 3.3.14 were used to compute the combined suitability index (CSI) value based on the HSI criteria for the sea lamprey spawning life stage

- CSI values range from 0 to 1 with values closest to 1 representing the species' optimal spawning and incubation conditions

Below Turners Falls Dam:

- FirstLight proposed to evaluate suitable sea lamprey spawning habitat using the IFIM Study No. 3.3.1

Habitat Classification:

- Sea Lamprey spawning habitat within the project area was classified as 1) Non-suitable habitat 2) Suitable habitat no observed spawning 3) Active spawning area 4) Active spawning area with larval sampling

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3.3.15 Sea Lamprey Spawning

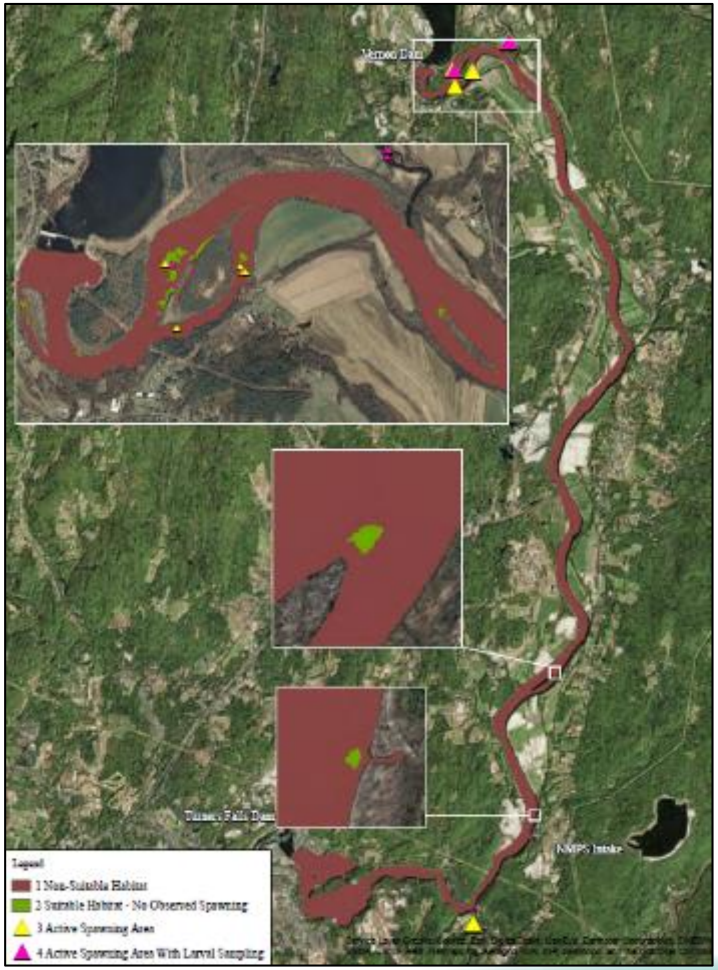
- Suitable Lamprey spawning habitat in TFI with 9,630 cfs at Vernon and NMPS off
- Almost all suitable sea lamprey spawning habitat in the TFI is found near Stebbins Island

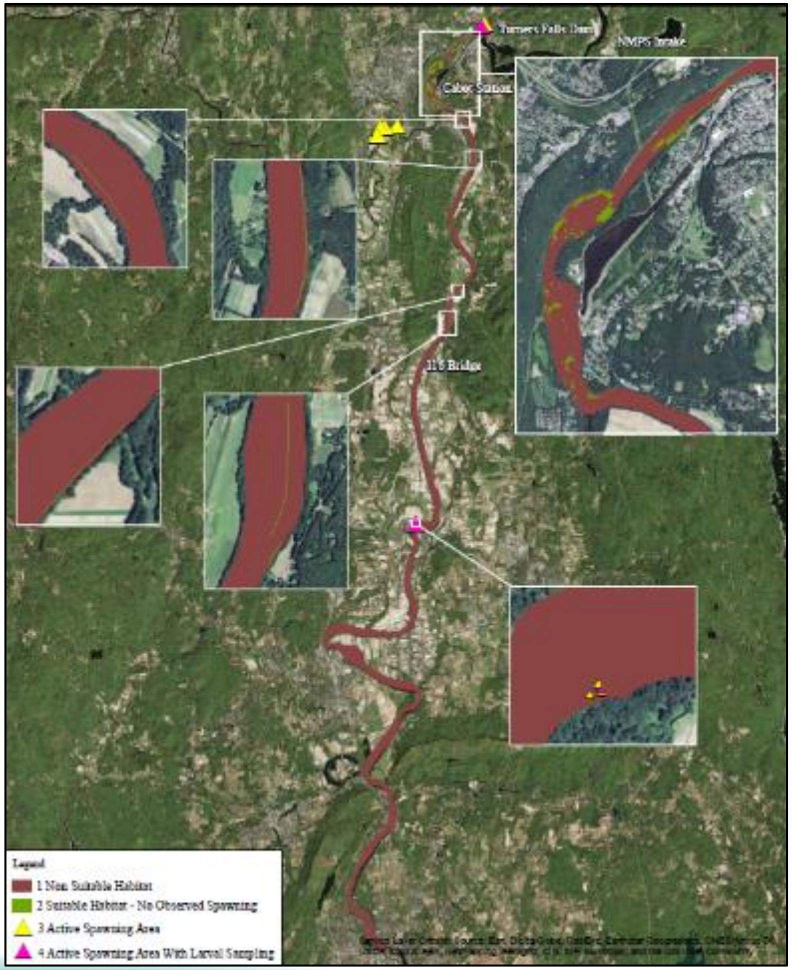
Habitat Suitability Index Values for Velocity, Depth and Substrate

Velocity		Depth		Substrate	
Velocity (fps)	**SI Value**	**Depth (ft)**	**SI Value**	**Substrate Class**	**SI Value**
0.00	0.00	0.00	0.00	Detritus – 1	0.00
0.30	0.00	0.13	0.00	Mud/soft clay – 2	0.00
1.28	0.34	0.46	0.50	Silt – 3	0.00
2.26	1.00	0.79	1.00	Sand – 4	0.04
3.25	0.86	1.12	1.00	Gravel – 5	1.00
4.23	0.30	1.44	0.60	Cobble/Rubble – 6	0.50
5.22	0.12	1.77	0.40	Boulder – 7	0.02
6.20	0.08	2.20	0.20	Bedrock – 8	0.00
6.23	0.00	2.30	0.00		

3.3.15 Sea Lamprey Spawning

Classification of suitable Lamprey spawning habitat above and below Turners Falls Dam





3.3.15 Sea Lamprey Spawning

Effect of Project operations on spawning habitat:

Spawning Site	Classification	Comments
Stebbins Island	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	-Inside Project area - -High velocity and depth under high Vernon discharge conditions
Ashuelot River	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	-Inside Project area --Backwater causing low velocity and increased depth
Millers River	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	N/A
Fall River	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	Backwater causing low velocity and increased depth during high TFD discharge
Hatfield S Curve	1) **No effect** (no observable difference to habitat/redd structure or lamprey activity).	N/A

3.3.15 Sea Lamprey Spawning

Conclusions:

- Following the criteria for possible Project effects, all five spawning sites monitored in this study were deemed to show no adverse effect due to operations
- Redds in the Fall River are susceptible to backwatering during times of high discharge at the TFD but there were no observation differences to habitat/redd structure or lamprey activity
- Fall River was one of two sites where an ammocoete was successfully captured, along with the Hatfield S curve site
- The Stebbins Island and Ashuelot River redds experienced only minor effects due to discharge at Vernon
- Overall, suitable spawning habitat for sea lamprey is limited in the TFI and the only sizable area is located around Stebbins Island
- The remainder of the TFI lacks appropriate conditions (relatively shallow, fast moving water in cobble or riffle area)

Variances:

- No variances existed in this study

Geology and Soils

3.1.3 Sediment Management Plan

Background

- Majority of the work was completed by the end of 2015
- 2016 activities included:
  - Finishing the physical model
  - Developing the sediment management measures
  - Drafting the final report
- Final Study Report filed October 14, 2016

Study Objectives

- To better understand sediment transport and dynamics between the Connecticut River and Upper Reservoir and to evaluate management measures to minimize the potential entrainment of sediment into the Project works and Connecticut River.

Work Completed

- Suspended sediment monitoring and grab sample collection (2012-2015)
- Annual Upper Reservoir Bathymetric Surveys (2011-2015)
- Computational modeling, including:
  - Upper Reservoir Computational Hydrodynamic Sedimentation Model (2013-2014), and
  - Northfield Mountain Tailrace CFD Model (2014-2015)
- Development of a physical model of the Northfield Mountain tailrace and surrounding area (2015-2016)
- Pilot dredge of the Upper Reservoir (2015)
- Development of proposed sediment management measures (2016)

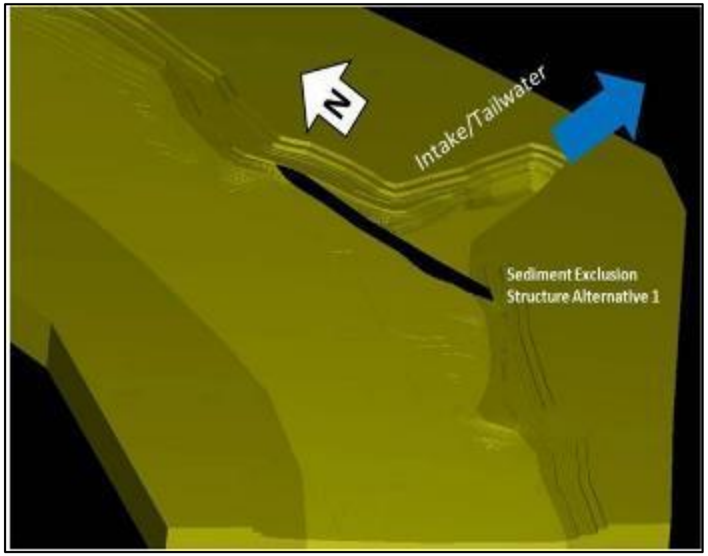
3.1.3 Sediment Management Plan

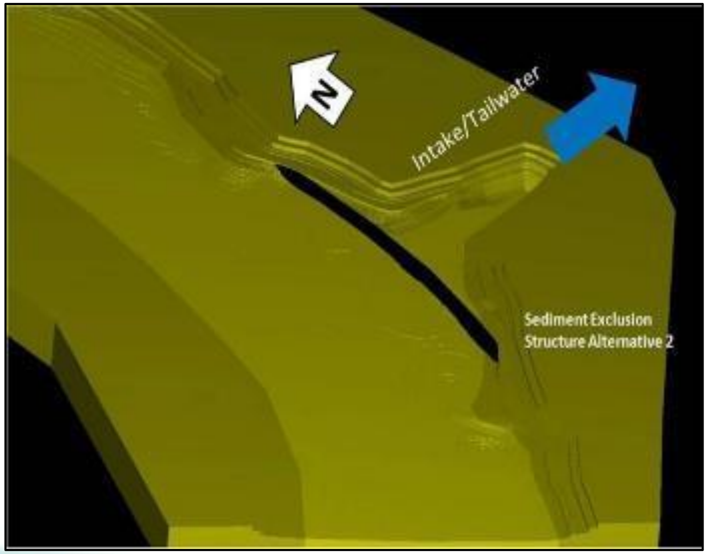
Conclusions

- **Computational hydrodynamic sedimentation model of the Upper Reservoir**:
  - Root cause of sedimentation in the Upper Reservoir likely begins with relatively high concentrations of entrained bed and suspended sediment loads from the Connecticut River transported during pumping phases
  - Once the water and sediment reach the wider and deeper Upper Reservoir intake channel a deceleration of the sediment rich pumped water occurs as well as subsequent deposition of the sediment in the upper reservoir
  - Exit velocities are lower in the intake channel under generation, meaning that much of the deposited sediment is not re-entrained during generation and discharged to the Connecticut River.
  - Findings are consistent with the observations made from the bathymetric and suspended sediment data analyses.
  - Changes in operating procedures and/or physical modifications to the Upper Reservoir intake channel which were analyzed were found to have minimal impact on reducing the amount of sediment entrained.

