January 17, 2017

VIA ELECTRONIC FILING

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

Re: FirstLight Hydro Generating Company, Turners Falls Hydroelectric Project (FERC No. 1889) and Northfield Mountain Pumped Storage Project (FERC No. 2485).
Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary

Dear Secretary Bose:

Pursuant to the regulations of the Federal Energy Regulatory Commission (Commission or FERC), Title 18 Code of Federal Regulations (18 C.F.R.) § 5.15(f), FirstLight Hydro Generating Company (FirstLight) encloses for filing this response to comments on FirstLight's Study Reports and meeting summary for the relicensing of the Turners Falls Hydroelectric Project (TF Project, FERC No. 1889) and Northfield Mountain Pumped Storage Project (NMPS Project, FERC No. 2485). The current licenses for the TF and NMPS Projects expire on April 30, 2018.

On October 14, 2016, FirstLight filed 10 study reports (and three addendums[1]) with FERC as follows:

Table 1: Reports filed with FERC on October 14, 2016

Study No.	Name
3.1.2	Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability
3.1.3	Northfield Mountain Project Sediment Management Plan
3.3.1	Instream Flow Study in Bypass Reach and below Cabot
3.3.2	Evaluate Upstream and Downstream Passage of Adult American Shad
3.3.3	Evaluate Downstream Passage of Juvenile American Shad (Interim Report)
3.3.7	Fish Entrainment and Turbine Passage Mortality Study
3.3.13	Impacts of the Turners Falls Project and Northfield Mountain Project on Littoral Zone Fish Habitat and Spawning Habitat
3.3.15	Assessment of Adult Sea Lamprey Spawning within the Turners Falls Project and Northfield Mountain Project Area
3.3.16	Habitat Assessment, Surveys and Modeling of Suitable Habitat for State-Listed Mussel Species in the Connecticut River below Cabot Station
3.6.6	Assessment of Effects of Project Operation on Recreation and Land Use

[1] As required by FERC, addendums were filed on Study No. 3.3.6 *Impact of Project Operations on Shad Spawning, Spawning Habitat, and Egg Deposition in the Area of the Northfield Mountain and Turners Falls Projects*, Study No. 3.3.8 *Computational Fluid Dynamics Modeling in the Vicinity of the Fishway Entrance and Powerhouse Forebays*, and Study No. 3.5.1 *Baseline Inventory of Wetland, Riparian and Littoral Habitat in the Turners Falls Impoundment and Assessment of Operational Impacts on Special-Species Status*.

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FirstLight held its Study Report meetings on October 31, 2016 (aquatic studies) and November 1, 2016 (geology/soils and recreation studies) and filed its meeting summary on November 15, 2016 per Commission regulations. Stakeholder comments on the meeting summary and studies were due by December 15, 2016. Comments were received from the following:

Commenter	3.1.2	3.1.3	3.3.1	3.3.2	3.3.3	3.3.7	3.3.13	3.3.15	3.3.16	3.6.6	Other Studies
USFWS Letter 1					x		x	x	x		
USFWS Letter 2				x							
USFWS Letter 3			x			x					
NMFS			x	x	x	x		x			
USEPA		x									
MADEP	x	x									
MADFW			x	x	x	x	x	x	x		3.5.1 (RTE addendum)
FRCOG	x										
CRWC	x	x	x	x	x	x	x	x	x	x	3.3.6 (shad addendum)
LCCLC	x										
AW, AMC, NEFlow										x	
Karl Meyer				x	x						3.3.12 (emergency water contro1) 3.3.18 (canal drawdown),
William Copland	x										

USFWS- United States Fish and Wildlife Service

NMFS- National Marine Fisheries Service

USEPA- United States Environmental Protection Agency

MADEP- Massachusetts Department of Environmental Protection

MADFW- Massachusetts Division of Fisheries & Wildlife

FRCOG- Franklin Regional Council of Governments

LCCLC- Landowners and Concerned Citizens for License Compliance

AW- American Whitewater

AMC- Appalachian Mountain Club

NEFlow- New England Flow

FirstLight's response to comments were due within 30 days or by January 14, 2017; however, because this date falls on a Saturday it defaults to the following Monday, which is a holiday, hence the due date is effectively January 17, 2017.

The purpose of the comment opportunity following the submission of the meeting summary is to give relicensing participants an opportunity to request modifications to approved studies or propose new studies pursuant to 18 C.F.R. § 5.15(c)(4). Such requests must demonstrate good cause and meet the criteria of 18 C.F.R. § 5.15(d) and (e), as appropriate. The majority of the comments received on FirstLight's study reports, however, simply disagreed with study results, or sought additional analysis or data collection not specified by the approved revised study plans (RSP). Where commenters requested modifications to approved studies or proposed new studies, in each case they failed to demonstrate good cause or did not otherwise meet the Commission's required criteria for making such requests.

Request for New or Repeated Studies

Mr. Meyer requested another year of study with respect to Study No. 3.3.12, *Evaluation of Emergency Gate and Bypass Flume Discharges*, a study FirstLight conducted in 2015 that evaluated the emergency water control gate discharge at Cabot Station and that FirstLight filed with FERC on March 1, 2016. At no point in the study determination process for Study 3.3.12 did Mr. Meyer (or any other stakeholder) request modification of or any additional information with respect to Study No. 3.3.12, as set forth in FERC's regulations. FERC's June 29, 2016 Determination Letter referred to Study No. 3.3.12 as a "finalized study;" and required no additional information with respect to the study. Mr. Meyer does not claim that the approved study was not conducted as provided for in the approved study plan, or that the study was conducted under anomalous environmental conditions. Although he calls his request a new study, he similarly does not make a showing of good cause as to why his proposal should be approved—let alone demonstrate extraordinary circumstances warranting a new study at this late stage in the process. Instead, he makes the unsupported claim, based apparently on a single observation of a "very brief" release from the emergency spillway, that emergency spillway releases "have implications" on shortnose sturgeon. Without making any required showing, Mr. Meyer suggests that this warrants an entirely new year of study of these releases. FirstLight is not proposing to conduct a new study, as Mr. Meyer requests, to document and track all emergency spillway releases in 2017.

Mr. Meyer also requested another year of study of the Turners Falls canal drawdown (Study 3.3.18)—a study FirstLight filed with FERC on September 14, 2015. As part of the study determination process, Mr. Meyer requested an additional year of study. FERC rejected that request in its June 29, 2016 Determination Letter, finding instead that the study satisfied its objectives and that the information FirstLight collected was "adequate for staff's analysis and development of any license requirements." Mr. Meyer makes no case for FERC to reconsider its previous conclusion FirstLight does not intend to conduct another year of study of the canal drawdown, as Mr. Meyer requests.

Juvenile Shad Study

One of the objectives of the juvenile shad study (Study No. 3.3.3) is to determine the rate of entrainment of juvenile American Shad at NMPS. In 2015, FirstLight deployed hydroacoustic monitoring equipment in the NMPS intake/tailrace to estimate the number of juvenile shad entrained as they emigrate past the Project. Unfortunately, milling was a major issue and no estimate of entrainment resulted from this effort. Radio telemetry was also used to estimate entrainment of the juvenile shad at NMPS. However, poor tag retention and low survival of test fish, along with limited detection of test fish yielded questionable results. In their comment letter dated December 13, 2016, USFWS indicated that it is not appropriate to base an entrainment estimate on numbers of tagged fish detected in the upper reservoir due to potential tag loss upon entrainment. Given that hydroacoustics evaluation is not feasible at NMPS, and given USFWS concerns with tag loss at NMPS, FirstLight proposes to base entrainment estimates of juvenile shad at NMPS on a previous robust netting study conducted in 1992. Since the numbers of adult shad passing the Turners Falls Dam at the time of the study were similar to current passage numbers and NMPS operation was similar, FirstLight believes the previous entrainment study conducted in 1992 is still applicable today. Attachment A (Study No. 3.3.3) of the responsiveness summary includes a memo summarizing the entrainment estimate of juvenile shad at NMPS from the previous study. Attached to Attachment A (Study No. 3.3.3) is the previous study report from 1992 (which was also filed into the record in 2014).

FirstLight Responsiveness Summary

FirstLight developed the attached responsiveness summary that addresses questions provided by stakeholders. It lists the stakeholder name, comment and FirstLight's response. In some cases, additional information has been included in the form of Attachments. For study responses having more than one attachment, the labeling is as follows: Attachment A (Study 3.1.2), followed by Attachment B (Study 3.1.2) and so on. There are also Attachments for other studies, which are identified by the Study Number.

As reflected in the attached response matrix, FirstLight has agreed to additional data analysis in some instances, and is providing additional information where warranted. Except where noted, however, FirstLight is not planning to revise or revisit its study reports. Any additional analysis required to evaluate Project effects will be included in FirstLight's amended Final License Application.

Responsiveness Summary Availability

FirstLight is filing this document with FERC electronically. To access the document on FERC's website (http://www.ferc.gov), go to the "eLibrary" link, and enter the docket number, P-1889 or P-2485. FirstLight is also making the document available for download at the following weblink: http://www.northfieldrelicensing.com/Pages/Documents2017.aspx.

In addition to this electronic filing with FERC, a paper copy of the document is available to the public at the Northfield Mountain Visitor Center at 99 Millers Falls Road, Northfield, MA 01360 during regular business hours.

If you have any questions regarding the above, please do not hesitate to contact me. Thank you for your assistance in this matter.

Sincerely,

Gus Bakas

Attached: Responsiveness Summary and accompanying Attachments

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TABLE OF ATTACHMENTS

STUDY NO. 3.6.6 ATTACHMENTS

Study No. 3.1.2 Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability

Commenter	Comment	Responses
CRWC-1	Unfortunately, the study was set up in several ways that would preclude a determination of project effects – the instigating effect of erosion of the bank at the water level was apparently not taken into consideration, no model scenario considered erosion without operational fluctuations, the river was segmented into four sections and project operations were not considered in all segments during the extrapolation phase, erosion impacts caused during flows that occur in the river over 90% of the time (and when the river is under the influence of hydropower peaking operations at three facilities) were mostly not evaluated, and study results were completely ignored and erroneous conclusions written. In addition, we are not clear what river velocities were used at the bank, and these are very important inputs to the study. The extrapolation methodology is fatally flawed and either should be modified or eliminated altogether**.**	This comment is not factually accurate. BSTEM was run on an hourly time-step over a 15-year period and, therefore, examined the full range of flows, water levels, and erosion processes that occurred during that time (including the effect of erosion of the bank at the water level). Hydraulic effects of flow along the entire wetted perimeter were accounted for, including waves. In regard to the assertion that no model scenario considered erosion without operational fluctuations, a model scenario was executed (Scenario 1 – Northfield Mountain idle) without operational fluctuations. As for Turners Falls operations, various analyses were conducted using BSTEM results and the hydraulic, geomorphic, and geotechnical properties of the lower Turners Falls Impoundment (TFI) to determine the Project's impact on erosion. For modeling purposes, the river was not segmented into 4 reaches but was modeled at each of the 25 detailed study sites which spanned the geographic extent of the TFI. The impact of Project operations were considered in all river segments, including as part of the extrapolation approach. Through this evaluation, and based on the hydraulic characteristics of the TFI combined with the BSTEM results, it was determined that a project only has an impact on erosion within its given hydraulic reach. In other words, saying that a project will not impact erosion outside of its reach does not mean that it wasn't analyzed, instead it means that it was analyzed and found not to be a factor. The Energy Grade Line (EGL) slope was one of the primary hydraulic metrics used to determine the hydraulic reaches. Regarding use of EGL, the USACE 1979 report states: *The slope of the energy gradient plays an extremely important role in the hydraulics of river channels. Slope is utilized in velocity equations such as the Manning equation to estimate average velocity, and it is utilized in the tractive force equation,* $\tau = \rho g d S_E$*, to estimate the tractive force exerted on the bed and banks of open channels.* Erosion impacts were evaluated over all flows during the 15-year modeling period, including the lower flows that are more frequent. The study team used the EGL slope on an hourly basis as computed in the unsteady HEC-RAS model to calculate EGL slope for use in BSTEM. The hourly time step allowed the EGL slope to be calculated for different water surface elevations used in BSTEM. Given the dynamic nature of the river flow on the Connecticut River, the unsteady approach was deemed appropriate. BSTEM did not use river velocities but instead used boundary shear stress. BSTEM determines the boundary shear stress along each node of the wetted perimeter of the bank according to the water surface elevation, EGL slope, and bank geometry. This allows the applied shear stress to vary vertically for each time step according to hydraulic parameters and bank geometry and provides a more accurate calculation that using HEC-RAS or River2D velocities. In contrast, the 2D modeling (River2D) provides only a depth-averaged shear velocity at the near-bank node. The method used to calculate shear stress in BSTEM provides more accurate values along the wetted part of the bank. The study was conducted in accordance with the FERC approved Revised Study Plan (RSP) and Study Plan Determination Letter (SPDL) based on state-of-the-science technology and sound scientific methods. The team of professionals who conducted the study, including one of the developers of BSTEM (Dr. Andrew Simon), has experience examining sediment transport and erosion issues all over the world. In addition, the team of experts was approved by MADEP prior to the study commencing. The results of the study represent the most comprehensive understanding of erosion dynamics in the TFI conducted to date.

CRWC-2	• More data should be provided to reviewers, including:
	  • The BSTEM simulation results in higher resolution (#1),
	  • Clarification of the use and inputs to the River2D model, as well as figures or data tables giving velocities modeled at the banks used or converted for use in BSTEM (#7),
	  • Cross-section surveys with the water surface elevation range (#8),
	  • Data to support reasoning that decreased water surface fluctuation increases the impact of waves and ice on the bank (#21)
		In regard to the data requested by CRWC:
		• **Bullet #1**: Due to how the final PDF of the report was put together a number of figures in the report are relatively difficult to review. FL will review the report and re-issue any figures which are deemed to be of low resolution in higher resolution. This supplemental data will be provided to stakeholders by 4/3/2017.
		• **Bullet #2**: River 2D velocity results are not used in BSTEM. BSTEM determines boundary shear stresses along each node of the wetted perimeter of the bank according to the water-surface elevation and EGL slope, as well as the bank geometry. The results of the River2D modeling were used to conduct supplemental analysis as described in Section 5.5 (Volume II) of the Final Report. As noted above, River2D outputs were not used as inputs for BSTEM.

Commenter	Comment	Responses
		• **Bullet #3**: FL had originally agreed to include the Ordinary High Water Mark (OHWM) and the minimum and maximum water surface elevation (WSE) per the FERC license on the cross-section plots. While the OHWM was provided, the min and max WSE were not as those values are measured at the Turners Falls Dam and would not be the same at all locations along the TFI given the change in topography of the TFI as one moves in an upstream direction. • **Bullet #4**: The small range of WSE fluctuations at the lower-end of the TFI occur because of proximity to the dam. This concentrates the effects of boat waves along a narrow band of bank, making the waves more effective at undercutting the bank at these sites. The data in support of this dynamic are the results of the BSTEM modeling provided in the report, which demonstrate the impacts the decreased WSE fluctuations have on erosion over the 15-year modeling period.
CRWC-3	The entire report seems to ignore that erosion at the water line (the toe of the bank) can instigate erosion and contribute to larger failures that are washed away during high flow events. Given this could be an important effect of project operations, several changes to the study are necessary to gain a better understanding of project operations (#2, #5, #12, #20)	See response to comment CRWC-1. This comment is not factually accurate. Erosion at the toe of the bank is simulated at every one-hour time step over the entire 15-year modeling period. BSTEM contains a hydraulic sub-model that handles this process at the bank toe, along the bank face and at every node along the wetted perimeter. The results of the hydrologic and hydraulic analyses conducted for Study 3.1.2 found that for the vast majority of the time (79-99%) the water level in the TFI rests on the lower bank, below the toe of the upper bank. The flow required for the water surface to rest at the toe of the upper bank or higher is typically above the high flow threshold. BSTEM results found that the vast majority of **all** erosion (i.e., hydraulic and geotechnical erosion) occurs at flows greater than 30,000 cfs; this includes both minor particle by particle erosion at the toe of the bank and large mass wasting events. BSTEM results found that minimal to no erosion occurs on the flat, beach-like lower bank that could instigate erosion of the upper bank during low flow periods when hydropower operations control flow and water levels in the TFI. This includes the particle by particle erosion of the toe of the bank that could instigate larger failures during high flow events. In other words, erosion at the toe of the bank which could instigate erosion and lead to larger failures at a later date only occurs when flows exceed the high flow threshold and not during low flow periods when hydropower operations control flow and water level in the TFI. The results of the Final Report adequately reflect the dynamic described in the comment.
CRWC-4	The BSTEM analysis should be re-run to: • determine if preclusion of vegetative growth due to operational-induced river level fluctuations contributes to erosion (#3), • create new scenarios that would isolate project effects from the operation of Turners Falls and Vernon, and no project effect (#5, #15), • assess primary causes of erosion in all reaches of the river (#6), • use stage and discharge data from the HEC-RAS modeling near the Turners Falls dam (#11),	In regard to the CRWC's recommendations: • **Bullet #1**: BSTEM was run with the appropriate amount of vegetation according to conditions at the start of the simulation. These were based on photos. Most of the banks were vegetated to some degree. • **Bullet #2**: Additional scenarios are not warranted as the methodology utilized for the study took into consideration the potential impacts of project operations at Vernon, Northfield Mountain, and Turners Falls. Vernon operations were assessed by examining the BSTEM results at each detailed study site combined with the hydraulic characteristics of the TFI; Northfield Mountain operations were assessed by executing a modeling scenario where the Project was idle; and Turners Falls operations were assessed via a modified extrapolation approach which incorporated BSTEM results as well as hydraulic, geotechnical, and geomorphic characteristics. Each hydropower project in the study area was examined in detail to determine the impact of operations on erosion. As discussed in the response to comment CRWC-1, saying that a hydropower project does not impact erosion outside of its hydraulic reach does not mean that the potential for that impact was not examined, instead it means that this dynamics was evaluated and found to not occur under the modeled conditions. • **Bullet #3**: See response to comment CRWC-1. The primary causes of erosion were assessed in all reaches of the river. • **Bullet #4**: Because stage varied very little over the entire range of discharges near TF Dam, a reliable stage-discharge relation could not be established. Additional information pertaining to this comment can be found in later responses to USGS and USDA reviewer comments.
CRWC-5	Revise the extrapolation portion of the study in the following ways. • Assess impacts of project operations throughout the entire impoundment rather than using the 4 river reaches (#11), • incorporate 2D modeling into near-bank analysis (#11), • thresholds for dominant and primary causes of erosion should be re-examined and agreed upon (#12), • eliminate bias by conducting a random review by a third-party reviewer (#13, #14), • avoid direct comparison of BSTEM analysis results with land use analysis (#16)	In regard to the CRWC's recommendations: • **Bullet #1**: See response to comment CRWC-1. The impacts of Project operations were assessed throughout the entire TFI. • **Bullet #2**: See response to comment CRWC-1. BSTEM calculates shear stress and does not use outputs from River2D. • **Bullet #3**: The thresholds for the dominant (>50%) and contributing (<50% but >5%) causes of erosion were determined based on a statistical analysis of the model results (particularly the 5% cutoff). Rather than arbitrarily selecting a threshold value to determine what a "significant" amount of erosion is, a distribution of annualized rates of current bank-erosion rates was developed to determine the erosion rate that represents the lowest 5% of

Commenter	Comment	Responses
		those rates. For this study, the 5% threshold represents erosion rates that are equal to or less than 0.163 ft^3/ft/yr. Erosion rates equal to or less than the 5% threshold are statistically insignificant and well within the noise of the field data collection methods and/or modeling. In regard to the 50% threshold, 50% was chosen at it represents a majority. It should be noted, that based on the results of the BSTEM modeling, there were no contributing causes responsible for more than 26% of the erosion at a given site. In other words, the dominant causes were often so dominant at a given site that the threshold could have been as high as 74% without it changing the results of the study. • **Bullet #4**: As part of FERC's ILP process, stakeholders, resource agencies, and the public are all afforded the opportunity to review and provide comments on the study, including review of all available data and reporting. To date, the report was reviewed by, and comments were received from: NOAA NMFS (including peer reviews by the USGS and USDA), MADEP, FRCOG, CRWC (including a peer review by Princeton Hydro), as well as other stakeholders. In addition, FERC will also review the report and findings as part of the ILP process. In response to the comments received, FL and its team of experts have developed detailed responses providing additional clarification and detail. • **Bullet #5**: The land-use results were not directly compared to the BSTEM results. Although the extrapolation method calculated % of total riverbank statistics for both BSTEM and land-use these analyses were conducted separately. This is why the % of total riverbank statistics for the land-use classifications are reported as **potential** contributing causes of erosion as opposed to contributing causes of erosion.
CRWC-6	Revise conclusions to reflect observations or results (#17, 19, #20, #22, #23)	See response to comments CRWC-51, 53, 54, 56, and 57 found later in this table.
CRWC-7	Improve groundwater analysis to better understand how movement of groundwater may weaken the bank materials (#9)	BSTEM contains a near-bank groundwater sub-model which takes into consideration the impacts of groundwater movement on bank erosion processes. The groundwater model adjusts the strength of the bank materials at every time step according to the magnitude of the positive or negative pore-water pressure in the bank layers. The groundwater model was run on an hourly time-step for the entire 15-year modeling period. The groundwater data contained in Section 5.5.2 of the Final Report (Volume II) was used for supplemental analysis independent of BSTEM. The BSTEM model adequately takes into consideration the impact of groundwater movement on bank stability.
CRWC-8	Improve investigation of ice impacts due to operational water surface fluctuations (#24);	See response to comment CRWC-58 found later in this table.
CRWC-9	Revise definition of lower and upper bank to be consistent with general scientific practice (#4,#15).	The definitions of lower and upper bank used for this study are consistent with general scientific practice and are based on field observation and riverbank characteristics, including vegetation, slope, height, sediment, etc. The definitions used for this study are consistent with those used for other relicensing studies and past riverbank surveys conducted throughout the TFI. In addition, the definitions of upper and lower riverbank were presented and discussed with MADEP and incorporated into the RSP. Some people argue that the toe of the bank is the upper part of the lower bank, just below the transition to the upper bank. Others argue that the toe is the base part of the upper bank just above the lower bank. This debate is not particularly important as the analysis conducted for this study considered and utilized the geometry and characteristics of the bank from lower bank, toe and upper bank as well as the range of water levels as they varied over time from low flow and low water levels up to high flow and high water levels and everything in between. The recommended changes to the definition are a matter of semantics and have no impact on the analysis and modeling or the final results of the study.
CRWC-10	Use historical past aerial photos to compare against current aerial photos as required by FERC in the Study Plan Determination (#18)	The historic assessment conducted for this study, and included in Section 2 of the Final Report (Volume II), is consistent with the FERC approved RSP and SPDL. The historic geomorphic assessment included comparing historic aerial photos against photos from recent decades to examine changes in riverbank conditions in order to provide context. Analysis and comparisons of historic aerial photos beyond those described in the report would not be an appropriate use of the dataset given the limitations of historic aerial photos. These limitations, and the reason why more in-depth analyses are not appropriate, are discussed in great detail in Section 2.3.1 of the Final Report (Volume II).
CRWC-11	Potentially extrapolate erosion analysis downstream of Vernon to downstream of Turners Falls operations to provide consistency (#10).	This recommendation is beyond the scope of the RSP and was never included in any of FERC's SPDL's. The downstream extent of this study has always been the Turners Falls Dam.
CRWC-12	<u>Historic bank analysis</u> Inexplicably, the end of the first paragraph on page 2-16 says, "The results of georeferencing efforts conducted by FirstLight as part of this study typically yielded root-mean-squared (RMS) values less than ±15 ft." What this analysis is based on is never explained	The RMS values of +/-15 feet were determined by comparing control points from 1952 aerial photos to MassGIS Digital Ortho Photography (2009) – 30 cm Pixel Resolution. The difference between the location of fixed control points between these two sets of photographs yielded an RMS error of +/-15 feet.
CRWC-13	<u>Historic bank analysis</u> We note that the Field, 2007 Report in section 9.3b recommendation #10 was, "Portions of the 1971 ground surveys by Ainsworth and Associates, Inc. of Greenfield, MA should be resurveyed to identify changes in bank position since the opening of the Northfield Mountain	The section of the Final Report from which this comment is based (Section 2.3.1, Volume II) discusses the historic dataset analysis which was conducted in order to develop a geomorphic understanding of the Connecticut River and TFI. The analysis and discussion included in this section was done in order to provide context for the study, in accordance with the

Commenter	Comment	Responses
	Pumped Storage Project." CRWC Recommendation: There are several possible ways FirstLight could have analyzed bank movement over time. What they have produced in this report is inadequate and should be re-done.	FERC approved RSP and SPDL. More in-depth and detailed analysis of changes in riverbank position over time were conducted as part of the BSTEM modeling. The BSTEM modeling utilized time-series cross-section surveys at 25 sites over a 15-year period to determine bank movement with time. This analysis served as the basis for BSTEM calibration. The BSTEM modeling baseline condition was then able to quantify the change in riverbank position at every cross-section for the modeling period. In addition, National Map Accuracy Standards suggests that the 1970s mapping should have been compiled to an accuracy of 1/40th of an inch, which translates to 10 feet. One should expect some loss of accuracy in the scanning and translation to a digital format. Unlike today's mapping which does not tend to lose much fidelity when plotted, this mapping was hand drawn and is susceptible to errors accumulated there from. The level of accuracy from the 1970s mapping plus the level of accuracy from any new survey would have to be added together. Any differences between an old survey and new survey that are less than the combined levels of accuracy for both sets of data must be considered as inconclusive as far as actual change in channel or bank geometry is concerned. In discussing the issue of utilizing historic information such as maps and aerial photographs, the study report refers to work conducted by NDT stating, *"significant changes (beyond the accuracy limits of the datasets) were not observed in the decades since the 1940's."* This issue renders the map comparison ineffective in addressing this question. It must also be remembered that riverbanks are areas of relatively steep topographic change which are typically covered to a significant degree by relatively dense vegetation. These factors also tend to decrease the level of accuracy of a mapping product, which then increases the potential for error and lack of accuracy when attempting to estimate riverbank erosion. The limitations of conducting such a comparison are discussed in-depth in Section 2.3.1 (Volume II). The approach used by FL (i.e., BSTEM) provides a far more scientifically sound method to evaluate changes in riverbank position over time (in addition to actually quantifying that change). Additional analysis of changes in bank movement over time is not warranted.
CRWC-14	<u>River Segments</u> We have also found two instances, described below, in which other relicensing reports describe river fluctuations that influence the river outside of the river segment that FirstLight created: • Section 2.4 and Figure 2-5 of the October 2016 Alden Report included in Appendix C of Study 3.1.3, notes a Northfield tailwater surface elevation fluctuation range of 5 feet at lower flows. The Report indicates that the RFP stated that, "the fluctuation is not an artifact of operations at Northfield but results from downstream control of the river." • Study Report 3.6.6 goes into much detail about the conditions under which the Governor Hunt Boat Launch located just downstream of the Vernon Dam are affected by operation of Turners Falls Dam and Northfield Mountain Pumped Storage. Though Study 3.6.6 concludes that the operation of Vernon Dam has the most control, the operation of the downstream facilities do affect river levels in this area below the Dam. CRWC recommendation: We re-iterate the Peer Review recommendation to look at operational effects in the entire reach	FL explicitly notes in multiple sections of the Final Report (Volumes I and II) that Turners Falls and Northfield Mountain operations can impact water level and flow throughout the entire TFI and not just within their given hydraulic reach, especially during low flow periods. The important distinction to understand for this study is that the vast majority of erosion does not occur until the water surface reaches the toe of the upper bank (or higher), which typically occurs at flows greater than 30,000 cfs. Once flows exceed 30,000 cfs the French King Gorge becomes the hydraulic control for the middle and upper portion of the TFI, meaning that Turners Falls Dam water level management has minimal to no impact on water level or flow upstream of the gorge (i.e. outside of hydraulic reach 1). Furthermore, while it is observed that at flows greater than 30,000 cfs Northfield Mountain can still impact water level as far upstream as Stebbins Island, the impacts are so negligible that they do not alter the EGL slope (and therefore the shear stress) outside of hydraulic reach 2. As a result, even though a project may influence water level and flow outside of their given hydraulic reach, due to the hydraulic characteristics (i.e., EGL slope) of the TFI, project operations do not impact erosion outside of their given hydraulic reach.
CRWC-15	<u>Riverbank Transects</u> FirstLight's November 23, 2016 Answer on page 4-5 indicates that some of the transect profiles in Appendix E to Study 3.1.2 were inadvertently flipped, but that the data are correct and FirstLight will file an errata report, as needed. To date, no errata report has been filed for this study.	As noted in the comment, several of the cross-section surveys included in Appendix E were inadvertently flipped. FL will distribute corrected cross-section plots by 4/3/2017.
CRWC-16	<u>Riverbank Transects</u> CRWC recommendation: FirstLight submit SOPs for review to state and federal agencies for bank transect survey work.	The annual cross-section surveys are conducted by a licensed surveyor. Survey shots of the bank are taken at every notable change in slope; sometimes that is every foot, sometimes it could be every several feet. Survey shots are also taken anywhere undercutting is observed. In addition, the licensed surveyor uses waders to collect survey shots into the water to ensure overlap exists between the ground survey and the hydrographic data. For the hydrographic data, HYPACK software is used to record depth data and navigate the cross-section at each site. For the surveys conducted by North by Northeast, a Robotic Total Station is used to maintain a direct tie to the reference baselines/elevations; GPS is not used. After collecting the data, it is post processed to reduce the elevations to every foot and merged with the ground shots to generate the cross-sections. The licensed surveyor follows standard surveyor data acquisition and post processing methodologies for the surveys.
CRWC-17	<u>Riverbank Transects</u> CRWC recommendation: FirstLight submit an addendum that explains which transects have permanent markers and which do not.	Every cross-section has at least two permanent reference points, many have three or four or tie into existing riverbank baselines. Permanent reference points may include iron rods, spikes, PK nails, or property monuments.
CRWC-18	<u>Riverbank Transects</u> CRWC recommendation: FirstLight explain what transect data was input into the BSTEM model – if FirstLight has determined that some transect data can erroneously show dramatic movement in banks, yet this was used to "calibrate" the BSTEM model, did FirstLight smooth out or modify the transect data to fix these errors?	There is not smoothing of the ground data at all. The hydrographic data is only smoothed as an average elevation per square foot of river bottom as mentioned in response to comment CRWC-16. In very rare instances, erroneous points may be observed when comparing the survey data to the previous year's survey. If the licensed surveyor deems a point to be erroneous it is then removed from the survey.

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CRWC-19	<u>Riverbank Transects</u> CRWC recommendation: FirstLight should clarify if the flipped profiles were input into BSTEM on the wrong bank side, or if the presentation in Appendix E doesn't reflect how the profiles were input into BSTEM	As a result of the comment received from CRWC, FL re-examined all BSTEM input data to ensure that the correct bank geometry was used for each detailed study site. During this review it was discovered that two sites (2L and BC1-R) used the incorrect geometry. This error was specific only to the bank geometry at these two sites, all other input parameters were correct. BSTEM will be re-run at these two sites for both the baseline and S1 scenarios. The final report (all three volumes) will be reissued by 4/3/2017. The amended final report will include corrected text, tables, and figures to account for this error.
CRWC-20	<u>Riverbank Transects</u> CRWC recommendation: Appendix E transect profiles should be corrected and should be re-drawn showing no vertical exaggeration, and the typical operating range of the river elevations should be shown on each profile.	Cross-sections in the TFI can cover over 40 vertical feet and span a width of several hundred to over a thousand feet. Given this, plotting cross-sections without any vertical exaggeration would be extremely uninformative as there would be very little to no detail for the banks. Using the appropriate amount of vertical exaggeration is necessary in order to see the detail of the riverbank for a full cross-section plot and is consistent with common and accepted practice. The cross-section plots in the report were plotted with appropriate levels of vertical exaggeration consistent with accepted practice. The typical operating range of the river, as determined by the FERC license, were not shown on the cross-section plots as these elevations are measured at the Turner Falls Dam and, therefore, vary from site to site throughout the TFI.
CRWC-21	<u>Hydraulic Modeling and Sheer Stresses</u> The Field 2007 report used two-dimensional numerical hydraulic modeling using bathymetric data. That report stated in Section 6.0 that, "While erosion does occur where high flow velocities and sheer stresses approach near the bank (Figure 17), significant amounts of erosion also occur where flow velocities near the bank are low (Figure 18 and Appendix 4)." Study 3.1.2 comes to the opposite conclusion, that erosion occurs only during high flow events. However, we aren't sure what velocities were used in Study 3.1.2.	The Field 2007 modeling used bathymetry data that was collected by Hydroterra Inc., in 2006. During the early stages of hydraulic modeling by FL for Study 3.2.2 *Hydraulic Study of Turners Falls Impoundment, Bypass Reach and Below Cabo*t, it was discovered that there was a major vertical datum error which affected the bathymetry in the upper half of the TFI. Given this, FL recollected bathymetric data in the upper half of the TFI with a more detailed grid and also collected additional bathymetric data for the majority of the rest of the TFI for Study No. 3.3.9 *Two-Dimensional Modeling of the Northfield Mountain Project Intake/Tailrace and Connecticut River Upstream and Downstream of the Intake/Tailrace.* These datasets were then merged with LiDAR topographical data for the river banks and flood plain to create a seamless bathymetric and topographical map of the TFI which was more detailed and correct than the bathymetry used in the Field 2007 modeling. In regard to the question of what velocities were used, BSTEM uses shear stresses at every one-hour time step (see response to comment CRWC-1). Some hydraulic erosion may occur at low to moderate flows and, if it does occur, it is accounted for in each and every time step for the 15-year modeling period. Field (2007) has no deterministic, quantitative analysis of when bank erosion occurs (i.e., flow ranges); Study 3.1.2 does. In addition, it should be noted that the section of the Field report which CRWC cites discusses the hydraulic conditions in the vicinity of the Rt. 10 Bridge, which is an area that has been identified by the hydraulic models as having unique hydraulic conditions (i.e., eddy formation caused by the Rt. 10 Bridge) that enhance erosion. This area and its associated hydraulic conditions are not representative of the hydraulic conditions found throughout the TFI. The Erosion Causation Report (2016) cites *"extreme hydraulic conditions with eddying and strong currents,"* based on hydraulic analysis and observations of this area. The Field report goes on to agree with the Erosion Causation Study (3.1.2), that (as stated by Field): *…the eddies that form immediately upstream of the Route 10 Bridge, where bridge abutments and bedrock constrict the channel, may enhance erosion (see Section 6.0).* Finally, to state as CRWC does that Study 3.1.2 finds that *"erosion occurs only during high flow events,"* is an exaggeration and misrepresentation of the results of this study. While high flows were found to be the dominant cause of erosion at the vast majority of sites throughout the TFI, the report clearly acknowledges other dominant and contributing causes of erosion which are present.
CRWC-22	<u>Hydraulic Modeling and Sheer Stresses</u> As for the River2D model, it appears from the description that the River2D model for this study may be different than the 2-D model developed for Study 3.3.9. This should be clarified, particularly with regard to comments that USFWS submitted regarding the roughness coefficient in this study and other technical comments.	The River2D model for Study 3.3.9 extended 5 km (about 3.1 miles) upstream and downstream of the Northfield Mountain Tailrace. The River2D model for Study 3.1.2 was created specifically for this study and included the entire TFI. The bed and mesh geometry for this model were built with a finer resolution in the areas immediately surrounding the detailed study sites, while the remainder of the model had a coarser resolution adequate for flow conveyance. Calibration and verification at the observed stations was within 0.5 feet throughout the TFI, and generally within 0.25 feet. It should also be noted that the River2D model was not developed in order to provide input data to BSTEM and that the shear stresses used in BSTEM did not come from River2D. The River2D model was developed to conduct supplemental analysis pertaining to velocity and shear stress throughout the TFI. BSTEM calculates a shear stress at every node along the wetted perimeter at each time-step over the entire 15-year modeling period. The shear stress values calculated by BSTEM provide more accurate results than those produced by River2D. The River2D model used for this study (3.1.2) did not incorporate the changes in the laterally varying roughness values