3.1.3 Sediment Management Plan

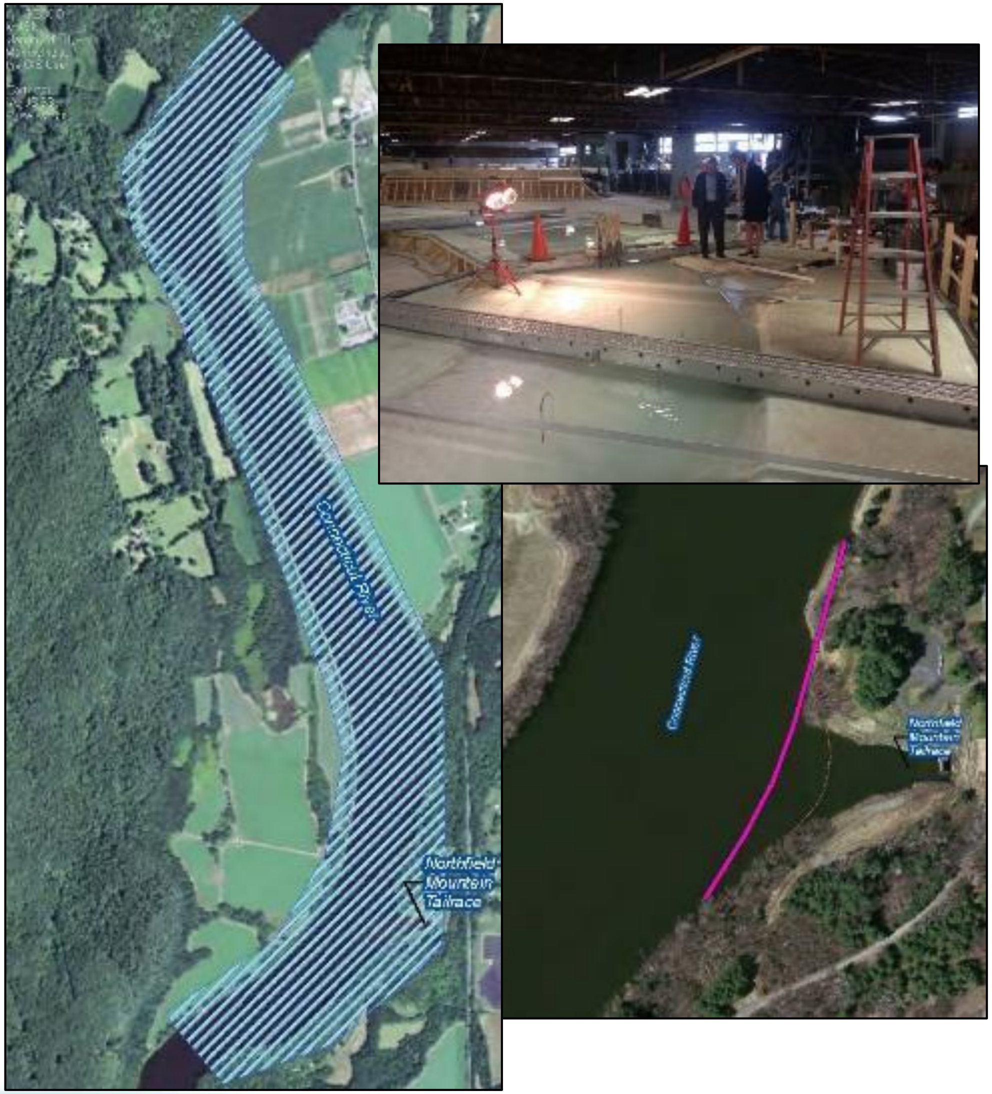
- **CFD modeling of the tailrace area**:
  - Operational conditions with 3 or 4 pumps were found to cause the majority of sediment uptake to the Upper Reservoir
  - Model examined the effectiveness of constructing two different types of sediment exclusion structures including a shorter convex and longer concave sill built above the bed of the intake and spanning the width of the tailrace
  - Modeling results showed that these potential management measures were more effective than the Upper Reservoir alternatives, however, they were still found to have limited effectiveness overall





3.1.3 Sediment Management Plan

- **Physical model of the tailrace area**:
  - Examined the effectiveness of two different 1,000 ft. long sediment exclusion structures, one with a 700 ft. long fixed crest overflow section and the other with a 700 ft. long moveable crest overflow section
  - Potential structures were modeled in the approximate location of the original riverbank prior to construction of NFM
  - The model found that constructing a sediment exclusion structure would have low to moderate effectiveness
    - The fixed crest overflow alternative had a similar, limited effectiveness as observed from the results of the tailrace CFD model.
    - The moveable crest overflow section was found to be slightly more effective than the fixed crest section
- Based on the findings of the various modeling efforts, operational changes or physical modifications were not considered for further evaluation as potential sediment management measures due to their limited effectiveness



3.1.3 Sediment Management Plan

Pilot Dredge:

- Approximately 46,000 cubic yards of sediment were successfully removed from within and immediately upstream of the Upper Reservoir intake by deep water hydraulic dredging
- On average 26 cubic yards of sediment per hour were removed
- The availability of the Project for generation and pumping was not affected by the dredging operations
- The dredging operation successfully removed sediment from within and upstream of the Upper Reservoir intake channel without having any material sediment impacts to the Project works or sediment discharges to the Connecticut River
- Hydraulic dredging was found to be a viable sediment management measure

3.1.3 Sediment Management Plan

Proposed Sediment Management Measures

- Encompass the most effective and successful management measures examined over the course of the study
- Focus on minimizing the entrainment of sediment into the Project works and Connecticut River during dewatering activities
- Proposed measures include:
  1. Employ a monitoring program based on bathymetric surveys of the Upper Reservoir and intake channel (conducted every 1-2 years) to determine the amount of sediment present at a given time
  2. Results of the surveys will be reviewed to determine: the estimated depth, location, and shape of accumulated sediment as well as the estimated incremental amount of sediment which has accumulated between surveys
  3. Based on this review, excavation of the intake channel and/or other target areas will be planned and initiated as needed to minimize the potential for entrainment of sediment into the Project works and Connecticut River during dewatering activities
  4. Excavation would occur via methods including, but not limited to, hydraulic dredging prior to dewatering or mechanical excavation after dewatering. The method will be developed based on the location and amount of sediment, the necessary timeframe for removing the sediment, and then-available technologies and methods
  5. FirstLight will notify MADEP, FERC, and USEPA in advance of any excavation activities

3.1.3 Sediment Management Plan

Proposed Sediment Management Measures (cont.)

6. Following completion of excavation activities, a bathymetry survey of the excavated area will be conducted in order to establish an updated baseline
7. FirstLight will develop protocols to be followed in the event of a dewatering (both emergency and maintenance or other types). Dewatering protocols will be provided to MADEP, FERC, and USEPA. Protocols may be updated periodically as needed
8. In the event of a dewatering, FirstLight will visually monitor turbidity in the tailrace area throughout the dewatering for any noticeable increases
9. FirstLight may explore other sediment management measures as technological advancements occur and the understanding of sediment dynamics at the Project continues to evolve. FirstLight will consult with MADEP, FERC, and USEPA in the event that future modifications are made.

Variances

- None, however, the study scope was expanded as the study progressed (i.e., additional monitoring years, computational modeling, physical model, pilot dredge).

3.1.2 Erosion Causation Report

Background

- Study was initiated in 2013 following issuance of FERC SPDL
- Addendum to the RSP was filed in 2014 to examine the impacts of ice as a result of the closure of Vermont Yankee
- Study examined a 15-year period (2000-2014)
- Data gathering, field data collection/post processing, and data analyses occurred 2013-2016
- BSTEM, HEC-RAS, and River2D Modeling occurred 2015/2016
- Supported by data from other studies, including:
  - 3.1.1 *Full River Reconnaissance;*
  - 3.1.3 *Northfield Mountain Project Sediment Management Plan;* and
  - 3.2.2 *Hydraulic Study of Turners Falls Impoundment, Bypass Reach and below Cabot Station*
- Study team included personnel from Simons & Associates; Gomez and Sullivan Engineers; Cardno; The National Center for Computational Hydroscience at the University of Mississippi; and Dr. Kit Choi, PE. Field support also provided by New England Environmental. Study team was approved by MADEP prior to the study commencing

Work Completed

- All tasks identified in the RSP and addendum to the RSP have been completed

Variances

- Supplemental boat wave data collection and analysis (discussed at 2015 USR meeting)

Study Objectives

- Primary goal of the study was to evaluate and identify the causes of erosion in the Turners Falls Impoundment and to determine to what extent they are related to Project operations.
- In order to accomplish this goal a number of objectives were identified:
  1. Conduct a thorough data gathering and literature review effort of existing relevant data to identify data gaps
  2. Conduct field investigations and field data collection to fill data gaps. Gather the field data required to conduct detailed analyses of the causes of erosion and forces related to them
  3. Develop an understanding of the historic and modern geomorphology of the Connecticut River to provide context when analyzing the modern geomorphology
  4. Identify the causes of erosion present in the Turners Falls Impoundment, the forces associated with them, and their relative importance at a particular location. Conduct various data analyses to gain a better understanding of these causes and forces
  5. Identify and establish fixed riverbank transects that will be representative of the range of riverbank features, characteristics, and conditions present in the Turners Falls Impoundment
  6. Conduct detailed studies and analyses of erosion processes at the fixed riverbank transects
  7. Evaluate the causes of erosion using the field collected data and the results of the proposed data analyses. This evaluation will include quantifying and ranking all causes present at each fixed riverbank transect as well as in the Turners Falls Impoundment in general
  8. Develop a final report that will summarize the findings of this study and the methods used

3.1.2 Erosion Causation Report

Potential Primary Causes of Erosion Assessed *(per the RSP)*

- Land management practices and anthropogenic influences
- Ice*
- Hydraulic Shear Stress due to flowing water
- Water level fluctuations due to hydropower operations
- Boat waves