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		that the USFWS suggested for the River2D model used for Study 3.3.9. In areas with sediment material in the riverbed and banks, all available information did not indicate a change in the grainsize distribution between the channel and riverbanks. However, the River2D models did incorporate changes in the roughness values in the French King Gorge area where the channel banks consist largely of cobbles, boulders, and bedrock.
CRWC-23	Hydraulic Modeling and Sheer Stresses Sheer stresses at flows below 30,000 cfs apparently were not assessed under the RIVER2D model constructed for Study 3.1.2. Pumping and generating with 3 or 4 units apparently was not assessed either, see page 5-29. It is unclear what sheer stress numbers were used in BSTEM for lower flows. If no modeling was done for flows under 30,000 cfs, then it seems like a foregone conclusion that no impacts would be seen if they weren't even assessed	See response to comment CRWC-22 above. BSTEM does not use River2D outputs in order to determine shear stress. BSTEM calculates a shear stress at every node along the wetted perimeter at each time step over the entire 15-year modeling period including during low flows, moderate flows, high flows and scenarios with and without Northfield Mountain operations and boat waves. Shear stress values were calculated and BSTEM modeling was done at every flow, including flows above and below 30,000 cfs.
CRWC-24	Hydraulic Modeling and Sheer Stresses The pumping data in Study Report 3.1.2 Volume II Table 5.1.3.1-2 for inflow >30,000 cfs does not quite match what was listed in the September 2016 Alden Report for Study 3.1.3. Also, the pumping velocity for 1 and 2 pumps does not match what was listed in the Alden Report. Please see Table 7 in the September 2016 Alden Report and accompanying text for flow and pump use scenarios	Small differences as noted by the CRWC are likely when there are differences in the period of records used in these types of analyses. The 2016 Alden Report for Study 3.1.3 used an 11 year period of record (2000-2010) and the period of record for this study (3.1.2) was 15 years (2000-2014).
CRWC-25	Hydraulic Modeling and Sheer Stresses Though one would need to zoom in, a look at these maps (Appendix B of Study Report 3.3.9 – Scenario 36 Map 3 (river flow 40,100 cfs with 4 units generating) compared to Scenario 12 Map 3 (river flow 4,900 cfs, 4 units generating)} hint that there may be areas where bank velocities are higher at the bank under the lower flow scenario (4,900 cfs) than the higher flow scenario. We could find no evidence in Study 3.1.2 of that dynamic being considered.	Velocities at the banks can be affected by wide range of variables including river flow, impoundment level at the Turners Falls Dam, and operations at the Northfield Mountain. Therefore, the BSTEM model was run on an hourly time-step for a 15-year period which examined all flow and water level conditions that occurred during the modeling period. Shear stress values were calculated in BSTEM for every time-step at every node along the wetted perimeter. In addition, it is also important to take into consideration where the water level rests on the bank during these low flow conditions. The results of this study included examination of the dynamic mentioned in the CRWC comment.
CRWC-26	Hydraulic Modeling and Sheer Stresses Red circles in the next two pages highlight areas that should be compared to look at the higher flow (40,000 cfs) vs. a lower flow (4,900 cfs) under maximum generation of 20,000 cfs. Note the higher velocities near the banks under the lower flow scenario. Velocities of water in contact with the bank are not known	See response to comments CRWC-22-25.
CRWC-27	Hydraulic Modeling and Sheer Stresses See also our comments on page 15 later in this letter on Study 3.1.3. Table 7 in the September 2016 Alden report indicates significant uptake of sediments to the upper reservoir during low flows over a given year. This seems to undermine the hypothesis in Study 3.1.2 that erosion only occurs during naturally high flows.	The CRWC comment seems to attribute all suspended sediment in the TFI to being from erosion of TFI riverbanks. This assumption ignores washload from upstream sources, bedload, overland runoff, and other potential sources. Furthermore, review of Table 7 in the September 2016 Alden report indicates that approximately 18% of the total sediment uptake to the Upper Reservoir occurs at flows of 5,000 cfs, while 82% occurs at flows of 15,000 cfs or greater. The findings of Study 3.1.2 indicate that some erosion does occur in the upper reach of the TFI (hydraulic reach 4, downstream of Vernon) at flows below 17,130 cfs. The approximately 18% of suspended sediment which is transported to the Upper Reservoir at flows of 5,000 cfs is likely a combination of the factors mentioned above. Finally, the CRWC comment also assumes that the Project pumps for the same amount of time during the five flow scenarios examined by Alden. Further review of the table indicates this is not true and that 56% of the time when the project is pumping is during the low flow condition. In reviewing the table, the Project actually operates the least during high flow periods yet still transports the most sediment to the Upper Reservoir. Contrary to CRWC's comment, this seems to confirm the findings of the study that erosion typically only occurs during moderate to high flows (i.e., greater than 17,130 cfs).
CRWC-28	Hydraulic Modeling and Sheer Stresses FirstLight should explain in detail how the RIVER2D model was used. If flows less than 30,000 cfs were indeed not modeled, this appears to be inconsistent with the RSP and FirstLight should explain the rationale.	See response to comments CRWC-22-25.
CRWC-29	Hydraulic Modeling and Sheer Stresses FirstLight should provide detailed data on hydraulic modeling results and sheer stresses at each of the transects to allow for a complete review.	BSTEM calculates a shear stress at every wetted bank node at every time step for every site and for every scenario. From the comment, it is unclear just what the reviewer is requesting; which shear stresses?. There is no input from a hydraulic model as the shear stresses are calculated internally within BSTEM. Much like discharges, these shear stresses range all over the board depending on discharge, slope and geometry. Although BSTEM calculates shear stress at every wetted node, it outputs the average, boundary shear stress for the wetted part of the bank for each time step. We could provide this hourly data if required. It would be quite voluminous, representing about 131,500 points per model run for each of the 25 sites.

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CRWC-30	Cyclical Process of Erosion Section 7.4 of the Field 2007 report described a cyclic process of erosion, started by the creation of a notch or undercut at the base of the bank by the individual removal of particles. The notch grows taller and steeper, and eventually there will be a topple or slide, and the mass of sediment can be washes away from the bank by water currents. When the report came out in 2007, this description made sense to CRWC and the members of CRSEC, because it described a condition we saw happening out on the river. This process appears to have been lost in the complexity of Study 3.1.2.	Field (2007) qualitatively describes the process of hydraulic erosion and/or undercutting with subsequent failure of the bank. Those are exactly the processes that BSTEM is modeling, every hour over a 15-year period. Thus, the process is not lost as is suggested by the reviewer but explicitly incorporated in a quantitative way. Furthermore, analysis of the relative strength and duration of forces demonstrate that the forces that act on riverbanks the preponderance of the time are very small and insufficient to cause erosion. In contrast, significant erosion has been observed under three other scenarios (despite the fact that they occur much less frequently): high flow events, ice, and boat waves (particularly at moderate to high flows that impact the upper bank). Analysis of forces and durations confirm that these are the primary drivers of erosion and that low flow hydraulics and fluctuations play a relatively minor role in this process. As confirmed by the scientific literature, Study 3.1.2, and the 1979 USACE study; high flows are the primary and dominant cause of erosion. The 1979 USACE study provides perspective: *An analysis of the data at the test sites established by the Corps of Engineers verifies that bank erosion is at least as severe in the non-pool reaches as within the limits of the pools. In fact, the measured data indicates that the natural river is 1.30 times more susceptible to bank erosion than are the pools (Table 9). This is very close to the theoretical evaluation which yielded a value of 1.34. In other words, the presence of pools reduces bank erosion on the order of 34 percent compared to the natural river.*
CRWC-31	[NOTE: CRWC comments from here down are from the peer review conducted by Princeton Hydro] Recommendation No. 1 - Difficult to Review In order to facilitate stakeholder and FERC review of the study, many of the BSTEM figures should be regenerated at a higher resolution and submitted again. Where model results overlap so significantly that it is hard to differentiate each scenario run, the hidden and overlapping runs should be called out with leader lines and an explanation, to clarify what the figure is presenting.	FL will review the report and provide higher quality figures for those that are of poor resolution by 4/3/2017.
CRWC-32	Recommendation No. 2 – The Comparison of Erosion Rates by Volume and Material Eroded, Disregards Cyclical Erosion Process Because of the interconnected nature of various types of streambank erosion, toe erosion, which results in a small quantity of sediment eroded, can instigate a more significant bank failure during periods of high flow, resulting in larger quantity of sediment eroded. Specifically minor toe erosion caused by daily operational water surface fluctuations can instigate more significant erosion volumetrically during high flows. We recommend that the analysis be revised to include the causal nature of each contributing factor. Otherwise, the study goals and objectives from the approved RSP cannot be met, and a critical element of the cycle of erosion has been overlooked in this study.	The critical element of hydraulic erosion at the bank toe has not been overlooked. In fact, it is an integral part of the BSTEM analysis as described in numerous responses to earlier review comments. The BSTEM analysis has, in fact, included these calculations.
CRWC-33	Recommendation No. 3 - WSE Fluctuation Precludes Riverbank Vegetation We recommend that the BSTEM analysis be rerun to determine if the preclusion of vegetative growth due to operational induced WSE fluctuation is a contributing factor to streambank erosion	See response to comment CRWC-4, Bullet #1
CRWC-34	Recommendation No. 4 - Upper and Lower Bank Terms are used Inconsistently We recommend that this inconsistency between the analysis and report discussion be corrected. In addition, we recommend that the lower and upper bank definition be revised to correspond with the definitions consistent with general scientific practice, which typically include the toe of the bank within the lower bank	See response to comment CRWC-9
CRWC-35	Recommendation No. 5 - No Model Run Isolates the Effects of the Turners Falls Operations Analysis of the effects of Turners Falls throughout the impoundment is simply dismissed by interpretation of the Energy Grade Line. The Energy Grade Line is not an absolute determination of the limit of influence of dam operations; wherever water levels fluctuate from dam operations, there is a potential for an impact. In addition we propose that a scenario be run that assesses the “instigating” role of toe erosion on proceeding streambank erosion under high flow scenarios (i.e. how toe erosion, relating to operational WSE fluctuation and associated ground water differentials, instigates additional bank failure during high flows). We recommend that the entire Turners Falls Impoundment (TFI) be analyzed for impacts due to Turners Falls Dam, and at a minimum, this modeling scenario must be incorporated into the study prior to completion. Further, additional scenarios should also be completed that isolate (i) both Northfield Mountain Project Operations and Turners Falls Operations combined, (ii) the operations of Vernon Dam (e.g. a “Scenarios 3 and 4”)., and (iii) the “instigating” role of toe erosion on proceeding streambank erosion.	See response to comment CRWC-1. The potential impact of Turners Falls operations on erosion was examined in detail through the modified extrapolation approach discussed in the report (Volume II, Section 6). This approach took into consideration the results of the BSTEM modeling conducted at the detailed study sites in the lower reach as well as the geomorphic, hydraulic, and geotechnical characteristics of this area. At flows greater than 30,000 cfs (when the vast majority of erosion throughout the TFI occurs), the French King Gorge becomes the hydraulic control for the middle and upper portions of the TFI. In other words, water level management which occurs at the Turners Falls Dam has minimal to no impact on erosion processes in the TFI upstream of the gorge at the flows that cause the majority of erosion. To state that the impacts of Turners Falls operations were dismissed by interpretation of the EGL is a mischaracterization of what was actually done. This suggested scenario was included in every scenario that was run for the report (baseline and S1). The hydraulic sub-model in BSTEM runs at every time step for every model scenario for the entire 15-year modeling period; it is never shut off. Separate scenarios to examine Turners Falls operations are not warranted for the reasons discussed in previous responses. As discussed in multiple responses throughout this matrix, these additional modeling scenarios are not necessary as all of the dynamics mentioned in the comment have already been examined in-depth.
CRWC-36	Recommendation No. 6 – Large Portions of the Turners Falls Impoundment Remain Unassessed We do not agree with the application of the Energy Grade Line assessment to justify the exclusion of reaches from analysis and we do not	See response to comments CRWC-1 and 14.

Commenter	Comment	Responses
	agree that operational WSE impacts are limited to the reaches where the facilities exist, since the analysis shows these impacts extending throughout the TFI.	
CRWC-37	Recommendation No. 6 – Large Portions of the Turners Falls Impoundment Remain Unassessed [From the table found on page 5 of the Princeton Hydro Review] Vernon Operations: Reach 1 (near Turners Falls Dam): Not Assessed Reach 2 (Vicinity of NFM tailrace): Not Assessed Reach 3: Not Assessed Reach 4 (Downstream of Vernon Dam): Assessed but discounted for lower half of reach	The potential impact of Vernon operations on erosion was examined throughout the entire TFI. The results of the BSTEM analysis (including the flow analysis conducted) as well as the hydraulic, geomorphic, and geotechnical characteristics of the TFI were all taken into consideration to determine where Vernon operations could have a potential impact on erosion processes. The results of this analysis found that Vernon only potentially impacted erosion in the upper reach (Reach 4), and more specifically, in the upper portion of that reach. To say that the impact of Vernon operations were not assessed in the other reaches of the TFI is not factually accurate. The impacts associated with Vernon were assessed, but were not found to be present outside of the upper reach.
CRWC-38	Recommendation No. 6 – Large Portions of the Turners Falls Impoundment Remain Unassessed [From the table found on page 5 of the Princeton Hydro Review] Northfield Mountain Operation: Reach 1 (near Turners Falls Dam): Not Assessed Reach 2 (Vicinity of NFM tailrace): Assessed by discounted, even though model output showed significant impact Reach 3: Not Assessed Reach 4 (Downstream of Vernon Dam): Not Assessed	The potential impact of Northfield Mountain operations on erosion was examined throughout the entire TFI. Two separate model runs were executed (Baseline and S1 – Northfield Mountain idle) for all 25 detailed study sites spanning the geographic extent of the TFI. Differences in the scenarios were attributed to Northfield Mountain operations. This included identifying a number of segments in the Northfield Mountain reach (Reach 2) where project operations were a contributing cause of erosion. The report also clearly states that Northfield Mountain operations were the dominant cause of erosion at one detailed study site, pre-stabilization. In the post-stabilization condition Project operations are a contributing cause of erosion. Given that FL has already repaired the only riverbank segment that was identified as having Project operations be the dominant cause of erosion, the extrapolation methodology was based on the condition of the riverbank as of 2014. To say that the impact of Northfield Mountain operations were not assessed throughout the TFI or that they were discounted in Reach 2 is not factually accurate. The impacts associated with Northfield Mountain were assessed but were not found to be present outside of reach 2.
CRWC-39	Recommendation No. 6 – Large Portions of the Turners Falls Impoundment Remain Unassessed [From the table found on page 5 of the Princeton Hydro Review] Turners Falls Operations: Reach 1 (near Turners Falls Dam): Assessed qualitatively, without BSTEM Reach 2 (Vicinity of NFM tailrace): Not Assessed Reach 3: Not Assessed Reach 4 (Downstream of Vernon Dam): Not Assessed	The potential impact of Turners Falls operations on erosion was examined throughout the entire TFI. The BSTEM baseline scenario included the impact, if any, of Turners Falls operations at each of the 25 detailed study sites located throughout the geographic extent of the TFI. The results of this analysis found that the vast majority of erosion occurs at flows greater than 30,000 cfs. At flows above 30,000 cfs the French King Gorge becomes the hydraulic control for the middle and upper portions of the TFI effectively eliminating any impact Turners Falls Dam operations may have on erosion in those portions of the TFI. A modified extrapolation approach was then used to examine any impacts in Reach 1, including running BSTEM at three detailed study sites in the vicinity of the dam. To say that the impact of Turners Falls operations were not assessed throughout the TFI and that BSTEM was not utilized in Reach 1 is not factually accurate. The impacts associated with Turners Falls were assessed, but were not found to be present outside of reach 1.
CRWC-40	Recommendation No. 6 – Large Portions of the Turners Falls Impoundment Remain Unassessed The analysis should be extended to include assessment of all the reaches for all of the primary causes of erosion. Segmenting the river into the four reaches and only looking at particular influences in that reach is not acceptable and does not meet the study goals laid out in the RSP.	See response to comment CRWC-1. The entire TFI was examined.
CRWC-41	Recommendation No. 7 – 2D Modeling Not Used It is unclear in reading the Relicensing Study 3.1.2. if these corrections [USFWS comments on Study 3.3.9] relating to the calibration of the roughness coefficients were implemented for the River2D model proposed for use in the RSP for this study. In addition, the USDA also conducted a peer review, comments dated 11/28/16, that explain how the River2D modeling results were not utilized to verify the hydraulic shear stresses estimated by BSTEM. Our review as well has noted the lack of integration of the 2D modeling results within the analysis. However based on our peer review of the Study 3.1.2 Report, we cannot determine how or whether RIVER2D was used to revise near bank velocities and shear stresses, and if so, what values were used. In addition, RIVER2D appears to have been developed only for high flows, which is inconsistent with the RSP We recommend that FirstLight provide more information that would aid in stakeholder review, and we suggest that the USFWS and USDA recommendations be included in a revised analysis which incorporates the results of the 2D modeling to more accurately assess roughness and near bank velocities and shear stress.	See response to comment CRWC-22 The River2D modeling results were used to conduct supplemental analysis independent of BSTEM. River 2D provides for vertically-averaged shear stresses at nodes distributed across the channel, including the near-bank zone. BSTEM calculates 2D shear stresses along the bank that are vertically-distributed, thereby providing more accurate values along the entire wetted part of the bank. Given the differing methods in which BSTEM and River2D calculate shear stress, a direct comparison of the results is not appropriate. See previous responses to comments pertaining to the use of River2D or how shear stress is calculated in BSTEM. BSTEM uses shear stresses, not flow velocities and it employs 2D (vertically varying) shear stresses along the wetted bank face. In contrast, the 2D modeling (i.e., River2D) provides only a depth-averaged shear velocity at the near-bank node. The method used to calculate the shear stress in BSTEM provides more accurate values along the wetted part of the bank. Given this, the recommended modifications are not warranted.
CRWC-42	Recommendation No. 8 – Key Figures are Not Provided Figures for each cross-section do not overlay the range of WSE fluctuation, which is a key component in interpreting bank erosion. In addition, no figure is provided comparing the WSE fluctuation for the Baseline Condition versus Scenario 1. This figure would be important since it would highlight the fact that there was no scenario run that excluded daily WSE fluctuations associated with hydro-power operations.	See response to comment CRWC-2, Bullet #3.

Commenter	Comment	Responses
	We recommend that these additional figures be included in a revised Relicensing Study 3.1.2 so as to be in compliance with Task 4c of the RSP. {Figures for each cross-section do not overlay the range of WSE fluctuation, which is a key component in interpreting bank erosion. In addition, no figure is provided comparing the WSE fluctuation for the Baseline Conditions versus Scenario 1.}	
CRWC-43	Recommendation No. 9 – Groundwater Analysis Based on the limited groundwater investigation described in the Study 3.1.2 Report, the observed groundwater level was approximately 1 foot above the river's water surface elevation. The USDA review comments pointed out that this groundwater differential indicates "persistent movement of groundwater towards the TFI during lower flows, which may weaken the bank materials" and potentially "reduce the suction forces in the upper part of the bank." The USDA reviewer, who was one of the developers of BSTEM, states that based on his peer review it appears that "this reduction in bank-material shear-strength was not simulated" in BSTEM. We agree with the concerns stated in the USDA review and feel that this potentially critical reduction in bank material strength and suction forces needs to be integrated into the analysis in order to appropriately assess the impacts of daily operational WSE fluctuations. It is also noted that these field observations were conducted at one location only, approximately 50 feet away from the Connecticut River. We recommend a quantitative analysis be conducted to determine if the seepage force or increased pore-water pressure could not only weaken the bank material over a height of 1 foot above the water surface elevation of the river, but also reduce the suction forces in the upper part of the bank, as per the USDA observations, over the full length of the TFI	The limited groundwater investigation noted by the CRWC and USDA refers to the dataset described in Section 5.5.2 (Volume II), which discusses groundwater data collected in the vicinity of the Rt. 10 Bridge in 1997-1998. This dataset was used for supplemental analysis independent of the BSTEM modeling effort. As previously noted, BSTEM includes a near-bank groundwater sub-model which analyzes the impact that groundwater movement has on bank stability. Parameter inputs for the near-bank groundwater model are based on literature values of the important parameters, based on field classification of soil texture and composition. As such, the bank strength was adjusted at each 1 hour time step for the 15-year modeling period according to the magnitude and distribution of both positive and negative pore-water pressures. No further study modifications are required given that the modeling results already take this dynamic groundwater table into account. BSTEM calculates any and all reductions in matric suction throughout the bank profile, as well as reductions in frictional strength from positive pore-water pressures lower down on the bank.
CRWC-44	Recommendation No. 10 – No Assessment of Downstream Impacts Any discussions of impacts downstream of Vernon Dam operations could be expanded to include potential impacts downstream of Turners Falls Dam and the power canal.	See response to comment CRWC-11.
CRWC-45	Recommendation No. 11 - Extrapolation Step 1 - Analyze the variability of hydraulic forces throughout the TFI We do not agree with the determination that operations only impact the reach in which they have been allotted to in the Relicensing Study. The EGL approach described appears to only apply when looking at impacts associated with high flow (>37,000 cfs) where the 1-dimensional velocity and shear stresses determined through HEC-RAS play a dominant role in erosion. The assessment of the hydraulics and determination of hydraulic reaches using an energy grade line assessment, also did not incorporate the near-bank data that was supposed to have been developed from the 2D hydraulic modeling once the friction coefficients were corrected per the USFWS recommendations (1/12/16). Once corrected the 2D analysis would have provided more accurate near-bank hydraulic forces. Furthermore, the USDA (11/28/16) letter, written by one of the principal designers and developers of BSTEM, states that the development of stage-discharge rating curves to convert hourly stage values to discharge values, is not an appropriate method and cannot adequately represent the significant scatter in the flow versus depth data. It is noted that this inappropriate rating curve method was also used to set the threshold flows based on 10,000 cfs intervals (see page 30 Volume I). USDA also recommends that the accuracy of the BSTEM results would be improved if the flows and stage output from the HEC-RAS analysis had been used and that this would allow for the Turners Falls operations to be analyzed in a similar manner as was the Northfield Mountain operations. For Step 1 in the methodology, we recommend that the impacts of operation be assessed throughout the entire impoundment reach and not be limited to the single reach the facilities are in, especially when assessing impacts during moderate and low flows. We therefore recommend that the delineation of 4 reaches, based on the EGL assessment under high flows, be disregarded, and not used to limit the analysis of impacts throughout the TFI. Our recommendation is supported by the fact that Study 3.1.2 makes it clear that the hydroelectric operations of Turners Falls and Northfield Mountain are both controlling factors for the WSE elevation fluctuation throughout the entire TFI for flows that occur over 90% of the time. We recommend that the results from the 2D modeling be incorporated into the analysis to better calibrate the near-bank data utilized. We recommend that the method of converting hourly stage into discharge, and then using the resulting hourly discharge erosion records to calculate erosion exceedance probabilities, be discarded. The BSTEM model should then be run with the stage and discharge data from the HEC- RAS modeling, thereby eliminating the error associated with this approach (as described in the USDA 11/28/16 review memo) and allowing for a BSTEM analysis of the impacts of the TF operations to be conducted.	The results of the hydrologic and hydraulic analyses discussed in Volume II Section 5.1 and 5.4.1 clearly indicate the significant role the varying EGL slope has on velocity and shear stress throughout the TFI. The EGL slope shows a clear delineation of reaches throughout the TFI and includes the full range of flows observed during the 15-year modeling period. It does not only apply to high flows (>37,000 cfs) as the reviewer claims. As described in previous comments, 2D boundary shear-stress was calculated by BSTEM at every detailed study site throughout the geographic extent of the TFI, for every one hour time-step, for the entire 15-year modeling period, for the entire wetted perimeter. This method provided more accurate shear stress values than either HEC-RAS or River2D would have. As a result of the comment received from the USDA reviewer, FL conducted a sensitivity analysis comparing the results of the stage-discharge relationships used in the final report to the flow and stage output from the HEC-RAS model. The results of this analysis found that minimal to no appreciable difference was observed between the two methods at the detailed study sites examined in hydraulic reach 2 (Northfield Mountain), 3 (middle), or 4 (upper). In regard to reach 1 (French King Gorge to Turners Falls Dam), the downstream boundary condition of the one-dimensional HEC-RAS model is the water surface elevation based on historic hourly data. The Barton Cove area (where the three detailed study sites in this reach are located) is only about 3,000 feet from the dam. Due to the large amount of conveyance capacity in this area a substantial hydraulic gradient is very rare. In a modeling sense, analyzing the flow values very close to a downstream boundary that is based on stage, in a dynamic reservoir under unsteady flow conditions, especially in an area without much of a hydraulic gradient is questionable at best. Given this, a distinct stage vs discharge relationship is not feasible in most of Reach 1, including at the detailed study sites. This comment is not factually accurate and does not reflect the analyses conducted during this study. As previously discussed (response to CRWC-1 and others), the impact of hydropower operations for all projects were assessed throughout the entire TFI. The final report clearly acknowledges the impact that hydropower operations have on flows and water levels throughout the TFI, especially during low flow periods, and was accounted for in the BSTEM modeling. For the reasons previously discussed, modifications to how the near-bank data were utilized are not warranted nor are modifications to how the stage and discharge data were analyzed. Finally, BSTEM was run with the HEC-RAS stage data, not the results of the polynomial regressions.
CRWC-46	Recommendation No. 12. Extrapolation Step 2 - Analyze and review the site specific BSTEM results We recommend that Step 2 of the study methodology (and any other steps where arbitrary thresholds not listed in the RSP were utilized) be reanalyzed after agreed upon thresholds have been vetted and approved by the stakeholders and FERC. We also suggest that an additional "cause of erosion" be defined and included in the analysis that looks at potential "instigating" causes of erosion, not solely based on	In regard to the portion of the comment pertaining to thresholds, see response to comment CRWC- 5, Bullet #3. As to the portion of the comment regarding the potential "instigating" causes of erosion, the suggestion here not to use "actual" erosion values but some other metric would be wrought with subjectivity and run counter to the scientifically sound quantification method used for this study. The reviewer does not suggest what kind of "potential instigating" cause should

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	volumetric comparisons of the percent of erosion to value contributing significance. This may allow for a better distinction between natural erosion and channel forming processes and how anthropogenic impacts (such as operational WSE fluctuations) might be inducing additional long-term stream bank erosion.	or could be used except for variations in WSE. WSE fluctuations were directly analyzed in BSTEM as discussed in various other responses.
CRWC-47	Recommendation No. 13. Extrapolation Step 3 - Analyze the Riverbank Features, Characteristics, and Erosion Conditions We recommend that a random detailed review of a portion of the studied sites and the segments described in the FRR, conducted by a third-party reviewer (perhaps a state or federal scientist), to provide a second opinion on what seems to be a potentially subjective process. A period of time and funding may need to be provided for this third party review such that stakeholders are not burdened with the cost of this verification of impartiality. Rationale for comparison of years, and methodology for the earlier data set along with that data set needs to be provided to stakeholders.	See response to comment CRWC-5, Bullet#4
CRWC-48	Recommendation No. 14. Extrapolation Step 4 - Assign each riverbank segment dominant and contributing causes of erosion This analysis only looked only at Reach 4 and 2, limiting potential impacts associated with Vernon operations to Reach 4, and potential impacts associated with Northfield Mountain to Reach 2. Application of results relating to segments seems arbitrary and biased against demonstrating any operational impacts. The determination of dominant and contributing causes by river segment are not always based on similar characteristics, and defaults to splitting a segment halfway between downstream and upstream apparently whenever adequate information was unavailable. It is also unclear how data from study sites that have undergone riverbank stabilization and restoration were or were not incorporated into the final determinations and contributing percentages of erosion. A random detailed review of step 4 must be included in the recommended review of step 3 in our comment #13, to ensure that the study has been conducted in an impartial manner. We also recommend that the analysis be conducted on all reaches of all operational impacts under all flows conditions, as previously stated, and that previously stabilized sites not be included in summaries of contributing percentages of erosion.	See response to comment CRWC-1. In regard to the splitting of riverbank segments as part of the extrapolation approach, delineation of riverbank segments was based on hydraulic, geomorphic, and geotechnical characteristics of the segments as compared to the nearest detailed study site as well as the proximity of the segments to that site. For those sites that were restored within the modeling time period, the BSTEM simulation was run using the initial riverbank conditions and then halted at the time of restoration. New input parameters were then used to represent the restored boundary conditions, and the model was continued. The final set of summary statistics are based on present day riverbank conditions; however, especially in the Northfield Mountain Reach, pre-restoration conditions were taken into consideration when extrapolating the site specific results. This is discussed in Section 6 (Volume II) of the Final Report. Study 3.1.2 was conducted based on state-of-the-science technology and methods by a team of world renowned professionals. The team of experts were approved by MADEP prior to commencing the study. The study methodology, including the detailed study sites which were selected, were approved by FERC and the study was executed in accordance with the FERC approved RSP and SPDL. As noted in various responses previously, the study examined all potential operational impacts throughout the entire geographic extent of the TFI. The repeated assertion that hydropower operations throughout the TFI or all flow conditions were not examined is not factually accurate.
CRWC-49	Recommendation No. 15. Extrapolation Step 5: Conduct supplemental hydraulic and geomorphic analysis in Reach 1 to determine the impact, if any, of Turners Falls Project operations It is noted that the exclusion of the TF operational impact assessment from the BSTEM analysis, was not discussed in the Revised Study Plan. The RSP stated that all operational impacts would be assessed using a similar analysis and methodology. In addition, the study's comments relating to bedrock seem justified at first…, but the only WSE fluctuation graph of Reach 1 included in the Relicensing Study 3.1.2, Figure 5.4.1.1-4, does not seem to support the conclusion that the WSE fluctuation is almost always on the lower bank, which they have stated is bedrock dominated. If in fact, the WSE fluctuation is not all limited to the lower bank, as seems to be demonstrated in Figure 5.4.1.1-4, then the study's concluding assumptions may not be valid. Please confirm with the results of the hydraulic modeling and gaging that the operational WSE fluctuation is limited only to what is defined as the lower bank and does not reach the toe of the bank or any portion of the upper bank. If this cannot be confirmed, then the conclusion of step 5 needs to be reassessed. In addition, it is clear after reading the USDA (11/28/16) review, prepared by a principal designer and developer of BSTEM, that the HEC-RAS stage and discharge data should be utilized and that a BSTEM analysis of the TF operations, similar to what was completed for the NFM operations, can be conducted. It therefore also follows that a scenario could be run with both the TF and NFM operations turned "off". We recommend that this additional scenario be included in the BSTEM analysis, along with a scenario that looks at just TF operations turned "off", as per our review comment #5 [CRWC-35].	All operational impacts from all hydropower projects were assessed throughout the geographic extent of the TFI on an hourly time-step for a 15-year period. The study was conducted in accordance with the FERC approved RSP and SPDL. The scaling of the entire hourly 15 year (2000-2014) period of record on the noted figure can enhance the appearance that the WSE is often on the upper bank. A review of the WSE duration curve for Site 12BL indicates that with a toe of the upper bank at about 183, the WSE is on the upper bank about 10% of the time. During high inflows to the TFI, FL is required to lower the WSE as measured at the Turners Falls Dam based on an agreement with the US Army Corps of Engineers described in detail in Exhibit B of the Final License Application (page B-3). Throughout most of Reach 1above Barton Cove, the TFI starts to gain riverine characteristics under the combination of a low WSE at the dam and high inflow conditions greater than 37,000 cfs. Therefore, most of the time when the EGL slope is high enough to induce shear stress based erosion, the WSE is on the bedrock dominated lower bank, thus limiting erosion. The analysis conducted for this study has also indicated that it is only during extreme flood events such as during Tropical Storm Irene in 2011, that the WSE generally reaches the upper bank. Boating activity generally only occurs during low to moderate inflows when conditions are safe, velocities within the upper part of Reach 1 are lower, and when WSE in Reach 1 can be higher; the combination of which results in boat wake induced erosion on the upper bank.
CRWC-50	Recommendation No. 16. Extrapolation Step 6 - Analyze land-use and width of riparian buffers We recommend that the analysis prepared for step 6 of the extrapolation methodology not be compared directly in this manner with the results determined through the BSTEM analysis.	See response to comment CRWC-5, Bullet #5
CRWC-51	Recommendation No. 17. Extrapolation Step 7 and 8 - Create a map identifying the causes of erosion and calculate summary statistics As previously discussed in our review comment #14 [CRWC-48], NFM operations are shown to be a dominant cause of erosion and are even listed as such in Table 13 on page 40 of Volume I. However the concluding statements from the study, as included below, completely contradicts the analysis results and reflects a potential bias in the extrapolation of the results and the study's conclusions. The study also states that since high flows were such a dominant cause that most of the sites have no contributing cause, which also seems contradicted by Table 13 on page 40 of Volume I.	The report explicitly acknowledges that Northfield Mountain operations were a dominant cause of erosion at Site 8BR-Pre prior to the bank being restored. Following restoration of the bank, Northfield Mountain operations were found to be a contributing cause of erosion at this site. The summary statistics reported for this study are based on the present day riverbank conditions; however, the extrapolation approach took into consideration the condition of the bank prior to restoration at Site 8BR-Pre. No sites in the Northfield Mountain Reach were found to have the same, or similar, conditions as the pre-restoration condition at that site. The summary statistics do not contradict the analysis results and do not reflect bias. On the contrary, the report is quite clear in acknowledging the impact of Northfield Mountain operations at that site,