** Originally classified as a potential secondary cause of erosion prior to the closure of Vermont Yankee*

Potential Secondary Causes of Erosion Assessed *(per the RSP)*

- Animals
- Wind waves
- Seepage and piping
- Freeze-thaw

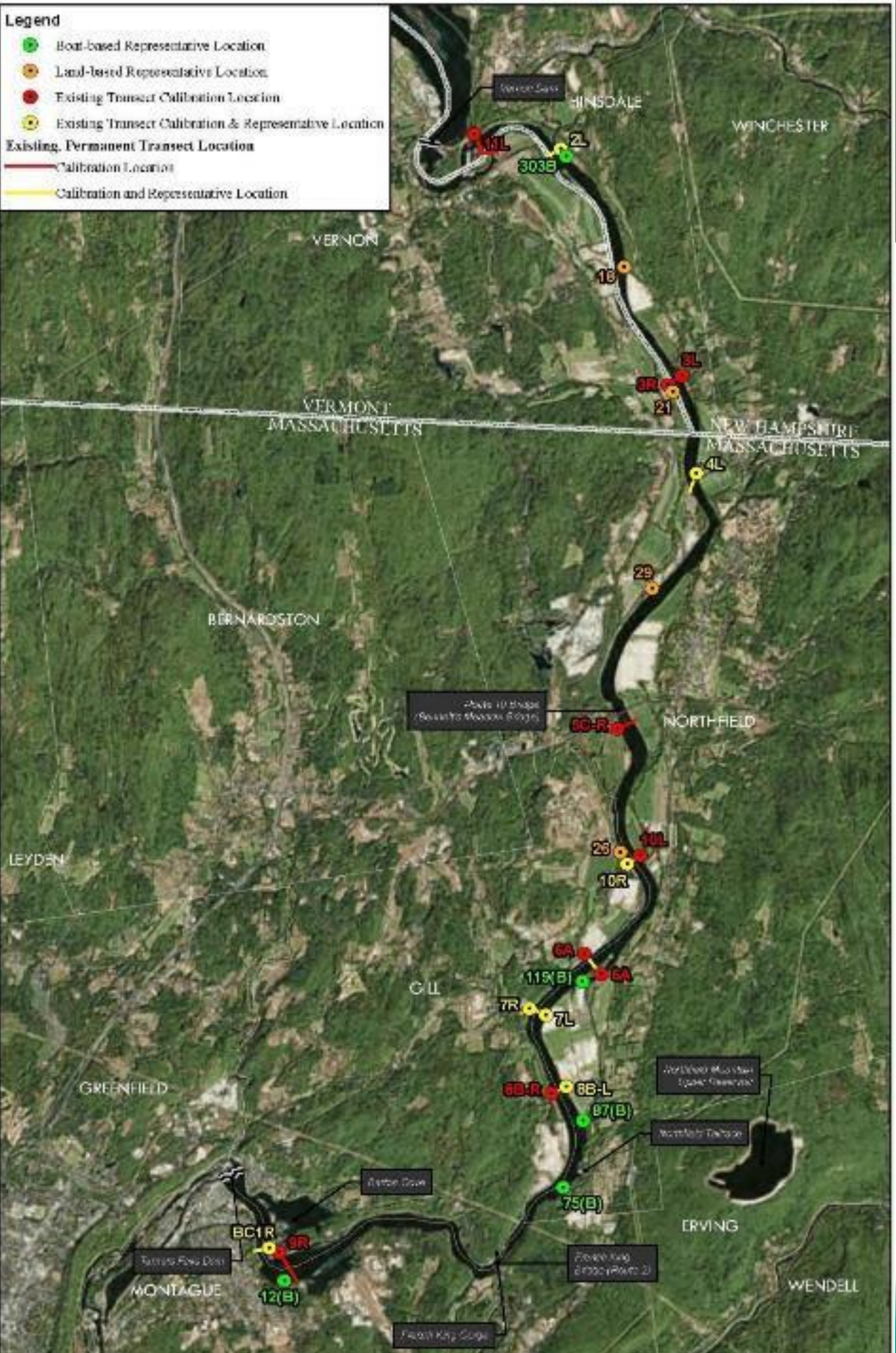
3.1.2 Erosion Causation Report

Data Analyses

- Historic geomorphic assessment and analysis of historic datasets
- Hydrology and hydraulics
  - Hydraulic shear stress, water level fluctuations, energy grade line slope, flow thresholds, etc.
- Near-bank groundwater and pore-water pressure
- Sediment transport
- Geotechnical evaluations
- Hydraulic and geotechnical erosion processes
- Boat waves – physical processes and their impact
- Land management practices
- Ice

Tools Used

- Historic imagery, photos, and documentation
- Various field data collection methods, equipment, and instruments
- Cross-section surveys, Project operations data, hydrologic data – 2000-2014
- HEC-RAS
- River2D
- Bank Stability and Toe Erosion Model (BSTEM)
- GIS – Digital elevation Models, LiDAR, aerial imagery, and other layers



3.1.2 Erosion Causation Report

Detailed Study Sites

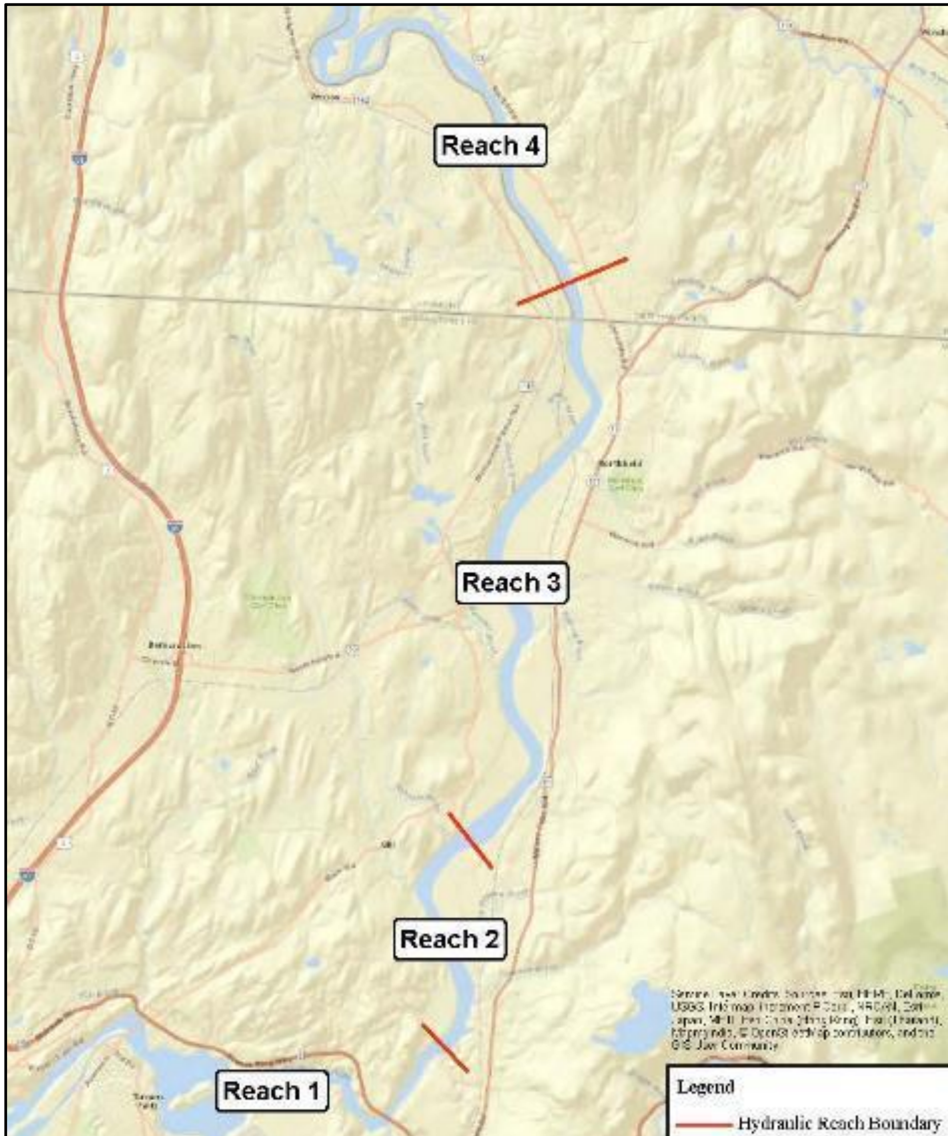
- Selected in collaboration with stakeholders, presented in *Selection of Detailed Study Sites Report* (September 2014)
- 25 sites spanning the geographic extent of the TFI
- Encompassed a representative range of riverbank features, characteristics, erosion conditions, and hydraulic characteristics
- Included both restored and non-restored sites
- Located at sites which have been surveyed annually since the 1990’s (16) and newly identified sites (9)
- Classified as either Calibration or Representative sites
- The potential primary causes of erosion, and the forces associated with them, were analyzed in-depth at each site (i.e., extensive field data collection, hydraulic and BSTEM modeling)
- Results were then extrapolated throughout the TFI

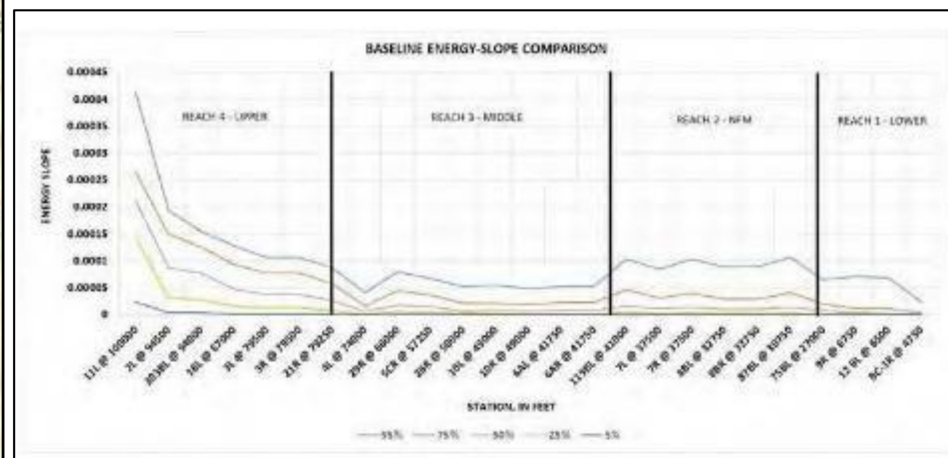
FirstLight Power Resources

Hydrology & Hydraulics – Key Findings

- The generating capacity of Vernon is 17,130 cfs, NFM is 20,000 cfs (4 units gen) or 15,200 cfs (4 units pump), and Turners Falls is 15,938 cfs
- At flows greater than ~30,000 cfs the French King Gorge becomes the primary hydraulic control for the middle and upper portion of the TFI
- Four hydraulic reaches were identified based on analysis of the Energy Grade Line Slope (HEC-RAS):
  - Lower Reach (Reach 1)
  - Northfield Mountain Reach (Reach 2)
  - Middle Reach (Reach 3)
  - Upper Reach (Reach 4)
- Although hydropower project operations can impact flows and water levels beyond their given hydraulic reach, the impacts at flows which cause erosion (as determined by BSTEM) are minor enough that they do not alter the EGL slope, and therefore the velocity or shear stress, outside of their reach
- The results of the hydraulic and BSTEM modeling indicated that hydropower operations can only potentially impact erosion processes within the hydraulic reach where the project is located due to the varying hydraulic characteristics of the TFI
  - In other words, the models showed that Vernon operations can only potentially impact erosion in Reach 4, NFM operations in Reach 2, and Turners Falls operations in Reach 1

3.1.2 Erosion Causation Report





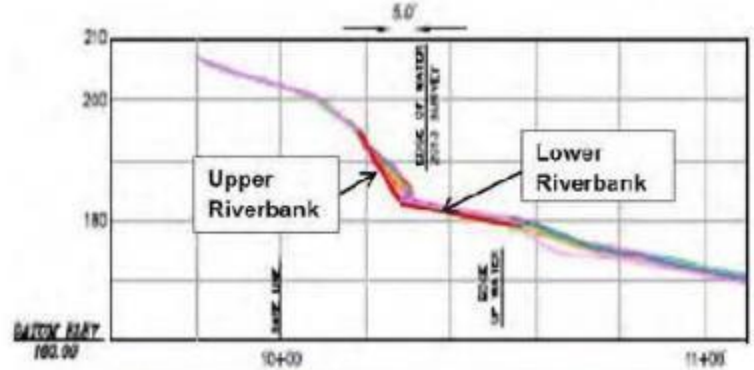
Hydrology & Hydraulics – Key Findings (cont.)