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	We recommend that the summary tables be revised to reflect the changes in methodology and analysis that we have recommended in our review comments #1 through #17, and that the final tables and figures reflect a consistent summary of the results.	took that into consideration during the extrapolation approach, and found that no sites with those pre-restoration bank conditions exist in that reach of the TFI today. In other words, the only site where Northfield Mountain operations were found to be a dominant cause of erosion has already been remediated. The findings of the study reflect this and were developed in accordance with the FERC approved RSP and SPDL. See responses to comments CRWC-31-50. The tables and figures provided in the report reflect a consistent summary of the results, are based on state-of-the-science technology and methods, and were conducted in accordance with the FERC approved RSP and SPDL.
CRWC-52	Recommendation #18 – Historic Geomorphic Conclusion is Incomplete We recommend that an analysis be prepared that compares past aerial photos with current aerials as requested by FERC, fully understanding that there are some limitation to this approach but agreeing with the utility of this comparison. See, for example, Appendix C to TransCanada's Study 1.	See response to comments CRWC-10, 12, and 13
CRWC-53	Recommendation No. 19 – Operational Water Surface Elevation Fluctuation Characterized Incorrectly Page 24 Vol 1 of the Relicensing Study inaccurately states that "operations can result in water level fluctuations up to 4 feet at a given location over the course of the day", when the daily fluctuation appears, based on the data, to range from 4 to 6 feet with regular peaks in fluctuation closer to 9 feet. In fact, 9 feet of WSE fluctuation is currently allowed based on the FERC license, and yet there was no analysis to show potential erosion on riverbanks if FirstLight exercised the full 9 feet of WSE fluctuation allowed by their existing license on a regular basis in the future. The study also states that "during low to moderate flow periods the water surface in the TFI typically rests on the lower bank" however Figure 5.4.1.1-4 to 6 of the cross sections included in the study on pages 5-58 to 5-60 in Volume II demonstrate otherwise. These figures show that the WSE fluctuations straddle the toe of the upper bank and extend into both the lower and upper bank. We recommend that the study conclusions regarding WSE fluctuations be revised to match the data provided. In addition it would be important to model the full 9 feet of WSE fluctuation allowed based on the FERC license, in the event that FirstLight chooses to exercise the full 9 feet of WSE fluctuation on a regular basis during the course of their new license period.	The reviewer is correct that the reference to a 4 ft. fluctuation on Page 24 Volume I is listed incorrectly. The incorrect text was an oversight when the report was drafted. The correct typical maximum range is up to 6 feet with only very rare daily WSE fluctuations in excess of 6 feet. Figures 5.1.3.1-4 through 5.1.3.1-7 of the final report (Volume II) provides the historical (2000 to 2014) modeled daily WSE variations at four representative locations - BC-1R, 75BL, 5CR, and 4L. At location 75BL (near the Northfield Mountain Tailrace) there were only 13 days with daily WSE variations above 6.0 feet, 4 days over 7 feet and one day over 8 feet. The one day with a daily WSE fluctuation of over 8 feet (8.65 feet) occurred on August 28, 2011 during inflows associated with Tropical Storm Irene. At this location, 8 of the 13 days with fluctuations above 6 feet occurred during days when the daily Vernon discharge was over 18,000 cfs. Similarly, all of the 4 days with daily WSE fluctuations over 7 feet occurred on days when the daily inflow from Vernon was over 18,000 cfs. This relationship indicates that the majority of the time when a daily WSE fluctuation is over 6 feet it is the result of flows from the rising or descending limb of a hydrograph associated with a high flow event. Downstream of the French King Gorge as represented by BC-1R, where the daily fluctuation is largely the result of operations of the Turners Falls Dam, there were 10 days with a fluctuation over 6 feet and no days with a WSE fluctuation over 7 feet. While the fluctuations at BC-1R are based on modeled data, this location is very close to the downstream boundary of the model near the Turners Falls Dam and basically mimics the historic hourly data for the entire 15 years of the modeling period. The range in WSE fluctuations and the hydrologic characteristics of the TFI are discussed in-depth in Volume II, Section 5.1. While the current FERC license allows for a 9 foot fluctuation, FL rarely utilizes its full allowable WSE range. In regard to the location of the WSE relative to bank position, Volume II Section 5.1 also contains detailed discussion and analysis pertaining to the location and duration of hydraulic forces relative to bank position. A water level duration analysis was conducted at a subset of the 25 detailed study sites to determine at what % of time the water surface rests on the lower bank. The results of this analysis found that the water surface rested on the lower bank 79-99% of the time depending on location in the TFI (as one moves upstream the water level rests on the lower bank less (79%) than in the downstream reaches (99%)). This analysis was conducted using the cross-section surveys and results of the HEC-RAS model. As noted in the response to comment CRWC 49, the appearance that the WSE is largely at the toe of the upper bank (or on the upper bank) is an artifact of the scale of the figure's horizontal axis. The results of a water level duration analysis at the sites shown in the noted figures finds results which are consistent to those listed above. That is, for the vast majority of the time the water level rests below the toe of the upper bank. As noted above, the study conclusions regarding WSE fluctuations accurately reflect the historical data. FL did not model the full 9 feet of fluctuation because that is not how the Project currently operates nor was it ever discussed in the FERC approved RSP or SPDL. However, given that BSTEM was run on an hourly time-step for a 15-year period, any instance when WSE fluctuations as great as 9 feet occurred during the modeling period were captured by the model. Finally, as part of its Draft License Application, FL has proposed to utilize increased Upper Reservoir capacity over the term of its new license. Supplemental BSTEM runs are currently being executed to examine what impact, if any, expanded use of the Upper Reservoir may have on TFI erosion. An addendum will be filed with FERC by 4/3/2017 discussing the results of this analysis.
CRWC-54	Recommendation No. 20 – Inaccurate Conclusion on Erosion Commencement The conclusions stated in the Relicensing Study should be revised to reflect the cross-sectional observations of toe erosion as well as the understanding that the cyclical process of fluvial erosion and mass failure, whereby erosion at the toe of a bank can initiate additional bank failure.	See previous responses pertaining to comments on the cyclical process of fluvial erosion. This process is recognized in an analytic way through the modeling process that simulates these cyclic processes. Given that BSTEM models the exact dynamic described in the comment, the results of the study reflect these processes.
CRWC-55	Recommendation No. 21 – Counter-intuitive Conclusion Regarding WSE Fluctuation Impacts	The dynamic referenced by the reviewer refers specifically to Reach 1 in the lower portion of the TFI. The small range of

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	An increase in the WSE fluctuation range due to operations increases the vertical range on the streambank where both boat waves and ice can now impact the streambank, however the study concludes the opposite (in the lower reach at least), claiming that a decreased WSE fluctuation increases the impact of waves on the bank, by stating "the impact of waves in reach 1 can be attributed to the general lake-like conditions found in the lower TFI where water surface elevations vary across a narrow range. The narrow bank of water surface elevation fluctuations focuses wave impacts in the zone where the beach/toe intersect the lower-most part of the upper bank." (Volume I, page 28). This conclusion is counter-intuitive. We recommend that the Relicensing Study provide further support for their reasoning behind this statement, due to the fact that it seems counter-intuitive and the study does not include enough data to prove otherwise.	water-surface fluctuations at the lower-end of the impoundment occur because of proximity to the dam. This concentrates the effects of boat waves along a narrow band of bank, making the waves more effective at undercutting the bank at these sites. This would be similar to a given volume of water being sprayed onto a bank. If it is spread out all over the bank there would be less erosion at any given point than if the spray was concentrated at only one elevation. The data which supports this finding is the observed narrow range of water-surface elevations over the modeling period at the downstream-most sites and the results of the BSTEM modeling which clearly show the impact this has on erosion processes.
CRWC-56	<u>Recommendation No. 22 – Inaccurate Conclusion</u> Page 28 Vol 1 of the Relicensing Study states "The operational differences between the two scenarios was determined to identify the change in erosion rates resulting from operations at Northfield Mountain. The results of this analysis showed very small effects at every detailed study site indicating that Northfield Mountain operations are not a dominant cause of erosion at any location." But the study then states: "except at 8BR-Pre", which they dismiss as significant because it has been stabilized, even though it contributed to 74% of erosion at that site. However recent stabilization of a site does not mean that WSE fluctuations were not impacting the site. Their dismissal of the significance of this impact was then applied across the entire TFI to similar sites that have not been stabilized. They also then state that sites 7L and 119BL also have minor impact due to NFM operations but fail to mention that Table 7 shows that 19 of the sites show some sort of impact due to NFM operations, 7 of them contributing to over 3.7% of the total erosion and 3 of those contributing over 5% of the total erosion. And yet the final concluding Tables show 0% (for dominant) and 4% (for contributing) for NFM operational impacts. We recommend that the results that show operation impacts not be dismissed as insignificant for subjective reasons, and therefore not be applied along reaches that were not included as study sites.	The report explicitly acknowledges in multiple places that Northfield Mountain operations were the dominant cause of erosion at site 8BR prior to it being restored. Since then the site has been restored and Northfield Mountain operations have been found to be a contributing cause of erosion. While the summary statistics provided in the report are based on the present day condition of the riverbanks, the pre-restoration condition found at site 8BR was taken into consideration during the extrapolation of results. In other words, the only site in the TFI where Northfield Mountain was found to be the dominant cause of erosion has since been remediated. The reviewer also notes that sites 7L and 119BL were found to have minor impacts due to Northfield Mountain operations but fails to note that the impact from Northfield Mountain operations at these sites was found to be 0.17 $ft^3/ft/yr$ and 0.09 $ft^3/ft/yr$, respectively. These erosion rates are unmeasurable and statistically insignificant. Erosion rates attributed to Northfield Mountain operations at the other sites alluded to by the reviewer are even less than those values reported at 7L and 119BL (i.e., <0.1 $ft^3/ft/yr$). Results were not dismissed for "subjective" reasons, but based on an analysis of the distribution of the these percentages and the quantification of erosion at each site.
CRWC-57	<u>Recommendation No. 23 – Conclusion Misleading</u> The Relicensing Study's conclusion that most of erosion occurs during high discharges oversimplifies/ignores the bank weakening processes active at lower flow stages (ice, freeze/thaw, wave, etc.). Large flows are likely simply removing material that has been weakened at lower flows. We recommend the study incorporate discussion of the cyclical processes of erosion and, as previously stated, modify their extrapolation methodology and conclusions to reflect that understanding.	The process described by the reviewer is a qualitative description of the processes that we have modeled quantitatively with BSTEM. In fact, it is Simon et al., (1999) that described this and used it as the basis for the development of BSTEM. The results of the study include the cyclical processes of erosion as analyzed for every hour over the 15-year modeling period at 25 detailed study sites that spanned the geographic extent of the TFI. As such, no further modification to the study are warranted.
CRWC-58	<u>Recommendation No. 24 – Conclusion Regarding Ice Potential</u> The Relicensing Study largely cast aside ice as a major erosion factor despite clear photographic evidence of cracked ice sheets/blocks active along the channel margins within the stage-fluctuation ("toe" and "lower bank") zones. These ice blocks will jostle and move with stage changes, abrading the bank surface in the process. They may also detach/reattach to sediments as they move with operationally influenced stage fluctuations. We recommend that the study investigate the potential for increased ice impacts due to operational WSE fluctuations.	The effects of ice coupled with water level fluctuations were investigated based on observations in 2014/2015 when ice formed in the TFI and normal water level fluctuations occurred that winter. Adverse consequences were not observed as indicated by the survival and growth of young woody vegetation. As noted by discussions with the USGS, ice typically does not cause erosion if the ice simply melts in place without significant break-up and if ice floes moving down the river causing ice jams and impacting banks do not occur. If, on the other hand, there is significant break-up, ice floes moving down river with the potential for ice jams that are pushed against and scrape along the banks; then such an event could potentially cause erosion and damage to the riverbanks. Given this, the results of the analysis which was conducted indicate that ice has the potential to be a naturally occurring dominant cause of erosion in the TFI in the future if the right climatic and hydrologic conditions persist.
USGS-1	<u>Section 5.1 Hydrology</u> Comparison of the 1904-60 to the 1961-2014 peak flows would be better if the median value was used versus the average. The average is skewed by the l 936 and 1938 annual peak flows	The median values could be an additional comparison but the differences are relatively minor between the average and the median. The median value for the 1904-1960 period is 93,500 cfs as compared to the average of 97,600 cfs and the median value for the 1961-2014 period is 81,000 cfs as compared to the average of 83,600 cfs.
USGS-2	<u>Section 5.1 Hydrology</u> Was a trend analysis performed on the annual peaks for 1904-2014 to show that there is a difference over time to help support that annual peak flows are lower since flood control dams were completed in 1960?	A trend analysis was not performed partly due to the natural variabilities of flood events and the different time frames that the tributary flood control facilities started operations. The limited analyses on peak flows, as measured at the Montague USGS gage, conducted for this study were completed to generally show that the peak flows during the 2000-2014 period used for the BSTEM analysis were close to the preceding 30+/- years when Northfield Mountain and Turners Falls was in operation under their current license.
USGS-3	<u>Section 5.1 Hydrology</u> In figure 5.1.3-9 (pg. 5-24) where is the discharge data from? Was it physically measured? Or how was it calculated or generalized for each location? These stage discharge curves look nothing like what would to the HEC-RAS stage-discharge polynomial equations in Table 5.4.2.2-3 (pg. 5-74). Also, in the following flow duration curves (figures 5.1.3-10 and 5.1.3-11) there are negative discharges but this stage-discharge relation shows none -so how were there negative discharges in the following flow-duration curve figures?	Figure 5.1.3-9 provides the generalized trendlines for sites 75BL, 5CR, 4L, and 303BL. Table 5.4.2.2-3 provides the stage vs discharge polynomial equations for each detailed study site; created from the HEC-RAS stage vs discharge data. Negative discharges, as shown in the HEC-RAS model, are an indication of flow reversals caused by operation of the Northfield Mountain Project. During creation of the stage vs discharge curves, negative flows required the use of polynomial equations, but Figure 5.1.3-9 only shows the generalized trendlines and not the sections of lines that could represent negative discharges partly due to the low velocities, below the threshold for erosion, that occur during flow reversals.

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USGS-4	Section 5.1 Hydrology In figure 5.1.3-10 (pg. 5-24) and 5.1.3-11 (pg. 5-25) how can the flows be below zero for sites 4L and 5CR, which are upstream of the Northfield Mountain withdrawal?	During a combination of low river flows and high generation at Northfield Mountain, river flow is reversed at locations upstream of the Project. These flow reversals are indicated in HEC-RAS as negative velocities and negative flow values.
USGS-5	Section 5.2 Hydraulics In table 5.2.2-1, the peak flows (10-, 50-, and 100-year recurrence intervals) which came from the effective FEMA Flood Insurance Study are fairly old. The Connecticut River and Millers River peak flows are from "FEMA, 1982, Town of Montague, Massachusetts, Franklin County, 25 p". It is likely that the peak flow data used to provide the estimates at the locations in the table are through the late 1970's or maybe 1980. Thus, there are about 35 years of additional data that could be used for a more accurate estimate of the peak flows using data at the USGS streamgages Connecticut River at Montague City, MA (01170500), Millers River at Erving, MA (01166500), and Ashuelot River at Hinsdale, NH (01161000) for the River2D production run boundary conditions. And likely the Deerfield River at West Deerfield, MA (01170000). The additional 35 years of data would also help in better understanding the effects of flood control structures in the Connecticut River Watershed and Millers River Watershed on peak flows.	If calculating the velocities and shear stresses at the 10, 50, and 100 year flood flows was the main goal of this study, updated peak flows would have been calculated. However, for this study, River2D was used to evaluate velocities and shear stresses over a range of flow conditions in the TFI including normal operating conditions and flood level type flows under steady state conditions. As such, the additional data noted by the USGS was not necessary for the purpose of this study.
USGS-6	Section 5.3 Sediment Transport For this study continuous Suspended-Sediment Concentration (SSC) data was collected at the Rt. 10 bridge and at the Northfield Tailrace. In trying to assess SSC in the study area it seems that to have measured continuous SSC at or above the Rt. 2 (French King) bridge and compared that at the Rt. 10 bridge would have helped assess difference due to the Northfield Tailrace?	The SSC data referenced in the comment was collected for Study No. 3.1.3 *Northfield Mountain Project Sediment Management Plan*, which had different objectives from this study (Study No. 3.1.2). Although Study No. 3.1.3 had different objectives, the data collected as part of that study still provided a valuable supplemental dataset to better understand sediment transport dynamics in the TFI as part of Study No. 3.1.2. One of the main goals of the SSC data collected as part of Study No. 3.1.3 was to better understand sediment transport dynamics specifically during Northfield Mountain pumping and generating cycles as compared to mainstem SSC levels. The configuration of the sampling locations accomplished that goal. In addition, sampling in the vicinity of the French King Bridge would be logistically very difficult and, in some cases, unsafe.
USGS-7	Section 5.3 Sediment Transport Where is the LISST data in Section 5.3? There is no mention of it after it was mentioned in depth in Section 4.2.9 Sediment Transport.	As noted above, the SSC data was collected as part of a different relicensing study. In-depth discussion and analyses pertaining to that study can be found in the report titled, *Relicensing Study 3.1.3 Northfield Mountain Pumped Storage Project Sediment Management Plan 2015 Summary of Annual Monitoring* filed with FERC in December 2015.
USGS-8	Section 5.3 Sediment Transport For the LISST HYDRO data collected via pumping from a point on a river, samples collected from a point location used to estimate continuous SSC for a cross-section of a river are generally compared to concurrent periodic (over the flow range and over time) cross-sectional samples (equal-width increment or equal-discharge increment samples collected with an isokinetic sampler). Was this done? If so. how did the concurrent SSC data compare? Was any correction needed?	Concurrent cross-section data were collected via two different methods over the course of Study No. 3.1.3 as a means of comparison to the point values collected at the edge of river. These methods included using a LISST-100X (Rt. 10 Bridge and Northfield Mountain tailrace) and grab sample collection via a Kemmerer (Rt. 10 Bridge only). Sample collection followed the EWI method. Additional details pertaining to this can be found in the report titled, *Relicensing Study 3.1.3 Northfield Mountain Pumped Storage Project Sediment Management Plan 2015 Summary of Annual Monitoring*
USGS-9	Section 5.3 Sediment Transport Grab samples of SSC are generally not representative of SSC for a cross section of a river. The techniques recommended for accurate determination of SSC for a cross section of a river are equal-width increment or equal-discharge increment sample methods with an isokinetic sampler. See: Edwards, T.K., and Glysson, G.D., 1999, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations Book 3, Chapter C2:89 p., at https://pubs.usgs.gov/twri/twri3-c2/	See response to comment above.
USGS-10	Section 5.4 Analysis of the Causes of Erosion - BSTEM Polynomial equations are not the typical way stage-discharge rating curves are done such as in Table 5.4.2.2-3, page 5-74.	We agree that stage-discharge curves normally do not require high degree polynomial equations; however, the TFI is a complicated area which at times is riverine and at other times more similar to a reservoir controlled by the WSEL at the Turners Falls Dam; this variation can vary spatially and temporally. In addition, the French King Gorge acts as a conveyance control feature at flows generally above 30,000 cfs resulting in limited influence of the Turners Falls Dam on WSEL in Reaches 2, 3, and 4 of the TFI. As this table indicates, the coefficient of determination (R-square) value shown generally decreases downstream from Vernon, indicating a lower fit. Dr. Andrew Simon is a former USGS stream gager and is aware of this. A polynomial regression needed to be used because there are negative flow values. Still, there is no analytic problem with using them with relatively high r^2 values, good agreement with temporal trends and excellent definition of mean conditions across the range of stages.
USGS-11	Section 5.4 Analysis of the Causes of Erosion - BSTEM Table 5.4.2.2-4, page 5-75 some numbers (for example: 500, 6991, and 7051 cfs) seem odd within the column "5% of Erosion: 95% erosion occurs at flows greater than 500 cfs". All are on the lower end of Total Erosion Under Baseline, so that number would seem that it should be a higher discharge	Discharge values for the erosion thresholds at sites 4L (6,991 cfs) and 6AR-Post (7,051cfs) are low, but the erosion rates (0.017 and 0.021ft^3/ft/yr) are also very low resulting in very minor differences in the amount of erosion indicated by the last three columns in Table 5.4.2.2-4. The low discharge value for the erosion threshold at Site 11L is attributed to the hydraulic characteristics and the impact that Vernon operations were found to have at that site.
USGS-12	Section 5.4 Analysis of the Causes of Erosion - BSTEM Figure 5.4.2.2-4 shows that the polynomial equation does not truly fit the stage-discharge data for this site. For example, from a stage of 54.8 meters to about 55.2 meters the flow is steady at about 5,000 or 6,000 cfs (where much of the stage occurs in this example). Also, at the extreme high flow the polynomial equation tails off and doesn't increase with the discharge -but the data does not show this	As discussed in response to comment USGS-10, a polynomial equation with an R-squared value of 0.90 indicates a general fit. This polynomial line shows a limited sloping line in the lower range for equation and flows as described by the USGS. In this figure, the data set for flow values over 80,000 cfs are based only on conditions in late August of 2011 associated with high flows from Tropical Storm Irene. The 'loop' in the stage discharge data at flow above 80,000 cfs and elevations above 59 meters is an indication of how the French King Gorge and travel time affects flows within the TFI. For example, flows largely from Vernon were above 86,000 cfs at an elevation of about 59 meters but later in the event an elevation of