- Three flow ranges present in Reaches 1-3: (1) <17,130 cfs (low flow), (2) 17,130 - 37,000 cfs (moderate flow), and (3) >37,000 cfs (high flow)
  - In Reach 4 (Upper) only two flow ranges were identified: <17,130 cfs (low to moderate) and >17,130 cfs (moderate to high). This was based on the generating capacity of Vernon.
- 37,000 cfs was identified as the high flow threshold for a number of reasons, including:
  - It exceeds the flows at which the French King Gorge becomes the hydraulic control
  - It exceeds the generating capacity of Vernon
  - It exceeds the maximum combined generating capacity for Vernon and NFM at a given location
  - Although NFM can operate at flows >37,000 cfs, historical operating records indicate this only occurred 0.025% (4 units gen) to 2.6% (1 unit gen) of the time during the 15-year modeling period.
- During high flows, the dominant impact on flow and water level is naturally occurring flows, not hydropower operations

3.1.2 Erosion Causation Report

Hydrology & Hydraulics – Key Findings (cont.)

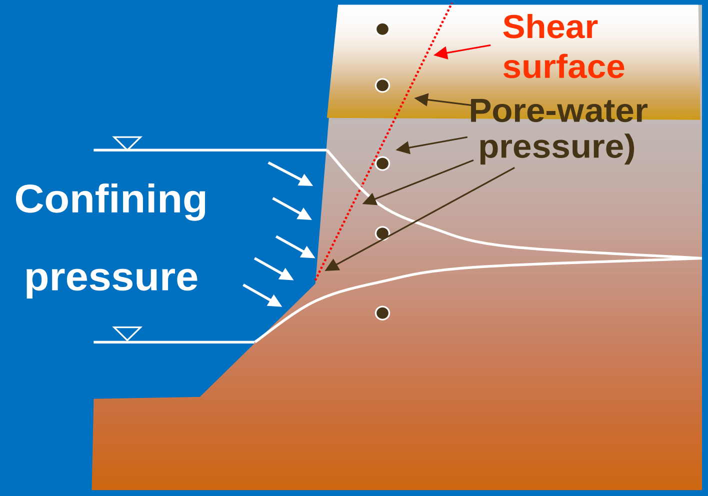
- The results of the study found that the vast majority of erosion only occurs once the water level reaches the upper riverbank
- Water levels rest on the lower bank 78% to 99% of the time depending on the location in the TFI.
- The flows required for the water level to reach the upper bank, and for the majority of erosion to occur, are often greater than the natural high flow threshold (37,000 cfs)
  - Based on the results of the BSTEM flow analysis (50% and 95% erosion flow thresholds), 50% of all erosion occurred at flows much greater than 37,000 cfs for 22 of the 25 simulations which were analyzed. Minimal to no erosion was found to occur at the three other sites.
  - Modeling results also indicated that 95% of all erosion occurred at flows greater than 37,000 cfs for the majority of detailed study sites

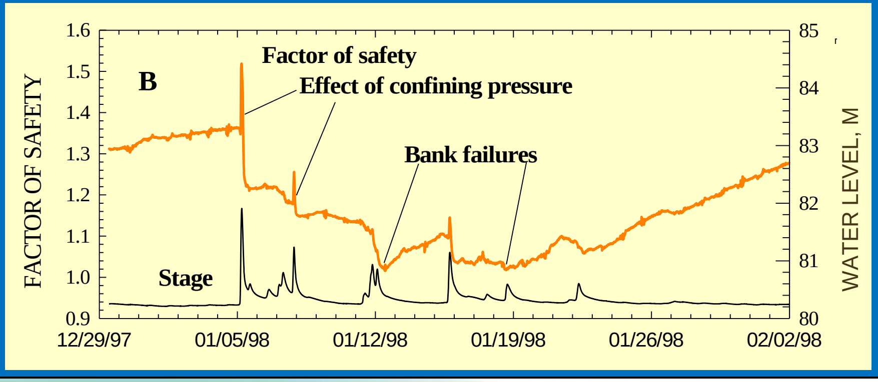


Application of BSTEM-Dynamic Ver. 2.3

- 2-D wedge- and cantilever-failures
- Search routine for failures
- 15-year flow series (1-hour time steps) for stage and water-surface slope
- Hydraulic toe erosion
- Accounts for grain roughness
- Hydraulic roughness by layer
- Complex bank geometries
- Positive and negative pore-water pressures
- Fluctuating groundwater levels
- Confining pressure from flow
- Layers of different strength
- Vegetation effects: RipRoot
- Boat waves
- Inputs from field measurements:

γ_s, c', ϕ', ϕ^b, h, u_w, k, τ_c





3.1.2 Erosion Causation Report

Determination of Primary Causes of Erosion

- **Moderate or High Flows** *(hydraulic shear stress due to flowing water)*: flow analysis which resulted in identification of the erosion flow threshold at which 50% and 95% of all erosion occurs at a given site.

- **Boats** *(boat waves)*: BSTEM was enhanced with a built-in boat wave module for this study. Two BSTEM runs were executed – boat waves "on" and boat waves "off". The difference in observed erosion between the two model runs determined the sites where boat waves were a cause of erosion

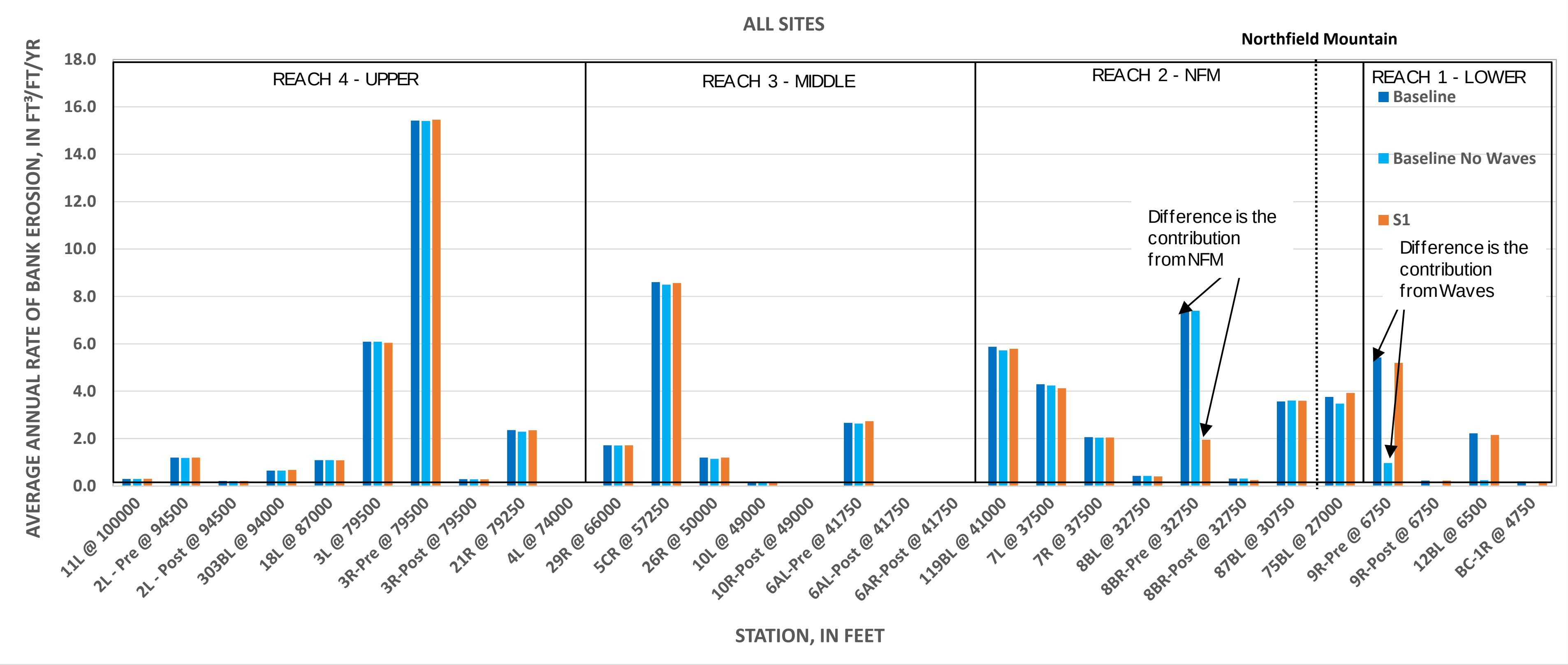
- **Vernon Operations** *(hydraulic shear stress due to flowing water, water level fluctuations due to hydropower operations)*: the results of the flow analysis were used to identify areas within the Upper Reach where erosion was observed at flows below 17,130 cfs

- **Northfield Mountain Operations** *(hydraulic shear stress due to flowing water, water level fluctuations due to hydropower operations)*: two BSTEM runs were executed, one representing the Baseline Condition and one representing NFM as idle. The difference in observed erosion between the two model runs determined the sites where NFM operations were a cause of erosion

- **Turners Falls Operations** *(hydraulic shear stress due to flowing water, water level fluctuations due to hydropower operations)*: modified extrapolation approach which utilized a combination of BSTEM results, geomorphic assessment, and hydraulic model analysis

3.1.2 Erosion Causation Report

BSTEM Results



3.1.2 Erosion Causation Report

Study Findings – Dominant Causes

- Dominant Primary Cause of Erosion: the cause of erosion responsible for greater than 50% of erosion at any given site.
- Study results found that naturally occurring high flows were the most prevalent dominant primary cause of erosion, followed by boat waves, and Vernon operations
- Northfield Mountain or Turners Falls Operations were not found to be a dominant primary cause of erosion at any riverbank segment
  - NFM operations contributed to less than 5% of the total erosion at 5 of the 7 sites in the NFM Reach
  - At Site 8BR-Post, NFM operations contributed to ~20% of the total erosion (0.312 $ft^3/ft/yr.$)
  - At Site 8BL, NFM operations contributed to ~7% of the total erosion (0.427 $ft^3/ft/yr.$)
- Dominant primary causes of erosion followed a clear spatial pattern
  - Vernon Operations: Vernon Dam to Stebbins Island
  - Natural High Flows: Stebbins Island to upstream of the entrance to Barton Cove
  - Boat Waves: upstream of the entrance to Barton Cove to Turners Falls Dam

Dominant Primary Causes of Erosion	% of Total Riverbank Length	Total length
Natural High Flows	78%	175,900 ft. (33 mi.)
Boat waves	13%	30,800 ft. (6 mi.)
Vernon Operations	9%	20,200 ft. (4 mi)
Northfield Mountain Operations	0%	0 ft.
Turners Falls Operations	0%	0 ft.
Ice	I	I

I = Indeterminate

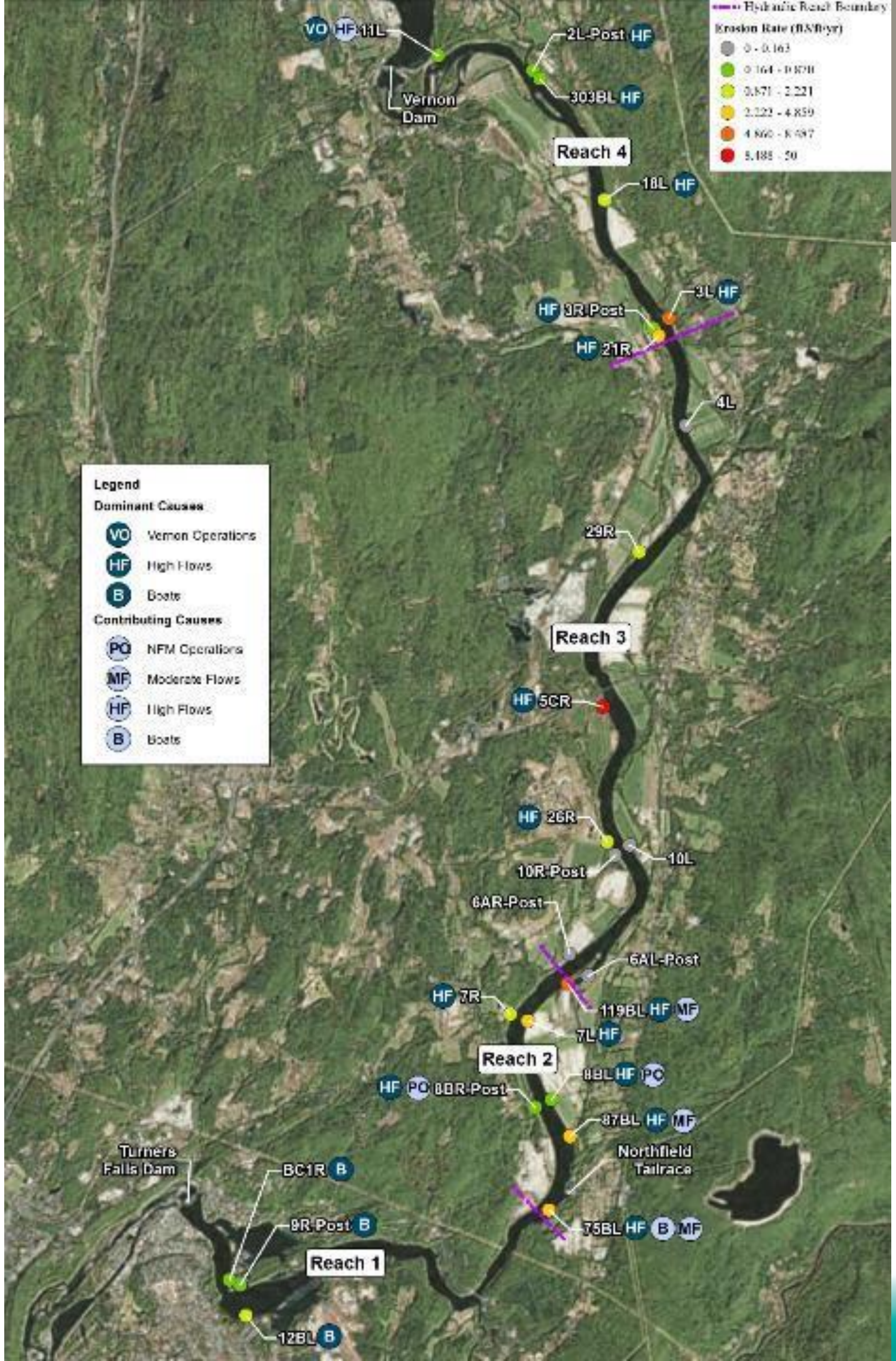
3.1.2 Erosion Causation Report

Study Findings– Contributing Causes

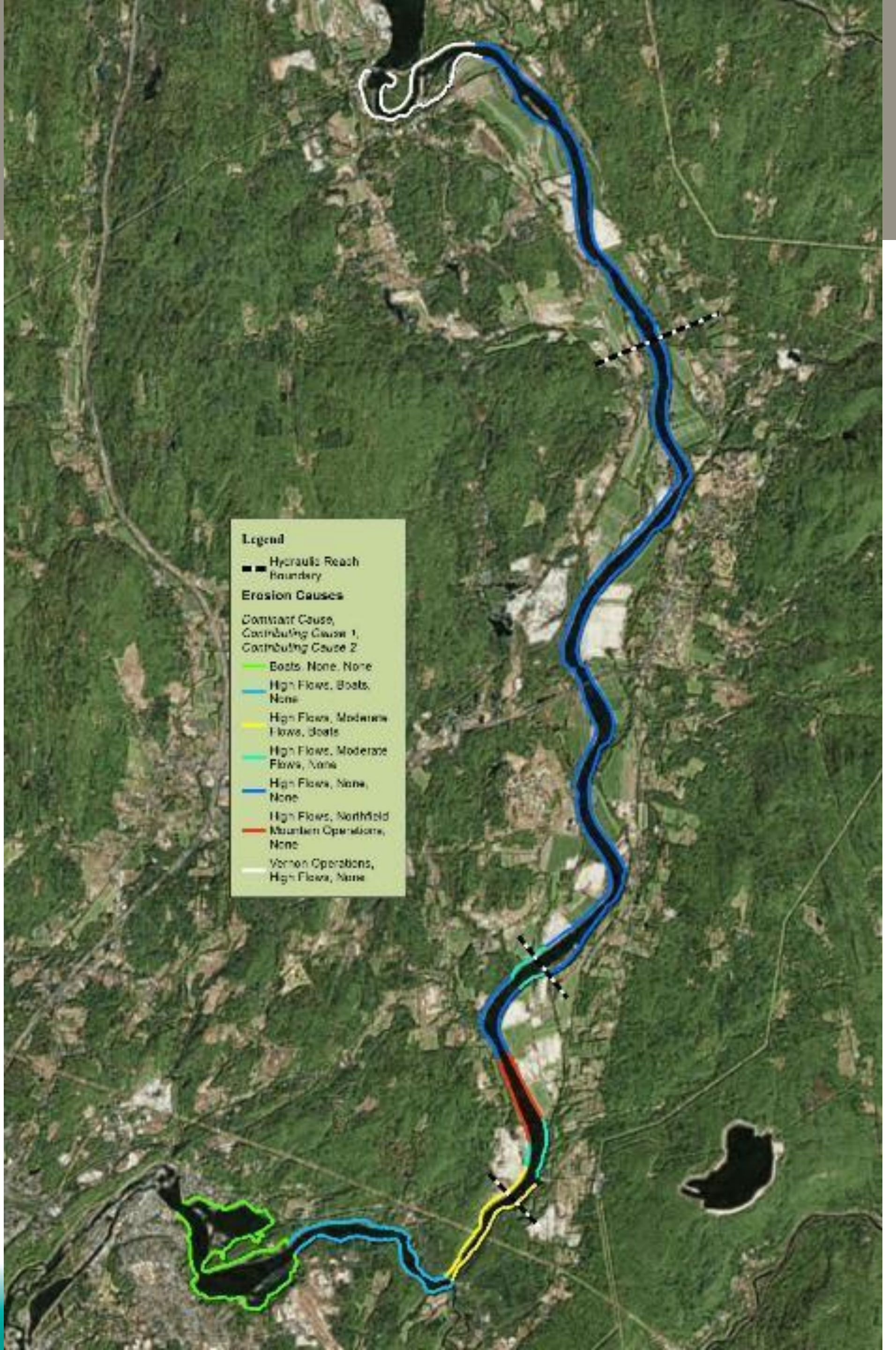
- Contributing Primary Cause of Erosion: the cause(s) of erosion responsible for greater than 5%, but less than 50%, of erosion at any given site.
- Natural high flows were such a dominant factor in erosion processes that no other contributing primary causes of erosion were identified at the majority of riverbank segments
- At riverbank segments that did have contributing primary causes of erosion, boat waves were most prevalent followed by natural moderate flows and Northfield Mountain operations
- Vernon or Turners Falls operations were not found to be contributing causes of erosion at any riverbank segment
- Land-use was found to be a potential contributing cause of erosion at 44% of the riverbank segments
- Secondary causes of erosion (i.e., animals, wind waves, etc.) were not found to be a dominant or contributing cause at any riverbank segment

Contributing Primary Causes of Erosion	% of Total Riverbank Length	Total length
None	68%	153,400 ft. (29 mi.)
Boats	16%	36,000 ft. (7 mi.)
Natural Moderate Flows	10%	23,200 ft. (4 mi.)
Natural High Flows	9%	20,200 ft. (4 mi.)
Northfield Mountain Operations	4%	8,600 ft. (1.5 mi.)
Vernon Operations	0%	0 ft.
Turners Falls Operations	0%	0 ft.
Ice	I	I

I = Indeterminate



Hydraulic Reach Boundary
Erosion Rate
0 - 0.163
0.871 - 2.221
2.222 - 4.859
VO HF 11L
2L-Post HF
303BL HF
Vernon Dam
Reach 4
18L HF
3L HF
HF 3R Post
HF 21R
4L
Legend
Dominant Causes
VO Vernon Operations
HF High Flows
B Boats
Contributing Causes
PO NFM Operations
MF Moderate Flows
HF High Flows
B Boats
29R
Reach 3
HF 5CR
HF 26R
10L
10R-Post
6AR-Post
6AL-Post
119BL HF MF
HF 7R
7L HF
Reach 2
8BL HF PO
HF PO 8BR-Post
87BL HF MF
Northfield Tailrace
Turners Falls Dam
BC1R B
9R Post B
75BL HF B MF
Reach 1
12BL B



Legend
Hydraulic Reach Boundary
Erosion Causes
Boats, None, None
High Flows, Boats, None
High Flows, Moderate Flows, Boats
High Flows, Moderate Flows, None
High Flows, None, None
High Flows, Northfield Mountain Operations, None
Vernon Operations, High Flows, None

3.1.2 Erosion Causation Report

Extrapolation Methodology

- Multi-step process used to extrapolate the results of the detailed study sites to every riverbank segment identified during the 2013 Full River Reconnaissance
- Steps included:

1. **Analyze the variability of hydraulic forces throughout the TFI**
2. **Analyze and review the site specific BSTEM results**
3. **Analyze riverbank features, characteristics, and erosion conditions**
   a) Identify the detailed study sites where hydropower operations were the dominant or contributing cause of erosion
   b) Identify the riverbank features, characteristics, and erosion conditions at those sites based on the 2013 FRR
   c) Identify other segments in the hydraulic reach that have the same features or characteristics
   d) Compare the locations of those segments against (1) the results of the nearest detailed study site, and (2) the hydraulic and geomorphic conditions at each location to determine if the riverbank features and characteristics or the hydraulics/geomorphology are the likely factors influencing erosion
4. **Assign the dominant and contributing causes of erosion to each riverbank segment identified during the 2013 FRR:**
   a) Identify sites where hydropower operations were found to be a dominant or contributing cause of erosion based on Steps 3c and 3d
   b) Extrapolate the results from a given detailed study site, halfway upstream and halfway downstream to the nearest detailed study site
5. **Conduct supplemental hydraulic and geomorphic analyses in Reach 1 to determine the impact, if any, of Turners Falls operations**
6. **Analyze land-use and width of riparian buffers**
7. **Create a map identifying the cause of erosion for each segment and calculate summary statistics**

3.1.2 Erosion Causation Report

Ice

- The closure of Vermont Yankee increases the potential for ice formation in the Turners Falls Impoundment
- Included historic analysis of ice formation and break-up in the TFI, upstream impoundments, and other river systems and observations of ice formation and break-up in the TFI during winter 2014/2015
- The impact of ice on erosion processes was not quantified as it was not a cause of erosion examined in BSTEM
- The results of the various analyses and observations found that:
  - Ice typically does not cause erosion if it simply melts in place without significant break-up and if ice floes moving down river causing ice jams and impacting banks do not occur. This is consistent with the findings of the historic analysis conducted and with observations made during the winter 2014/2015 when much of the TFI was frozen over
  - If there is significant break-up and ice floes moving down river occur, then such an event could potentially cause erosion and damage to the riverbanks
  - Analysis of historic data from the TFI and upstream impoundments found that ice has caused severe erosion under the right conditions (i.e., severe break-up, ice floes, and ice jams) and has contributed to bank instability which can eventually lead to erosion
  - These processes can also greatly effect riverbank vegetation thus also impacting the stability of the bank.
  - Available information and observations indicate that Project operations do not cause an ice break-up event to occur, as ice break-up events occur as a result of weather and hydrologic conditions which are independent of Project operations
- Based on the results of the analysis which was conducted, ice has the potential to be a naturally occurring dominant primary cause of erosion in the TFI in the future if the right weather and hydrologic conditions persist.