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		59 meters resulted in flows of slightly over 80,000 cfs. Due to issues like these, a very close fit of the stage vs discharge relationship is not possible even upstream of the French King Gorge.
USGS-13	Section 5.4 Analysis of the Causes of Erosion - BSTEM Is one set (3 wells) of "near river" groundwater wells truly representative of groundwater conditions along the Connecticut River for input into the BSTEM model	It is unclear if the limited supplemental groundwater data is representative of groundwater conditions throughout the TFI, however, these data were not input into the BSTEM model. BSTEM uses values of hydraulic conductivity based on soil type and a starting groundwater elevation to model groundwater levels at each time step. The initial groundwater elevation was assumed to be at the level of the surface-water in the channel. The data referenced in the comment were used as stand alone, supplemental dataset independent of the in-depth analysis conducted using BSTEM. The supplemental groundwater data was collected at one location in the TFI which covered a 6-month period of time that included a wide range of flows and WSEs. These data show that the groundwater levels near the river closely follow the pattern of WSE fluctuations and variations in the river. Similarly, the 1979 USACE study monitored groundwater over a relatively short period of time at 6 index sites (in a 141 mile reach of the river, resulting in a similar ratio of ground water date per linear mile of river as in the TFI). These data from the 1979 USACE study show the same results as the TFI data. As cited from the 1979 report, these data: *reveal a near-zero lag time between river stage peaks or troughs. This is primarily due to the nature of the bank material and the proximity of the recorders to the river bank. In general, piezometer readings are closely related to the variation in river stages and represent the inflow-outflow water movement within the banks.*
USGS-14	Section 5.5 Analysis of the Causes of Erosion – Supplemental Analyses Page 5-209, 5-215, and 5-216; although the idea of taking SSC grab samples along the bank as boat breaking waves impact the river bank seems interesting. And they are compared to higher flow "non-boat' traffic. One would need to collect edge water SSC samples when water levels are fluctuating from withdrawals and release from Northfield Mountain, Vernon Dam, etc. For a fair comparison, one would need to compare these samples to all possible conditions were water levels are changing along the river bank	The data referenced in the comment were used as a supplemental, standalone dataset to provide context when discussing sediment transport dynamics in the TFI. Suspended sediment samples were taken near the bank under a wide range of conditions including when boat waves were breaking as well as a range of flow from low to high and a range of operational conditions. These included low through high flows (including Tropical Storm Irene) and when hydropower operations were in effect.
USDA-1	Section 4 Background To accurately characterize the long-term bank erosion rate, the cyclic process of fluvial erosion and mass wasting must be adequately simulated by BSTEM. It appears that the period of this cycle is much larger than the 15-year simulation period for quite a few study sites along the TFI. The consequence is that the estimated long-term erosion rates at the study sites (which should include mass failures) could be underestimated	The cyclic process of hydraulic erosion and mass failure was adequately modeled using the 15-year time period, having included some particularly high magnitude events, including a hurricane. An assertion that a cyclic period of bank erosion is longer implies that erosion rates are low and that hydraulic undercutting over a 15-year period is largely not sufficient to destabilize these banks. Extending the period of simulation might have included additional failures at some sites but because of the increased length of the simulation period, would still have produced low, annual rates of erosion. Furthermore, the modeling period (2000-2014) was chosen as this represents the period for which digital Project operations and riverbank geometry data were available.
USDA-2	Section 4.2.6.6 Resistance to hydraulic erosion …only the measured critical shear stress values are used in the study. The Hanson and Simon (2001) relationship was used to calculate the erodibility coefficient from the critical shear stress value. I wonder why this formulation was used instead of the more recent formulation from Simon et al. (2010), which was derived from many more data sets. Also, for a given critical shear stress value, the erodibility coefficient can vary by several orders of magnitude; the calculated erodibility coefficient value can therefore vary quite a bit from that measured. Though, the erosion estimates were calibrated and this issue may therefore not be important, it could lead to unrealistic calibrated Manning n values	One of the primary authors of the paper cited by the reviewer was Dr. Andrew Simon who was a primary author of Study 3.1.2. The use of the Hanson and Simon (2001) relationship was used because it was based on results using the "original" jet-test device. The uncertainty in estimating the parameter "k" is well established in the technical literature. The variability in "k" described by the reviewer is inherent in the studies cited in the comment. Finally, as pointed out, potential uncertainty is handled through calibration using the roughness coefficient "n", something that all hydraulic and channel-erosion modelers also use in their studies. The roughness values that were employed were based on observed conditions in the field. Further, BSTEM was enhanced during this study to allow for variable roughness values by bank layer, thereby avoiding unrealistic "overall" roughness values. The final roughness values used are provided in Appendix L of the report.
USDA-3	Section 5.4.1.2 Bank resistance inputs The project team used Manning n, because this 'is customary in hydraulic modeling,' as the primary calibration parameter to minimize the difference between simulated and observed erosion at the detailed study sites. However, this is an erosion modeling study not a hydraulic modeling study. Also, the word primary was used, which indicates that other, secondary calibration parameters may have been used in the study. This was not indicated in the study report. Using Manning n as a calibration parameter may be appropriate but it should be explained how Manning n will affect simulated erosion rates.	It is true that "n" is used in hydraulic erosion studies to adjust the magnitude of the flow velocities, water-surface slopes, flow depths or boundary shear stresses being simulated. For erosion studies, hydraulic roughness affects the actual shear stress that is being applied to the grains of bank material, thus reducing the stress acting on those grains. This is referred to as "effective shear stress" and is calculated as an adjustment to the boundary stress as the grain stress squared, divided by the channel roughness squared. Thus, increasing roughness of a layer would decrease the magnitude of the shear stress acting on that layer. This formulation and application is described in the report. Regarding any secondary calibration parameters, if appropriate, the critical shear stress of the materials were increased to account for dense matts of fine roots in the materials. This increase reached a maximum of an order of magnitude, based on USDA research conducted on root-permeated soils.
USDA-4	Section 5.4.1.2 Bank resistance inputs For an excess shear stress equation, a change in applied shear stress is identical to equivalent changes in erodibility coefficient and critical shear stress. Hence, the actual critical shear stress after calibration may not be the same as that inputted.	The effect might be similar but there would be no way to account for the magnitude of the change in each of those parameters. The comment is fundamentally true. In the case that the reviewer describes, the critical shear stress is not changed. The change in roughness "n" for a given layer does not change the critical shear stress but changes the applied (boundary) shear stress. This changes the excess shear stress and hence, the erosion rate. It does not, however, change the critical shear stress.

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USDA-5	Section 5.4.1.2 Bank resistance inputs The details of the calibration conducted for each site are not presented in the report. It is therefore not known how much Manning n was changed and how it could have impacted the conducted analysis	We provided the final calibration values for each layer in the final report. One can see from the "final" n-values that we used (provided in the Appendix L (Volume III)) that they are reasonable for the conditions on the ground that were observed and recorded in the field. Given that the final "n" values are within what is generally accepted for bank surfaces that range from bare to various degrees of vegetated cover and have provided for a calibrated erosion rate, it would seem that selection of these values impacted the analysis appropriately as it was intended.
USDA-6	Section 5.4.2.2 Comparison to other modeling scenarios – Role of naturally occurring high flows Unfortunately, the polynomial rating curves do not adequately represent the significant scatter (hysteresis and hydropower operations) in the flow versus depth data, which can be as large as 30,000 cfs (Fig. 5.4.2.2-4). This scatter is especially large for discharges lower than 40,000 cfs, but can still be as large as 10,000 cfs for discharges exceeding the combined hydraulic capacity of Vernon Dam (17,130 cfs) and Northfield Mountain (20,000 cfs) of about 37,000 cfs. The hourly hydraulics used by BSTEM (water surface elevation and energy slope) was provided by HEC-RAS simulations. A matching discharge value should therefore be available for each water surface elevation. Hence, I don't understand why the project team did not use those discharge values directly instead of the developed rating curve. Given the scatter in the discharge, the erosion exceedance probabilities could be different, the significance of which should be determined. Using the corresponding discharge values should also allow for the sites on the TFI to be analyzed as rating curves could not be developed	As the reviewer states, BSTEM used HEC-RAS hydraulics for stage and EGL at every time step (hourly). At the time the high-flow analysis was conducted, it was determined that it would be very time consuming to go back and obtain the discharge at every time step for each of the 25 sites and for each modeling scenario. In lieu of this, it was decided to establish regressions between stage and discharge and to obtain the discharge value in this way. The reason for using a polynomial regression as opposed to the more common semi-log equations was because the data contained some negative discharge values, precluding the use of a power equation. The polynomial regression provide a very good model of the discharge value for a given stage; certainly as good as any other type of equation. The scatter at lower discharges is of course due to operations. Still, the scatter around the regression does not change the interpretation of the role of high flows, particularly above 37,000 cfs where the regression is much "tighter". In response to the reviewers comment, we compared the results for several sites using discharge values obtained from the polynomial regressions with discharge values obtained directly from HEC-RAS. Results of this comparison showed virtually no difference in the calculations of the discharge levels representing given erosion thresholds. It is true that that using discharge values directly from the HEC-RAS model would allow for the analysis to be conducted at the sites in the TF reach where regression relations were indeterminate. However, this is the reach where the dominant factor in bank-erosion is boat-generated waves. Thus, any differences in discharge relations would have no impact on results or report conclusions.
USDA-7	Section 5.5.1 Hydraulic shear stress data I wonder why the River2D results were not compared to the hydraulic shear stresses estimated by BSTEM. Such comparison could provide additional support to the conclusions of the study that the main controlling process is hydraulic erosion by high, natural flows.	Results from River2D were for only a few steady-state flows and not for the dynamic hourly hydrograph (unsteady flow). A comparison of such would not necessarily be viable because the River2D stresses are depth averaged whereas BSTEM calculates depth variable stresses.
USDA-8	Section 5.5.1 Hydraulic shear stress data No quantitative analysis is performed to determine if the seepage force or the increased pore-water pressure could not only weaken the bank material over a height of 1 ft above the water surface, but also reduce the suction forces in the upper part of the bank. This is important as I assume that during these lower flows the groundwater elevation simulated by BSTEM was at the elevation of the TFI water surface, and therefore this reduction in bank-material shear-strength was not simulated. It would therefore be helpful if the simulated groundwater elevations could be shown. If the simulated groundwater elevations were indeed similar to the TFI water surface elevation for lower flows, the impact of the non-captured increased pore-water pressures by BSTEM's groundwater model could be accounted for by reducing the effective cohesion by an equivalent 1 ft of water pressure (multiplied by the friction angle of the soil).	BSTEM calculates any and all reductions in matric suction throughout the bank profile, adjusting effective cohesion at every time step for each layer. For this study, the effective cohesion was adjusted every hour over the 15-year modeling period. BSTEM also accounts for changes in frictional strength from positive pore-water pressures lower down on the bank where saturation may occur. Thus, the reviewer is incorrect in stating that the reduction in bank strength is not simulated. As described above, these calculations take place at every time step according to the location of the groundwater table and a linear interpolation of the distance above or below that elevation. Groundwater elevations are initially set to the elevation of the free-water surface and are adjusted according to the hydraulic conductivity for each layer as determined by its texture.
USDA-9	Section 5.5.3 Boat waves …the erosion process shown in these Figures (Figures 5.5.3-2a through 2c), wave run up and wave breaking on a beach, was not simulated by BSTEM (cf. Section 4.28) as it does not model this process. This raises the question whether this would increase the importance and amounts of boat-wave erosion relative to that caused by river flows? There are analytical formulas (for example, Iribarren number based formulations) that quantify wave run-up, and could be used to possibly improve the elevation at which waves impact the bank. The turbulence produced by breaking waves can also enhance soil detachment and hence boat-wave erosion. It may be beneficial to perform a sensitivity analysis of various increases of the wave-induced shear stress on the simulated erosion	BSTEM does not directly simulate surf-zone processes including wave breaking and run-up. If the waves are perpendicular to the shore and without flow current, the wave will erode the bank toe and bank face (depending on its resistance) until an equilibrium beach profile is reached. If there is flow current or longshore currents due to oblique waves, the erosion may continue even on an equilibrium slope. Surf-similarity parameter (Iribarren number) is a dimensionless number that relates wave steepness to the beach slope, and it's used to characterize the type of wave breaking. Run-up height can be empirically estimated for a given wave type and beach slope, but it still has to be linked to erosion and undercutting. BSTEM calculates wave erosion up to the water/bank intersection point using wave-related bed velocity and shear stress neglecting shoaling and breaking. Inclusion of this additional process would probably show an even greater role of waves in undercutting the bank face and, therefore, would not change the general thesis of the report.
LCCLC-1	Andrea Donlon, River Steward, Connecticut River Watershed Council (CRWC), said that while understanding about effect of high flow events on erosion she asked about low flow thresholds and the gradual eating away at the toe of the slope and the impact on bank erosion. Andrew Simon responded that his BSTEM model does not tell the cause of erosion, but it can tell you when it happened.	The response attributed to Dr. Simon as noted by the reviewer is not an accurate quote. Yes, there are flow thresholds (as determined by the critical shear stress of the material). These thresholds may be crossed at low flows as well as high flows. It depends on the material strength, the geometry of the bank and the flow, but all are accounted for in BSTEM and the results of the study reflect this.
LCCLC-2	We found that 8BR was not surveyed but "was surveyed as land-based observation point #23. Then we went to 2013 FRR Appendix M, Riverbank segments with causes of erosion, and were not able to find the cause of the erosion. So, how did NMPSP cause erosion on this site, one of the very few for which FirstLight is taking responsibility?	Extensive field data collection occurred specifically for this study at every detailed study site. In addition, all detailed study sites have been surveyed annually. This is described clearly in the final report as well as the *Selection of Detailed Study Sites* report previously filed with FERC. Site 8BR was surveyed on numerous occasions, including: 12/2/1999, 6/2/2000, 8/2/2001, 7/9/2002, 7/14/2003, 6/14/2004, 7/15/2005, 7/15/2006, 10/15/2007, 8/15/2008, 8/15/2009, 8/15/2010, 7/5/2011, 6/28/2012, 9/18/2013, 8/26/2014, and 6/22/2015. Analysis using site-specific geometry and soils data and hydraulics over the study period (2000-2015) were used as inputs to BSTEM, the same as every other detailed study site throughout the geographic extent of the TFI. BSTEM was run on an hourly time-step for the 15-year modeling period at all sites.

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LCCLC-3	We also quoted an article from our local newspaper, The Greenfield Recorder (Davis, p. A1 9/29/16), on the release of Study 3.1.2. A member of the Town of Gill Selectboard, Greg Snedeker, who has lived on the river in Gill for 24 years, said "I read the report, and I could only laugh, because if I didn't laugh, I was going to cry. It's just horrendous. Those of us who live on the river, we see the erosion. We see it every winter, when they lower it down…(with) the mud literally falling into the river. Snedeker said that the impacts of the boats along the river has been worsened since FirstLight began lowering the water level several years ago to maximize how much water it could pump and then release from the mountain reservoir. When the boats go by, the erosion is worse because the river's been lowered to the point where there are drop-offs from the erosion, so when the waves hit, it hits the drop off and pulls the mud down. This is wreaking havoc. Those of us who live on the river, we see it on a daily basis." When the consultants were asked about this observation, they said that the BSTEM model does not measure this? What does the BSTEM model measure if it cannot answer basic questions like these	The consultant referenced in the comment was Tim Sullivan of Gomez and Sullivan. This is not an accurate recollection of what Mr. Sullivan said in response to the comment at the meeting. When Mr. Bathory recited the quote from the newspaper Mr. Sullivan responded that the quote was not consistent with what we have observed from the results of the study. Mr. Sullivan did not say that BSTEM does not measure this. On the contrary, these are the very processes that the BSTEM model simulates; water-level fluctuations, hydraulic erosion, boat waves and mass failure.
Copeland-1	The study claims to be a comprehensive "three level" modeling effort but is in fact completely inadequate to address the issue of ecological impact because it leaves out two of the three fundamental processes that constitute erosion modeling in river systems: detachment, transport and deposition.	Bank erosion was modeled and the dominant processes were simulated, including detachment of materials from the bank. The study was conducted in accordance with the FERC approved RSP and SPDL.
Copeland-2	The report itself, however, gives only scant attention to the transport of sediment (summarized in a word: "downstream"). No mention of transport processes other than high water events are given serious consideration and *no attention whatsoever* is paid to deposition - where the sediments end up - which is the most ecologically consequential of all the impacts of erosion	During the study scoping process, FL was not asked to do a sediment transport study but instead a riverbank erosion study. The RSP was developed in accordance with this request and the study was conducted in accordance with the FERC approved RSP.
Copeland-3	The report focuses almost entirely on detachment, the most visible but least ecologically troublesome process, for which all substantial rivers are well known. Rivers have been eroding their banks for hundreds of millions of years and the biota of rivers are not seriously harmed by it. It is very disappointing that the study spends so much effort documenting the obvious and avoids serious inquiry into perturbations of normal processes that are a direct result of energy infrastructure operations. This should have been the true aim of this contracted study. Their "robust datasets" all fail to inform us how the ecosystem services of the Connecticut River are being harmed by erosion caused by that infrastructure	One of the main study objectives, if not the main objective, was to determine the impact of hydropower operations on erosion and bank stability. The study was conducted in accordance with the FERC approved RSP and SPDL, which reflected multiple revisions per comments received from stakeholders. Investigating how the ecosystem services of the Connecticut River are being harmed by erosion was not one of the objectives of this study. Furthermore, it should be noted that Study 3.1.2 is but one of numerous studies that cover a wide range of issues which have been, or are being, conducted as part of relicensing.
Copeland-4	They make this ridiculous claim: "the models showed that Northfield Mountain operations can only potentially impact erosion processes at riverbank segments within the Northfield Mountain reach. Vernon operations can only potentially impact erosion processes within the Upper reach, and likewise Turners Falls operations can only affect the Lower reach." Since all these river reaches are connected by water transporting and depositing eroded sediments (the other two processes that must always part of any serious erosion modeling effort), this statement is patently false. One may conclude their effort was never intended to be informative in the first place	The report explicitly acknowledges that hydropower operations can impact flow and water levels throughout the entire TFI, especially during low flow periods. In addition, sediment transport occurs freely throughout the TFI. The delineation of hydraulic reaches are based on the hydraulic characteristics of the TFI as determined by the HEC-RAS model. Review of the results clearly indicates four distinct hydraulic reaches based on EGL slope, which is a key factor in determining shear stress. Shear stress plays an integral role in riverbank erosion processes. The delineation of hydraulic reaches does not mean that sediment in the upper reach of the river can't be transported to, or deposited at, a downstream reach as the reviewer seems to claim.
Copeland-5	By being so preoccupied with the bank, they fail to look at the river itself, which can handle sediment *if* the hydrologic processes that characterize free flowing rivers are intact. Because these processes are not intact in these river reaches, the study diverts our attention away from the real harms of the unique forms of erosion caused by the infrastructure, toward the cosmetic and ecologically trivial effects of erosion caused by natural high water events	The *"unique forms of erosion caused by the infrastructure"* were analyzed by the direct use of hourly hydraulic modeling which provides water level fluctuations and EGL variations due to hydropower operations as well as upstream and tributary hydrologic inputs. Erosion due to this aspect of the hydraulics as well as *"natural high water events"* was then evaluated to understand the various causes of erosion. Study 3.1.2 was not an ecological study, but instead was a study focused on geomorphic processes of riverbank erosion. The study was conducted in accordance with the FERC approved RSP and SPDL.
Copeland-6	The data contained in Figure 2 on page: "Distribution of Energy Grade Slope Lines throughout the Turners Falls Impoundment" comes closest to depicting what is really going on. It shows a clear signal from the pumped storage operation, with increased slope lines in that reach compared to the reaches above and below it. This shows without a doubt that the constantly changing water levels from the project there has altered the bank slope. It does so by repeated bank immersion which causes low energy lateral erosion into slack water. The particles released by this low energy process are smaller and stay suspended longer. They slowly settle into the bed of the river, smothering the benthic fauna	The EGL slope data referred to in this comment is the exact data that was used to identify the hydraulic reaches mentioned in comment Copeland-4 which was dismissed by the reviewer as being patently false. The EGL slope in the Northfield Mountain reach is a product of a number of complex hydraulic processes including the geomorphic configuration of this reach (including the French King Gorge) and the presence of the Northfield Mountain Project. The dynamic that the reviewer qualitatively describes (i.e., the impact of water level fluctuations) is the exact dynamic that BSTEM quantified. The study was never designed to examine the ecological impacts of erosion as this was beyond the scope of the FERC approved RSP and SPDL.
Copeland-7	This impact creates a kind of "dead zone" in the impounded areas. This may just be unavoidable in the lower reach of the TFI but every effort should be made to avoid this outcome in the reach just above it, where the pumped storage facility has been operating for years at levels above its licensed capacity in an effort to increase storage during times of "off peak" grid demand.	The study was never designed to examine the ecological impacts of erosion as this was beyond the scope of the FERC approved RSP and SPDL.
MADEP-1	MassDEP would like FirstLight to provide an explanation of the additional modules used in the B-Stem Model which are not typical of a B-Stem Model and the effect of those modules on the B-Model and results.	FL will provide an explanation of the additional modules used in BSTEM which are not typical of BSTEM and the role those modules have in determining the final results by 4/3/2017.
FRCOG-1	We are concerned that much of the foundation work (Tasks 1-3) for Study 3.1.2 is so biased and incomplete that the work conducted under the remaining four tasks is rendered unreliable and the conclusions of the study are fatally flawed. The basis of our concern is the simple fact that the Turners Falls Impoundment is a highly manipulated river with three hydroelectric projects, including two dams and the Northfield Mountain Pumped Storage project, that exert a huge influence on the geomorphology of the river system. Amazingly, FirstLight chose to completely ignore this in the work undertaken for Section 2 – Geomorphic Understanding of the Connecticut River of Study Report	Study 3.1.2 was conducted in accordance with the FERC approved RSP and SPDL. The team of experts, was approved by MADEP prior to the study commencing. The study implemented state-of-the-science technology, was based on scientifically sound methods, and provided multiple levels of independent verification of the results (i.e., modeling, geomorphic assessment, and various supplemental analyses). The majority of the comments received from FRCOG focus on data gathering, literature review, and the geomorphic assessment of the Connecticut River (RSP Tasks 1-3). These

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	3.1.2	were relatively small portions of the overall study which were conducted to provide context when understanding erosion dynamics in the TFI. The bulk of the study was conducted under RSP Tasks 4-7, which were largely not commented upon in the FRCOG letter. As noted in the report, Tasks 4-7 provided the data needed for the input parameters to BSTEM, included a wide variety of modeling (BSTEM, HEC-RAS, River2D), and included various supplemental analyses. The results of the study are scientifically sound and represent the most comprehensive examination of erosion in the TFI conducted to date. While we agree that the flow through the TFI is highly manipulated when flows are relatively low (i.e. less than the hydraulic capacity of Vernon and Turners Falls Dams (17,130 and 15,938 cfs), once flows exceed these values the projects operate in run-of-river mode. Northfield Mountain can operate during high flows; however, as shown in the report, it rarely does so. Furthermore, once flows exceed 30,000 cfs the French King Gorge becomes a natural hydraulic control for the middle and upper portions of the TFI. This hydraulic control would exist regardless of whether the hydropower projects existed. Despite the fact that low flows occur a significant percentage of the time, the data, analysis and observations show that the forces associated with the flow and water level fluctuations under these conditions are very small and are insufficient to cause significant erosion. As shown in the following responses, various studies (USACE 1979, Field, 2007, and Study 3.1.2) confirm the alluvial classification of the Connecticut River (except in limited reaches of bedrock) with the scientific literature supporting the fact that erosion occurs in all alluvial rivers. The analysis of historic aerial photographs reveals that significant erosion occurred prior to the projects (including at 14 of the 20 sites selected for consideration for stabilization as part of the 1999 Erosion Control Plan, in other words eroded riverbanks have been repaired that were eroded before the projects existed). The findings of this study are also consistent with other studies, which acknowledge high flows are a dominant cause of erosion. FRCOG has no basis using facts, data or analysis, to justify their comment when evaluating the effect of hydropower projects considering the entire flow and operation regime in context of appropriate geomorphic, engineering, and computer modeling analysis confirmed by other studies and the scientific literature.
FRCOG-2	We are frustrated and disappointed that much of the work completed for Study 3.1.2 brings us no closer to understanding the complex hydraulic and geomorphic processes at work in the Turners Falls Impoundment. FirstLight did not provide an accurate or scientifically defensible geomorphic assessment of the Connecticut River and Turners Falls Impoundment. The lack of discussion about the impact of dams on the river is particularly egregious and must be remedied.	As noted in the response above, the analysis included in Section 2 (Volume II) of the Final Report was conducted in accordance with the FERC approved RSP and SPDL in order to provide context when discussing erosion dynamics in the TFI. This qualitative assessment provided the appropriate amount of information to satisfy the goals and objectives of this specific task. The complex hydraulic and geomorphic processes are discussed in extensive detail throughout Sections 4-6 (Volume II) of the Final Report, which are largely ignored by FRCOG in their comments. The results of the modeling and supplemental analyses specifically answered the question regarding what impact hydropower operations (and by default dams) have on erosion processes in the TFI. The sections of the report which FRCOG has focused almost all of their comments on were always intended to be a qualitative analysis to provide context given that the other sections of the report examined the quantification of the impacts of hydropower operations.
FRCOG-3	Interestingly, the discussion regarding Implications for Bank Stability for the Missouri River study [excerpt included in comments, Page 7] could have been written for the Turners Falls Impoundment… If FirstLight had performed a reasonable literature search, they would have found many articles with information that could have informed their work for Task 2: Geomorphic Understanding of the Connecticut River, as well as the remaining tasks for Study 3.1.2.	As noted in their comments, the paper cited by FRCOG was written by Dr. Andrew Simon who was one of the primary authors of this study, a developer of BSTEM when employed at the USDA, and oversaw all BSTEM modeling associated with this study. In addition, Dr. Robert Simons (also one of the primary authors of this study) is currently working on sediment transport and erosion issues on the Missouri River. The authors of this study are quite familiar with geomorphic and sediment transport issues on the Missouri River as affected by the series of dams which have been constructed. The magnitude of changes in flow regime, sediment transport and geomorphic response on the Missouri River associated with these huge dams is in a far different league than the effect of dams on the Connecticut River and are not comparable. The literature search conducted for Task 2 focused largely on the TFI and Connecticut River as this was the focus of the study. Literature used included a range of sources including reports by Simons & Associates, Field Geology Services, the USACE, and various other widely accepted scientific literature. These sources provided context and were not used as input parameters for the modeling and supplemental analyses. The field collected data discussed in Section 4 (Volume II) of the Final Report served as the foundation for the detailed analyses conducted during this study.
FRCOG-4	Given the history of dam building on the Connecticut River and its tributaries, the river is the furthest thing from a natural, alluvial river as one could imagine, despite what Section 2 of Study Report 3.1.2 claims.	The comment distorts the discussion of the alluvial nature of the Connecticut River in the TFI. The authors of the report are aware that the TFI is a regulated river during flows below the hydraulic capacity of the hydropower projects. Regardless of this, the geomorphic characteristics of the TFI are consistent with the definition of an alluvial river. The study report states: *With the exception of rare segments (such as the French King Gorge located in the TFI), the Connecticut River is an alluvial river...*

Commenter	Comment	Responses
		As stated above, the Connecticut River is an alluvial river. As discussed in Leopold, et al. (Leopold, Wolman & Miller, 1964), alluvial river systems experience a continual adjustment by processes of aggradation, degradation, scour, deposition, lateral migration, and bank erosion. Even the concept of a river in equilibrium does not mean that a river, so classified, is static and un-changing but instead means that an equilibrium between erosion and deposition is achieved. Based on this concept, the form of the cross-section may not be constant over time and the position of the channel may change, albeit at slow rates. The processes of erosion and deposition can be characteristics of an alluvial stream in equilibrium so long as the changes do not represent large, systematic adjustments over time and space. Changing position, even while retaining overall average channel geometry, necessarily means riverbank erosion occurs even in such channels that are considered to be in equilibrium. This is also the case on the Connecticut River and, more specifically, the TFI. This assessment is consistent with the USACE (1979) report: *A predominant characteristic of alluvial channels is the change in location and shape that the channel and cross sections experience with time. These changes are particularly significant during periods when alluvial channels are subjected to comparatively high flows. . . it can be shown that approximately 90 percent of all river changes occur during that 5 to 10 percent of the time when large flows occur.* *The above comments are generally applicable to all alluvial rivers, including the Connecticut River bordering Vermont and New Hampshire and extending into Greenfield, Massachusetts.* And Field (2007): *Only 10 percent of the channel through the Turners Falls Pool encounters bedrock, however, with most of the channel flowing against glacial, lacustrine, or alluvial sediments underlying the various terraces.* Authors of Study 3.1.2 fully understand that the Connecticut River is affected by a number of hydroelectric dams including the Vernon Dam and the Turners Falls Dam at the upstream and downstream ends of the TFI and the Northfield Mountain Project. While the Turners Falls Dam was raised in the 1970s in conjunction with the construction of the Northfield Mountain Project, the dam does not control water levels in the moderate to high flow regime upstream of the French King Gorge. The hydraulic analysis included in the report demonstrates that during the time when flows and hydraulic forces are greatest – resulting in the greatest amount of erosion, hydropower project effects are minimal and very near "natural" conditions exist. The study report provides a comparison with other reaches of the Connecticut River as well as other river systems. This was done in part based on a recommendation by Field (2007) where he recommended comparison with other river reaches. One of the key points of this comparison was to show that erosion occurs on "natural" alluvial rivers such as those found in national parks where development is very limited and hydroelectric projects are typically not found. This emphasizes the point that erosion occurs and is expected on all alluvial rivers (i.e., both regulated and unregulated) as discussed in the scientific literature. The study report never states that the TFI is a "natural" alluvial river, but that most of this reach is alluvial and experiences erosion as discussed above and as reported consistently by several studies (Field, 2007): *Erosion occurs naturally on all rivers. A river can maintain an equilibrium condition, where the dimensions of the river remain unchanged, while migrating across its floodplain as long as erosion of one bank is balanced by an equal amount of deposition on an opposite bank. Erosion also results as rivers adjust to natural changes in the watershed such as occurred along the Connecticut River long before European settlement after the last Ice Age (see Section 5.1).*
FRCOG-5	We recommend that FERC require FirstLight to review the available scientific literature regarding the impacts of dams on rivers and revise Section 2 – Geomorphic Understanding of the Connecticut River to reflect the current understanding of the geomorphology of large, regulated rivers and to meet the Study Goals and Objectives	The study authors are aware of the effect of dams on rivers, having studied and analyzed these issues on rivers throughout the world for a number of decades, including decades of involvement on the Connecticut River starting in 1978 and continuing through the present. The analysis presented in Section 2 (Volume II) was done to provide context to better understand erosion dynamics throughout the TFI and Connecticut River. This analysis was conducted in accordance with the FERC approved RSP and SPDL. In addition to being discussed in Section 2 (Volume II), the impacts of hydropower operations on erosion in the TFI were studied extensively during RSP Tasks 4-7, which were largely ignored in FRCOG's comments.
FRCOG-6	We ask that FERC require FirstLight to use an available conceptual geomorphic model, such as the Inter-Dam Sequence Conceptual Model, to evaluate the geomorphology of the Turners Falls Impoundment.	The qualitative analysis conducted for Section 2 (Volume II) of the report was done in accordance with the FERC approved RSP and SPDL in order to provide context regarding the erosion dynamics of the Connecticut River and TFI.