3.1.2 Erosion Causation Report

Land Management Practices

- Investigation included field observations and geospatial analysis of land management practices and anthropogenic influences to the riparian zone throughout the TFI
- Although a variety of land-uses are found along the banks adjacent to the TFI, the strongest correlations between land-use and erosion have been observed in agricultural or developed areas
- Agricultural land-use practices can lead to erosion or bank instability due to the narrow riparian buffers that often exist at these fields as well as irrigation practices which may be employed
- Erosion has also been observed in areas where houses and other associated development are located in close proximity to the river
- Areas where the riparian buffer was found to be less than 50 ft. and the adjacent land-use was classified as Agriculture or Developed were identified in order to determine the potential impact land management practices may have on erosion processes. Segments that met this criteria were classified as being a potential contributing cause of erosion.
  - The results of this analysis found that 44% of the TFI riverbanks (19 mi.) met this criteria
- In addition, BSTEM's RipRoot sub-model also analyzed the impact of vegetation on bank stability throughout the TFI

3.1.2 Erosion Causation Report

Summary

- The study was conducted in accordance with the RSP and satisfied all study objectives
- The unique and varying hydraulic characteristics of the TFI play an integral role in erosion processes
- NFM or Turners Falls Project operations were not found to be a dominant primary cause of erosion at any riverbank segment in the TFI
- NFM operations were found to be a contributing primary cause of erosion at two detailed study sites in the NFM Reach (4% of total riverbank length). Turners Falls operations were not found to be a contributing primary cause of erosion at any riverbank segment in the TFI
- Naturally occurring high or moderate flows were found to be the dominant primary cause of erosion throughout the vast majority of the TFI
- Boat waves were found to be the dominant primary cause of erosion in the Barton Cove area
- Ice has the potential to be a naturally occurring dominant primary cause of erosion in the TFI in the future if the right weather and hydrologic conditions persist
- Potential secondary causes of erosion (i.e., wind waves, animals, etc.) were found to be insignificant in causing erosion in the TFI beyond the limited, localized areas where they may exist

Recreation

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Study Objective

Determine if the operation of the Northfield Mountain Project and Turners Falls Project has an effect on recreation facilities or land use within either Project and down to the Sunderland Bridge

Note: While consideration of Project operational effects on land use was included in the objectives statement of this study, this assessment focused on project operational effects, primarily water levels and flows, on recreation sites and facilities. Land use effects were considered in studies 3.1.2 (Erosion Causation Study), 3.1.1 (River Reconnaissance) and 3.6.5 (Land Use Inventory)

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Background

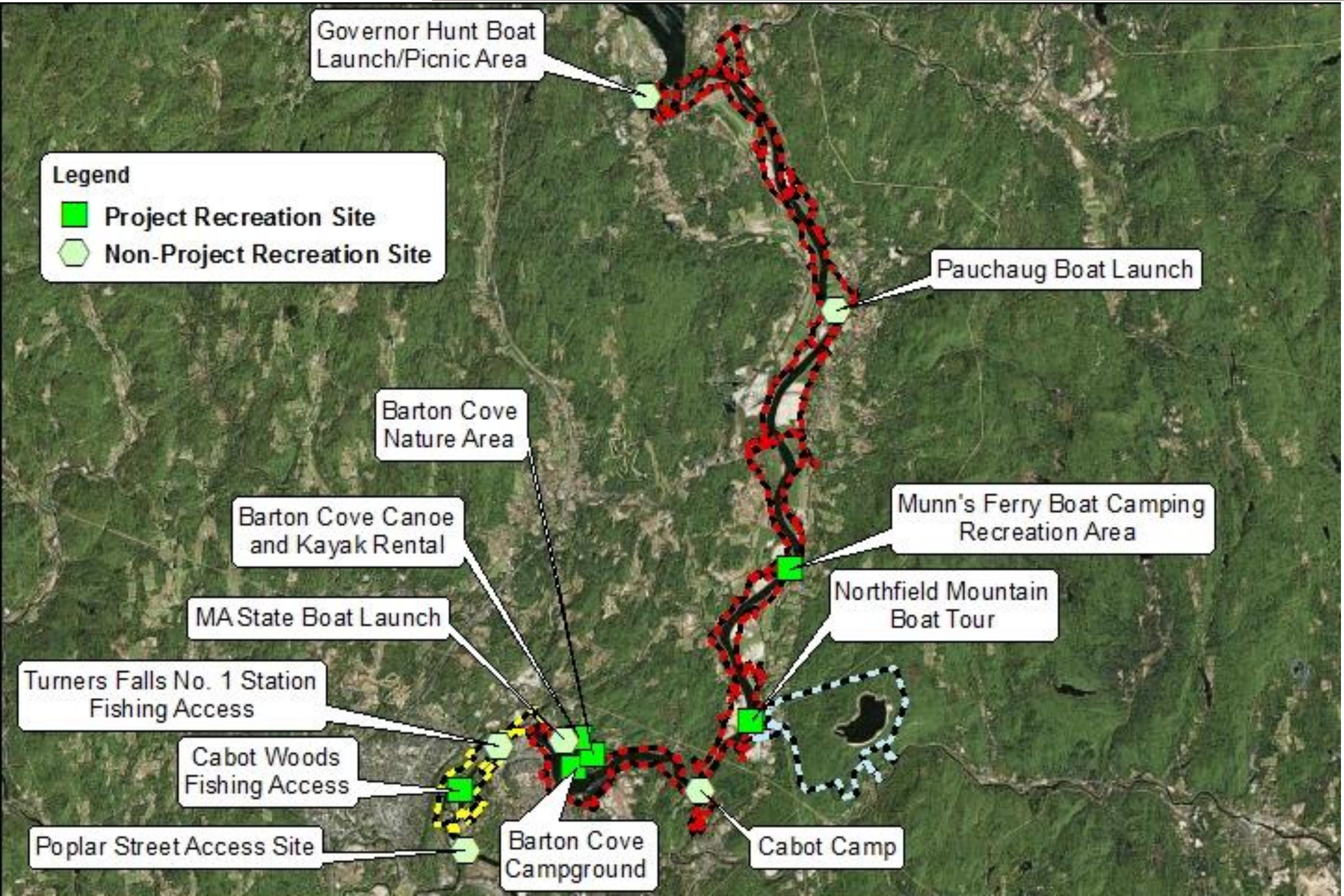
- Study Scope – lands and waters within the Project boundaries, as well as the Connecticut River from the Project downstream to the Sunderland Bridge

- Recreation Sites Assessed – sites providing water access

Table 2-1 Recreation Sites Assessed

Recreation Site	Waters Accessed
Governor Hunt Boat Launch/Picnic Area	Vernon Project Tailwater/ Turners Falls Impoundment
Pauchaug Boat Launch	Turners Falls Impoundment
Munn's Ferry Boat Camping Recreation Area	Turners Falls Impoundment
Boat Tour and Riverview Picnic Area	Turners Falls Impoundment
Cabot Camp Access Area	Turners Falls Impoundment
Barton Cove Nature Area and Campground	Turners Falls Impoundment
Barton Cove Canoe and Kayak Rental Area	Turners Falls Impoundment
State Boat Launch	Turners Falls Impoundment
Turners Falls Station No. 1 Fishing Access	Turners Falls Bypass
Cabot Woods Fishing Access	Turners Falls Bypass
Poplar Street Access Site	Connecticut River
Sunderland Bridge Boat Launch	Connecticut River

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Methods

Reviewed results of other recreation studies:

- Study No. 3.6.1 *Recreation Use/User Contact Survey;*
- Study No. 3.6.2 *Recreation Facilities Inventory and Assessment* ;
- Study No. 3.6.3 *Whitewater Boating Evaluation*;
- Study No. 3.6.4 *Assessment of Day Use and Overnight Facilities Associated with Non-Motorized Boats*; Study No. 3.6.7 *Recreation Study at Northfield Mountain, including Assessment of Sufficiency of Trails for Shared Use*.

Reviewed other studies that contained information relevant to evaluating potential operational effects on recreation sites and facilities that provide water access.

- Study No. 3.2.2 *Hydraulic Study of Turners Falls Impoundment, Bypass Reach and below Cabot Station*;
- Study No. 3.3.1 *Instream Flow Studies in Bypass Reach and below Cabot Station;*
- Study No. 3.3.9 *Two-Dimensional Modeling of the Northfield Mountain Pumped Storage Project Intake/Tailrace Channel and Connecticut River Upstream and Downstream of the Intake/Tailrace*;
- Study No. 3.1.2 *Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability.*

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Methods

Hydraulic models developed as part of the other studies were used to evaluate the range of water levels, flow velocities and flow direction associated with Project operation at/near each recreation site/facility:

- HEC-RAS model developed Turners Falls Impoundment (TFI) from the Turners Falls Dam to the Vernon Dam (“TFI hydraulic model”) (Study No. 3.2.2)
- HEC-RAS model of the Connecticut River from the United States Geological Survey Gage (USGS, Gage No. 01170500) in Montague to the Holyoke Dam (“Montague hydraulic model”) (Study No. 3.2.2)
- Turners Falls bypass reach hydraulic models developed as part of the instream flow study (Study No. 3.3.1).
- River2D 2-dimensional hydraulic model developed for the TFI around the Northfield Mountain Project intake and tailrace channel (Study No. 3.3.9)

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Methods

- Each water access site/facility was evaluated based on hydraulic conditions at the closest modeled transect.

- Assumptions were made regarding the minimum water depth required for the site/facility to remain operational and meet its intended recreation purpose

    - 3 ft water depth for launching trailered watercraft (motor boats) (SOBA, 2006)
    - 2 ft water depth for launching carry-in watercraft (canoes, kayaks, etc.)

- Recreation user survey results (Study No. 3.6.1) were examined individually, to discern what recreation users had to say about the effects of Project operations (primarily water levels), on the usability of a particular recreation site/facility.

- Observations of recreation site/facility conditions under a variety of conditions were gathered from a variety of sources, including observations made by FirstLight during the 3.6.2 Recreation Inventory Study, follow-up reconnaissance of recreation sites/facilities, and personal communication with recreation site managers including FirstLight and MA DFG.

- Emergency response managers were contacted to get more detailed information regarding their use of Project recreation sites/facilities for water rescue efforts.

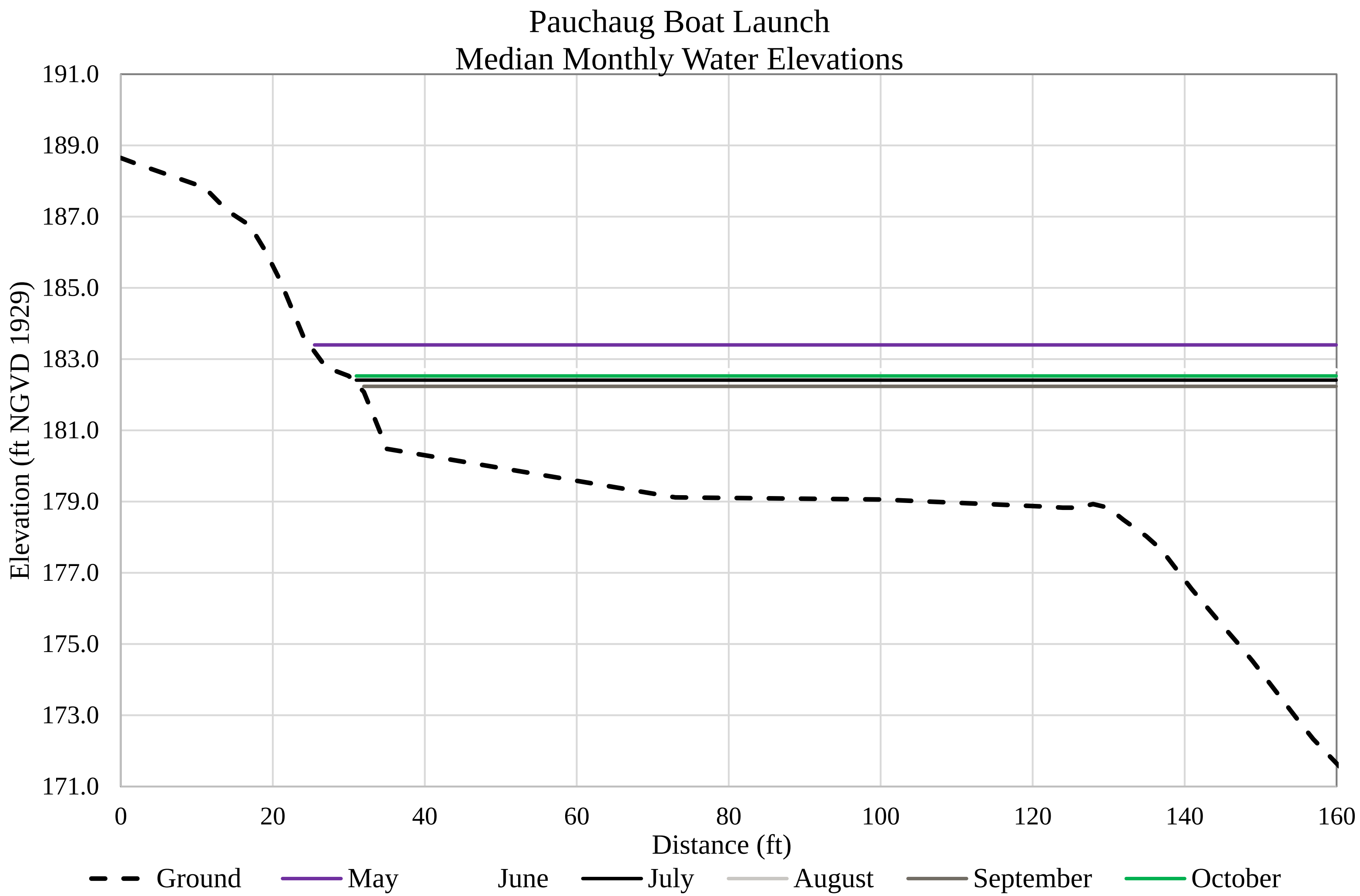
3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Results

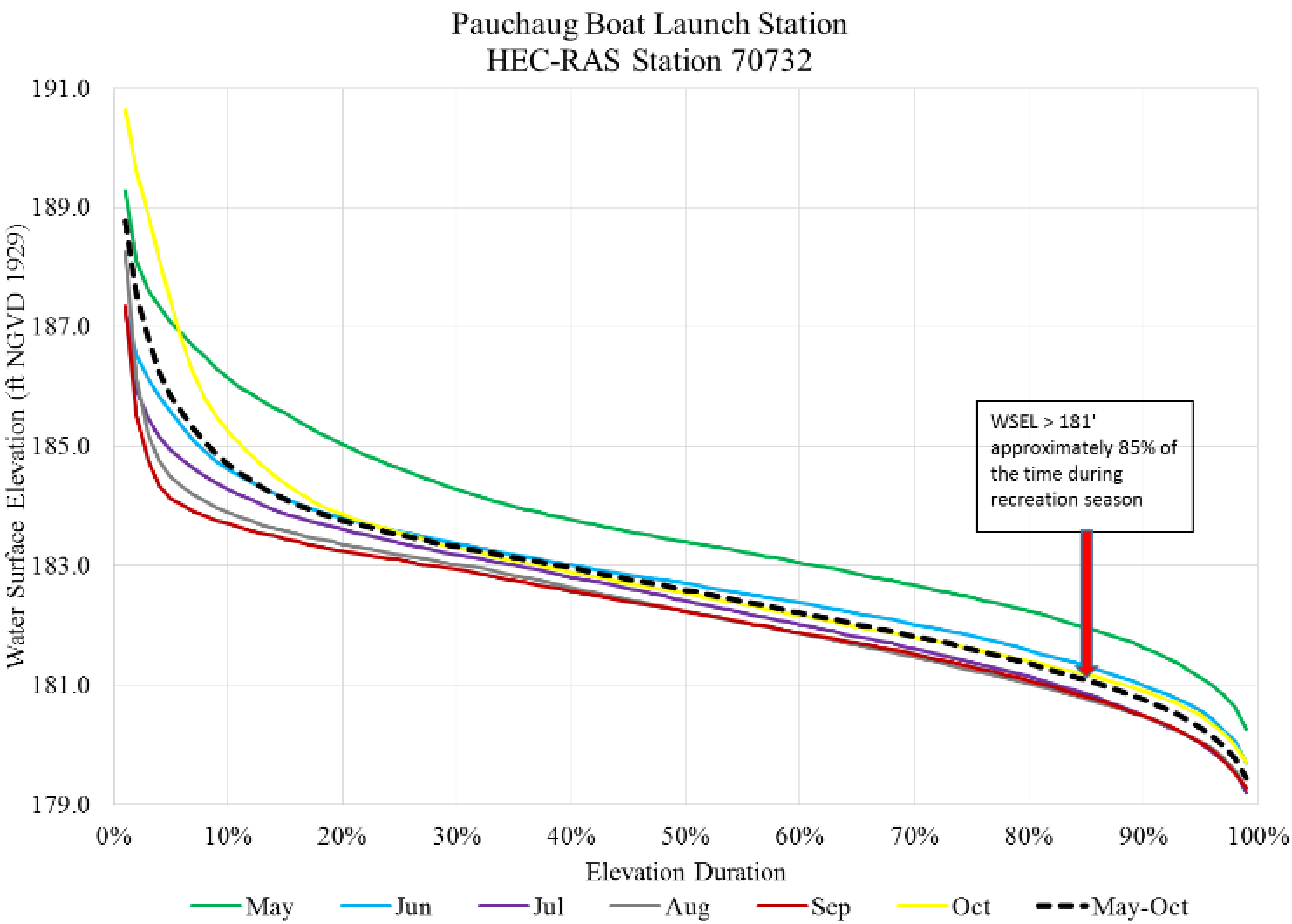
Example - Pauchaug Boat Launch

- Located on south side of Pauchaug Brook– in a narrow cut along a relatively flat, low-lying portion of the river bank
- Owned, operated, and maintained by MA DFG
- Suitable for launching small-moderate power boats, carry-in paddlecraft
- End of boat ramp estimated to be at elevation 178’
- Water surface elevation (WSEL) of 181’ or greater needed for boat ramp to have 3’ water depth for launching

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Results

Example - Pauchaug Boat Launch Results

Water depths at the end of Pauchaug Boat Launch are **3 feet or greater**:

- May 95%
- June 90%
- July 82%
- August 80%
- September 81%
- October 88%.boat

Water depth needed for Northfield Fire Dept rescue boat launching is 2 feet (el 180’). 2 ft water depth available 95-100% of the time throughout the recreation season.

The launch is susceptible to sediment accumulation generally during naturally occurring high spring flows. On an as-needed basis, MADFG clears/plows the launch ramp of sediment that accumulates during seasonal high flows, and excavates accumulated sediment at the end of the ramp to keep the channel open.

Review of 63 recreation user surveys from this site found 11 respondents indicated concerns with “mud”, several indicated the launch ramp was “muddy” due to sedimentation. A few indicated the ramp was slippery and difficult to traverse due to mud. One respondent commented “dredge the boat ramp”.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Conclusions

Example - Pauchaug Boat Launch Results

- Launch has sufficient water depth (WSELs > 181’) for small-moderate power boats and hand-carry paddlecraft from 80% (August) of the time to 95% (May) of the time during the recreation season (May-October).

- WSELs of < 181’ have the potential to affect use of this site by making it more difficult to launch trailerable boats, although canoes and kayaks can still be launched. WSELs of < 181’ occur anywhere from 5% of the time (May) to 20% of the time (August).

- Launch has sufficient water depth for emergency rescue craft use 95-100% of the time (May-October).

- Sedimentation also periodically interferes with the usability of Pauchaug Boat Launch. The ramp is susceptible to sedimentation during seasonal high river flows because of its location within a relatively narrow cut in the river bank, just downstream from the Pauchaug Brook confluence, and its orientation to prevailing river currents.

- MADFG clears/plows accumulated sediment from ramp, on an “as needed” basis, usually following seasonal high flows. MADFG also excavates the end of the launch ramp on an “as-needed basis” to remove accumulated sediment from the end of the ramp, and to maintain the channel cut. FirstLight works cooperatively with MADFG on its excavation efforts by attempting the hold the TFI close to the lowest allowable elevation.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

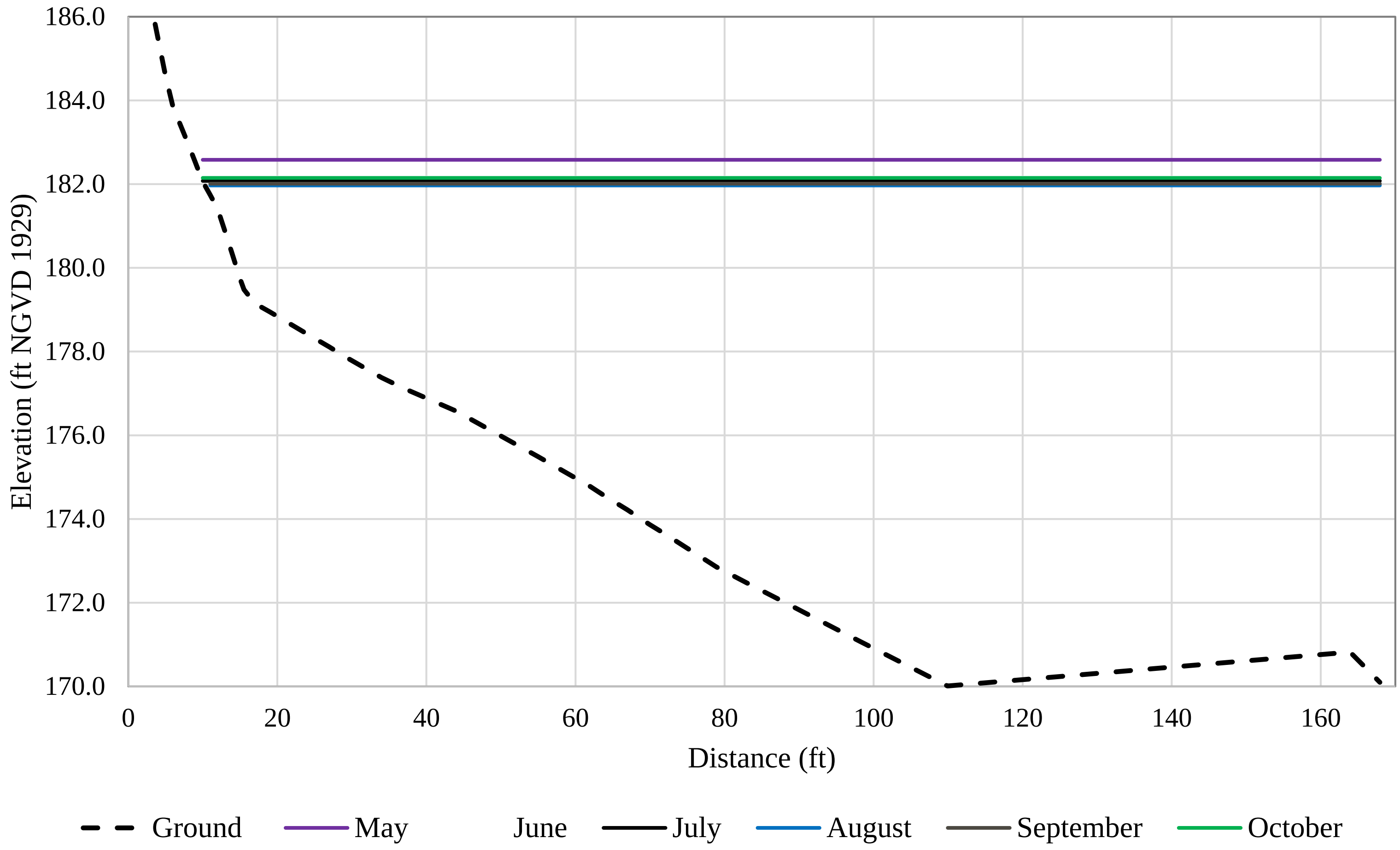
Results

Example – Riverview Boat Dock

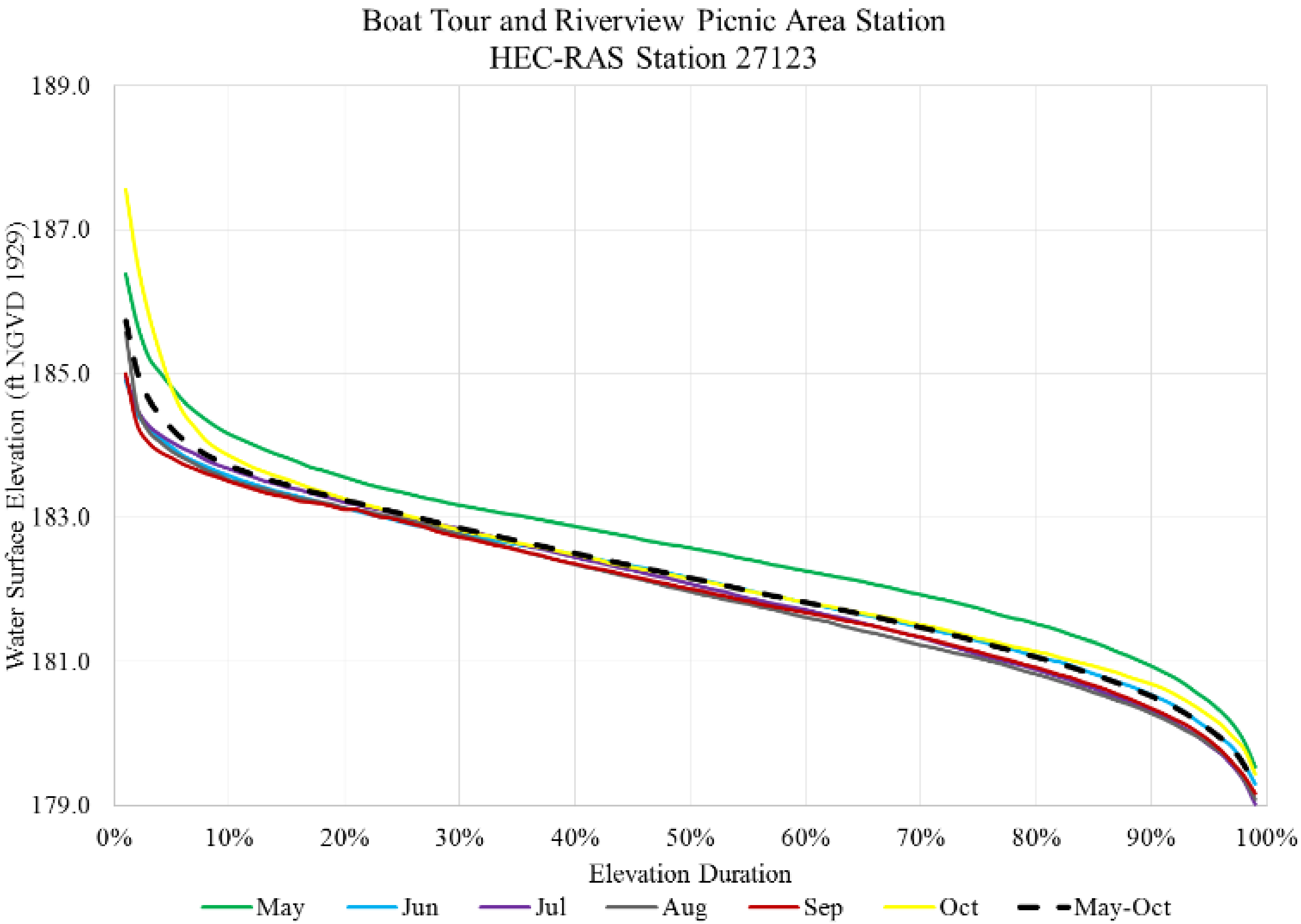
- Located on mid portion of TFI, immediately upstream of NM tailrace
- Owned and operated by FirstLight
- Suitable for docking Quinnetukut II (Q2) and small-moderate power boats
- Bottom elevation at end of boat dock estimated to be at elevation 172’
- Water surface elevation (WSEL) of 175’ or greater needed for boat dock to have 3 ft water depth for Q2 and other power boat use.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Boat Tour and Riverview Picnic Area
Median Monthly Water Elevations



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use



3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Results

Example – Riverview Boat Dock

- Water depth needed for Q2 boat docking is 3 feet or more.

- Water depths at the end of Riverview boat dock are greater than 3 feet 100% of the time throughout the recreation season.

- Review of River 2D hydraulic model results show that under the majority of operating conditions (60 combinations were modeled), river flow moves downstream at Riverview with an average channel velocity of 0-2 fps, and median of 0.5 fps; well within the Q2's safe operating range.

- 2D model results also show that when river flow is low, and Northfield Mountain is generating, the Riverview site may experience upstream flows ranging between 0-1 fps, and therefore do not impact the usability of the boat dock by Q2 or other powerboats.

- Review of 53 recreation user surveys from this site found 2 respondents indicated concerns with low water levels at this site. One was boating and indicated "water can be shallow at times". The other commenter was walking and indicated simply "shallow water". Nether commenter specifically indicated a problem with water levels on the use of the Riverview boat dock or other specific recreation activity at this site.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Conclusions

Example – Riverview Boat Dock

- Riverview Boat Dock experiences “None to Minimal” impacts from Project operations.
- At least 3 feet of water depth are maintained at the dock 100% of the time during the recreation season
- When river flow is low and Northfield Mountain is generating, the area experiences flow reversals as water moves upstream. However, upstream velocities are low and do not interfere with useabililty of the boat dock for Q2 or other power boats.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Recreation Site	Water Access Recreation Facilities/ Amenities	Water-based Recreation Uses	Project Operational Impacts
Governor Hunt Boat Launch/Picnic Area	Boat launch	Boating Fishing	**None**; the boat launch is located upstream of a hydraulic control, which limits the water surface elevation from falling below 181-ft
Pauchaug Boat Launch	Boat launch	Boating	**Moderate**; launch ramp use for small-moderate power boats and hand carry paddlecraft is affected at WSELs of < 181 feet. WSELs of < 181’ occur from 5 % (May) to 20 % (August) of the time during the recreation season (May-October). Launch also has sufficient water depth for emergency rescue craft 95% to 100% of the time (May-October).
Munn’s Ferry Boat Camping Recreation Area	Boat dock (floating)	Boating Fishing	**None**; WSEL of 167 feet is needed for docking power boats. The lowest allowable operating range for the TFI is elevation 176 feet. Thus, the WSEL at the boat dock is above 167 feet 100% of the time.
Boat Tour and Riverview Picnic Area	Boat dock (floating)	Riverboat cruise Boating Fishing	**None to minimal**; WSEL of 175 feet is needed for docking the QII; WSELs >175 feet 100% of the time during the recreation season (May-October); when river flow is low and Northfield Mountain is generating, the Boat Tour and Riverview Picnic Area is subject to flow reversals as water moves upstream. However the upstream velocities are low and do not interfere with the usability of the Riverview boat dock for the QII or other power boats

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Recreation Site	Water Access Recreation Facilities/ Amenities	Water-based Recreation Uses	Project Operational Impacts
Cabot Camp Access Area	None	Fishing	**None**; TFI shoreline remains fully accessible for bank fishing and those launching or retrieving canoes/kayaks under full range of allowable TFI elevations.
Barton Cove Nature Area and Campground	Boat dock (floating)	Fishing	**Minimal** water level impacts; floating boat dock adjusts with WSEL and remains useable at water levels of > 180 feet, which occur 89% to 93% of the time during the months of May through October.
Barton Cove Canoe and Kayak Rental Area	Canoe/Kayak launch	Canoeing/ Kayaking	**None**; the WSELs > 180 feet (2 foot depth) 90 % of the time during the recreation season (May-October); there may be infrequent occasions when a canoeist or kayaker would have to walk a short distance (approximately 15 to 30 feet) further to launch his/her craft at this site.
State Boat Launch	Boat launch	Boating Fishing	**Minimal** water level impacts; boat launch remains useable (3 foot depth at end of launch) at water surface elevations of > 179 feet, which occur 98 % to 99% of the time during the months of May through October. The launch has sufficient depth for emergency water craft 100% of the time between May and October.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Recreation Site	Water Access Recreation Facilities/ Amenities	Water-based Recreation Uses	Project Operational Impacts
Turners Falls Station No. 1 Fishing Access	None	Fishing	**Minimal** flow and water level impacts; Bypass reach shoreline remains accessible for bank fishing under a wide range of bypass flows; amount of available shoreline may diminish when flows exceed hydraulic capacity of the power canal.
Cabot Woods Fishing Access	None	Fishing	**Minimal** flow and water level impacts; Bypass reach shoreline remains accessible for bank fishing under a wide range of bypass flows. But recreation user safety may be impacted at higher bypass flows, particularly in the vicinity of Rock Dam.
Poplar Street Access Area	Canoe portage put-in	Canoeing/ Kayaking Fishing	**None**; River shoreline remains fully accessible for canoe/kayak put-in and take-out under the range of water surface elevations typically produced by normal Project operations.
Sunderland Bridge Boat Launch	Boat launch	Boating Fishing	**None**; Unimproved boat launch remains fully useable for small boat and canoe/kayak launching under the range of water surface elevations typically produced by normal Project operations.

3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use

Summary

- Turners Falls and Northfield Mountain Project operations have minimal or no impact on water based recreation facilities at most of the public recreation areas.

- Only one site, Pauchaug Boat Launch was found to be moderately impacted by Project operations due to insufficient water depths, but this site is still useable 86% of the time during the recreation season (May-Oct).

- The site also has sufficient water depths for launching emergency rescue craft nearly 100% of the time during the recreation season.

- The assessment was conducted in accordance with the RSP and satisfied all assessment objectives.