Commenter	Comment	Responses
		Quantification of the impact of hydropower operations on erosion in the TFI was conducted based on the analysis described in Sections 5-6 (Volume II) of the Final Report (RSP Tasks 4-7). In addition to not being necessary to achieve the goals and objectives of the RSP, FRCOG's recommendations go well beyond the scope of the FERC approved study methodology. Specific to the Inter-Dam Sequence Conceptual Model referenced by FRCOG, Literature regarding this model was obtained and reviewed regarding potential application to the Connecticut River ("*Large dams and alluvial rivers in the Anthropocene: The impacts of the Garrison and Oahe Dams on the Upper Missouri River,"* Katherine J. Skalak, Adam J. Benthem, Edward R. Schenk, Cliff R. Hupp, Joel M. Galloway, Rochelle A. Nustad, Gregg J. Wiche). This conceptual model was developed using a reach of the Missouri River between Garrison and Oahe Dams. As noted in the response to comment FRCOG-3, both Dr. Simon and Dr. Simons have extensive experience on the Missouri River. The magnitude of changes in flow regime, sediment transport and geomorphic response on the Missouri River associated with these huge dams is in a far different league than the effect of dams on the Connecticut River. Those that developed this Inter-Dam Sequence approach confirm the conclusion that this approach does not fit the Connecticut River situation: *We call this morphologic sequence the Inter-Dam Sequence, and we present a simplified model based on the Upper Missouri River that could be easily adapted to other river reaches. Although the morphologic sequence is a useful conceptualization, there are clear limitations to these results. This model likely only applies to large dams on alluvial rivers. Dams on rivers that are controlled by bedrock or where morphologic adjustment is limited by vegetation or cohesive banks may respond differently than the model presented here. Similarly, the downstream effects of small dams will likely attenuate over much shorter distances.*
FRCOG-7	We note for the record that FirstLight provides only a short paragraph discussing the limitations of the application of the BSTEM model in the Turners Falls Impoundment. BSTEM runs were only done on 22 of the 25 transect locations identified in the Revised Study Plan. FRCOG and other stakeholders previously filed comments with FERC that described our concerns with the transect locations chosen by FirstLight for the BSTEM runs	This comment is not factually accurate. The Final Report clearly states, and provide results for, BSTEM runs which were conducted at the 25 detailed study sites. In the event that a site had undergone restoration during the modeling period, the model was run using both the pre-restoration and post-restoration condition. During the detailed study site selection process, several of the long-term cross-sections were eliminated from consideration for this study for various reasons (usually because they were duplicative of other sites). In order to analyze a representative range of riverbank features and characteristics and to ensure the geographic extent of the TFI was adequately studied, the eliminated long-term transects were replaced with newly identified sites based on the results of land based survey conducted as part of the 2013 Full River Reconnaissance survey (Study 3.1.1). This is detailed in the report titled *Relicensing Study 3.1.2 Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Selection of Detailed Study Sites – September 2014*. As discussed in that report, and in the Final Report for this study, detailed study sites were chosen through consultation with MADEP, FERC, and stakeholders (including FRCOG).
FRCOG-8	We question the use of BSTEM at previously stabilized sites and do not believe the data to be relevant to a discussion of bank erosion. Almost 50% of the BSTEM runs (10 of the 22 transect locations) were performed on stabilized sites. This raises the important question of how was the input data for the pre-stabilization sites determined? We note that the input data for the BSTEM runs for 2L Pre-Restoration and 2L Post-Restoration are <u>exactly the same</u>; the input data for 3R Pre-Restoration and 3R Post-Restoration <u>are almost identical except for the riprap changing a</u> <u>few input parameters</u> for 3R Post-Restoration; and that trend continues for the remaining 3 sets of BSTEM input data for the pre- and post-restoration sites	In the event that a detailed study site was located at a restoration site BSTEM was run for both the pre-restoration and post-restoration condition. Pre-restoration riverbank conditions were determined based on historic full river reconnaissance surveys which have been conducted every 3-5 years since inception of the Erosion Control Plan in 1999. [Andrew/Jen to address their claim about 2L, 3R, and the other] The comment about the input parameters for 2L pre and post restoration being exactly the same is incorrect, the n values were increased to represent the planted banks. The difference between the 3R pre and post restoration is correct that n was increased to represent the rip rap but the n on the other layers was also increased to represent the added vegetation, the comment missed this. The statement that half of the runs were on stabilized sites is also incorrect. Out of the 25 sites 7 were stabilized and BSTEM was run at 5 of the 7 sites under pre-stabilization conditions. The 2 sites that were not run under pre-stabilization conditions were due to the initial surveys occurring too close to the restoration to allow for calibration of the model.
FRCOG-9	FirstLight does not acknowledge what are clear data deficiencies in the data input used for the model, particularly the glaring and inexcusable lack of groundwater elevation data (used less than 1 year of groundwater elevation data (July 97-Feb 98) for 3 wells near the Rt. 10 bridge rather than installing piezometers at each transect); using what appear to be reference values for hydraulic conductivity; and the questionable similarity among transects for the data input for certain parameters, despite the field data collection efforts described in Volume II of the Study Report	See previous responses to CRWC and USDA comments regarding the use of groundwater data. The groundwater data referenced in the comment was used for supplemental analysis independent of BSTEM. BSTEM contains a near-bank groundwater sub-model which took into account the impact of groundwater fluctuations on an hourly time-step over the 15-year modeling period. In other words, the model was adjusted to account for groundwater fluctuations every hour for 15-years. Details on how the BSTEM near-bank groundwater sub-model takes this into account can be found in earlier responses. The field data collection efforts conducted at each detailed study site that were subsequently used as input parameters for BSTEM were conducted in accordance with the widely accepted scientific methods and literature. The data collection and modeling followed sound scientific methods and represent the state-of-the-science. In addition, multiple references for these methods were provided in the Final Report.
FRCOG-10	FirstLight did not do a detailed stratigraphic analysis at the transect sites and used deficient data and analyses from the flawed 2013 Full River Reconnaissance	This comment is not factually accurate. The results of the FERC approved 2013 Full River Reconnaissance survey were used as qualitative descriptions of riverbank features and characteristics as recorded at the time of the survey. As described

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		in Section 4 (Volume II) of the Final Report, extensive field data, collected at every detailed study site, was then used to supplement existing information and as input parameters to BSTEM. This data included: riverbank sediment particle size distribution, erodibility, geotechnical properties, vegetation root density and strength data. Borehole Shear Tests were conducted at every site to determine those characteristics that control shear stress, such as cohesion, angle of internal friction, pore-water pressure, and bulk unit weight. Submerged Jet Tests were also conducted to determine the hydraulic resistance of the bank toe and bank face in order to predict scour and undercutting of the bank within BSTEM. Bulk bank material samples were taken at each location tested by the Borehole Shear Test and Submerged Jet Test. These data were combined with the bulk sample particle size analysis to determine an overall distribution of sizes. These efforts are described in extensive detail in Section 4.2 (Volume II) of the Final Report.
FRCOG-11	FirstLight dismisses the importance of the role that pool fluctuations and seepage play in bank instability despite the findings of the 1979 Army Corps study that indicated that "[a]lthough these forces (pool fluctuations and seepage) are not large in magnitude compared to forces acting on the banks at flood stage, the erosion caused by this combination of factors is significant because the forces have acted continuously and are confined within a fixed zone imposed by the dams and adopted operation techniques	See response to comment FRCOG-9 as well as the various responses to CRWC and USDA comments pertaining to this
FRCOG-12	FirstLight spent a lot of money and time trying to parse out "responsibility" for erosion and, in our opinion, mis-applied a potentially useful tool – the BSTEM model. BSTEM is *typically used to predict streambank erosion, sediment load estimates and test the effectiveness of mitigation and restoration measures*	The BSTEM model as used for this study was appropriate, conducted in accordance with the FERC approved RSP, and adequately satisfied the goals and objectives of the study. The BSTEM model simulated erosion on an hourly time-step over the course of 15 years at 25 detailed study sites which spanned the geographic extent of the TFI. Model runs included both pre- and post-restoration conditions at those sites which were restored during the modeling period. In addition, the results of the BSTEM modeling quantified the amount of erosion and determined the erosion rate of each site. In other words, it did exactly what the comment states it should do.
FRCOG-13	BSTEM has been applied in a range river of environments. Has BSTEM ever been applied to an impoundment and one that is likely to be one of the more dynamic hydropower pools in the country? If not, then the model might overstate the impact of river flow over project water fluctuations as the model was developed in alluvial environments where shear stress caused by river flow is more important than daily fluctuations	BSTEM has and is being applied to other rivers impacted by dam operations. Because BSTEM-Dynamic is a completely deterministic model that contains all of the relevant processes active in the TFI, the model cannot "overstate" the impact of river flow on bank-erosion rates. Because BSTEM-Dynamic contains the ability to vary bank strength according to the distribution of positive and negative pore-water pressures and the water-surface elevations at every time step, it very accurately accounts for bank stability under dynamic water-surface fluctuations typical of hydropower operations. We investigated hourly fluctuations, not daily fluctuations because that would be more reliable to quantify the role of operations.
FRCOG-14	The "methodology" used to extrapolate the BSTEM results is highly suspect and not based on any cited scientific methodology	See responses to previous CRWC comments regarding the extrapolation approach
FRCOG-15	A 2010 investigation used BSTEM to evaluate the impact on bank stability of 6 release scenarios downstream of the Bagnell Dam on the Osage River. This information could inform additional BSTEM runs for the Turners Falls Impoundment	The report that the reviewer refers to is a Master's thesis from the Missouri University of Science and Technology by Kathryn Heinley. In this study Ms. Heinly used the "static" version of BSTEM (ver 5.2). This version does not allow for variations on the elevation of the phreatic surface which makes it not an ideal selection for a study of the role release scenarios because bank strength is not able to vary across the hydrograph. The 2010 thesis attempted to work around this by assuming 2 end-member cases ("best" and "worst) where the groundwater table moved with the surface water in the case of the former, and where bank saturation was assumed in the case of the latter. For the work Cardno did in the TFI, we relied on a much more sophisticated version of BSTEM which calculated these effects at hourly time steps using a groundwater model that was built into the BSTEM code. The scenarios we ran were designed to "tease out" the causes of bank erosion in the TFI by identifying the role of operations, high flows and boat-generated waves. Flow scenarios were run to specifically determine these causes.
FRCOG-16	Two recent (2016 and 2015) peer-reviewed papers regarding the application and limitations of BSTEM are summarized below. We are intrigued by the paper that describes the coupling of two models – BSTEM and a 2-dimensional mobile bed model that accomplishes three things: 1) it predicts the complex flow field and sediment transport within the near-bank zone; 2) it simulates fluvial erosion of the bank face and bank toe in a relatively independent fashion; and 3) it more accurately characterizes how the failed bank materials are removed by flowing water. This enhanced version of BSTEM may be a more appropriate model for the Turners Falls Impoundment and may address some of the short-comings described in the Princeton Hydro and USDA peer review reports	We are aware of the paper referenced in the comment given that two of the primary authors are Dr. Andrew Simon and Dr. Yavuz Ozeren who are members of the Study 3.1.2 team. The BSTEM model used in Study 3.1.2 is the most advanced BSTEM model that exists. It includes enhancements and sub-models that are not included in the version that is contained in the one that is in the 2-D flow model. The model used in Study 3.1.2 does simulate bank erosion; at every node and at every time step. None of the exiting integrated models accurately characterize the removal of failed bank material from the bank toe. This process must be based on a measure of the size distribution of the material once it fails, the river stage, and the shear stress of the flow at the time of failure an subsequently. Attempts have been made by Langendoen (USDA) and others to do this empirically by assuming that the failed material fails as an intact block and not as individual particles and erodes to smaller and smaller particles according to some time constant that is imposed by the user. This approach contains large assumptions and potential errors. The BSTEM version that has been incorporated into 1-D and 2-D models are stripped down versions of the "static" code, and not the enhanced "dynamic" code used in this study. The BSTEM model used in Study 3.1.2 is the most advanced BSTEM model that exists.

Study No. 3.1.3 Northfield Mountain Sediment Management Plan

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USEPA-1	FirstLight has committed to developing dewatering protocols in the future as referenced on page 5-1 of the Northfield Mountain Pumped Storage Project Sediment Management Plan-Final Report. However, EPA's expectation was that these protocols would have been developed and published as part of the Sediment Management Plan Final Report. First Light has performed multiple years of sampling, monitoring, modeling and analysis; and to date it has still not developed a plan and procedures to prevent the release of excessive concentrations of sediment during dewatering events. EPA is concerned about this because prevention of the release of sediment during dewatering events is the most important of several requirements outlined in the Administrative Order. FirstLight also does not provide a schedule of when these plans and procedures will be developed and no schedule of when they will be reviewed or updated. We are concerned that the plan is to only "visually monitor turbidity in the tailrace area throughout the dewatering for any noticeable increases." Under the obligations of FirstLight's NPDES permit, they are required to prevent discharges of sediment that would violate water quality standards. EPA believes that a more robust monitoring program that incorporates more than "visual monitoring" must accompany any dewatering activities in the future. As part of the sediment study FirstLight purchased several suspended sediment monitoring devices that were used to determine suspended sediment concentrations in the Connecticut River, tailrace and power generating structures. These devices should be deployed to monitor suspended sediment concentrations in discharges to the Connecticut River in conjunction with laboratory analyses for suspended sediment concentration and turbidity.	As noted in the comment and referenced on page 5-1 of the Final Report, FL will develop a plan which details the dewatering protocols for two types of dewatering, including: (1) an emergency dewatering, and (2) maintenance or other types of dewatering. Once developed, the protocols will be implemented, in addition to the sediment management measures discussed in Section 5 of the Final Report, in order to minimize the release of sediment during dewatering events. Details specific to monitoring which will occur during a dewatering will be included in the dewatering protocols. FL intends to provide these protocols to MADEP, FERC, and the USEPA by 6/30/2017. The protocols will also include language regarding how often the protocols will be reviewed and updated.
CRWC-1	<u>Upper reservoir bathymetry surveys and sediment accumulation</u> FirstLight has chosen to conduct annual bathymetry studies to understand the accumulation rate of sediment in the upper reservoir. The study concludes on page 4-1 that the accumulation rate of sediment in the upper reservoir, based on two different methods, is ~4,000 to ~8,000 cubic yards/year. In Appendix C, Alden Research Laboratory used the bathymetric studies performed in 2010, 2011, 2012, and 2013 to estimate an average of 17,600 cubic yards of "sediment uptake to the Deposition Zone" (page 36 of September, 2016 Alden Report). Alden used the higher accumulation rate to calibrate a FLOW-3D model. If FirstLight thought the accumulation rate was too high, it is not apparent from the study. FirstLight should explain the order of magnitude discrepancy between its sediment accumulation rate and Alden's.	The accumulation rates which were calculated and discussed in the main report as being between ~4,000 and 8,000 cubic yards/year (page 4-1 and 4-2) were based solely on the area contained within the intake channel and did not include any of the other portions of the Upper Reservoir. By contrast, the accumulation rate calculated by Alden included both the intake channel and a portion of the Upper Reservoir in the vicinity of the intake channel. The Alden accumulation rates referenced in Appendix C of the Final Report were calculated as part of the Alden report titled, *"Engineering Studies of Sedimentation at the Northfield Mountain Project."* In that report Alden cites the "region of significant deposition" as being the intake channel and lower main reservoir, this same area is referred to as the "Upper Reservoir Deposition Zone" in the September 2016 Alden report (Main Report Appendix C). The "region of significant deposition" or "Upper Reservoir Deposition Zone" was the area from which the 17,600 cubic yards/year were calculated. As a result, the difference between the two accumulation rates is largely the result of examining two different sized areas.
CRWC-2	<u>Suspended Sediment Monitoring</u> - *Seasonal patterns and trends observed in relation to flow* The study concludes that suspended sediment concentrations (SSC) in the Connecticut River were relatively low and without an apparent trend when flows from Vernon Dam were below 12,000 cfs; increase between 12,000-35,000 cfs, and were significantly higher when flows exceeded 35,000 cfs. CRWC has examined the Figures and graphs in the appendices. What we have observed is that during spring high flows (above 35,000 cfs), SSC levels increase above 40 mg/L. In the spring, flows between 20,000-35,000 cfs experience low SSC levels (generally below 20 mg/L). However, in the summer and fall, SSC levels above 20 mg/L can be triggered by moderate high flow events in the range of 12,000- 30,000 cfs. We do not concur with the three flow thresholds identified in the report, therefore, and think the report should note the possibility of seasonal thresholds.	Upon re-examination of the plots provided in Appendix D of the Final Report, FL does not agree with CRWC's characterization of the data. While seasonality may potentially impact the amount of sediment that may be available for transport, the plots found in Appendix D very clearly show SSC values above ~50 mg/L and as high as ~160 mg/L when flows are between 20,000-35,000 cfs during the spring, in most instances. As flows continue to rise above 35,000 cfs, SSC values also continue to rise. This pattern is consistent with that observed in the summer and fall during comparable events. The data included in Appendix D of the report supports FL's finding that three distinct flow thresholds appear to exist in regard to SSC levels.
CRWC-3	<u>Suspended Sediment Monitoring</u> - *Patterns and trends observed in relation to flow, Vernon operations, and Project operating conditions.* Figure 4.2.1-15 shows box plots indicating that Northfield Mountain tailrace samples analyzed during pumping had higher SSC than during generating. This fits with the hypothesis that sediment in the river is deposited in the Northfield Mountain upper reservoir. What wasn't investigated in detail is whether pumping concentrations exceeded river concentrations. Are there situations where pump concentrations are higher than ambient river sediment?	In general, SSC values measured in the Northfield Mountain tailrace during periods of pumping were approximately the same as or less than ambient river SSC values observed at the Rt. 10 Bridge (LISST-StreamSide). However, as noted in comment CRWC-4 below, review of the data contained in Appendix D does appear to show some periods when measured LISST values were higher during pumping than the ambient river SSC levels. This is likely due to the fact that each LISST instrument (HYDROs and StreamSide) has unique lenses and is susceptible to instrument-specific sampling error (i.e., indirect laser scattering measurements), rather than actual differences in SSC. In other words, no two LISST instruments are likely to measure the same SSC values from the same water. This is discussed on page 4-16 of the Final Report, which notes that grab samples collected from opposite banks of the tailrace at approximately the same time showed no significant difference yet values measured by the LISST instruments showed noticeable differences. Additionally, the LISST data were relatively temperamental. It was not always clear whether certain data values provided by the instruments were valid, even after manufacturer review; therefore, some time periods when a given instrument provided questionable data may still be present within the dataset. Given this, it is more appropriate to examine the grab sample dataset to determine if there are situations where pump concentrations are higher than ambient river sediment. Review of the grab sample dataset indicates that, in general, SSC values measured in the Northfield Mountain tailrace

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		during periods of pumping were similar to or less than ambient river SSC values measured at the Rt. 10 Bridge. However, there were some instances where SSC values measured at the Northfield Mountain tailrace were higher than those measured at the Rt. 10 Bridge. This likely resulted from variability associated with sample timing and location. Sampling at the Rt. 10 Bridge primarily occurred during daytime hours, whereas samples during pumping from the Northfield Tailrace were primarily collected at night. The most extreme differences, when observed SSC seemed much higher at the Northfield Tailrace relative to the Rt. 10 Bridge, were observed between April 14th and 24th, 2015 when the river had experienced a high flow event. During this event, it appears as though SSC values were in flux, and were highly variable spatially and temporally. As a result, any observed periods when tailrace SSC values appear to be higher during pumping than values measured in the river are likely the result of instrument specific error, differences in sampling location, or differences in sample collection timing as opposed to actual differences in SSC.
CRWC-4	Suspended Sediment Monitoring - *Patterns and trends observed in relation to flow, Vernon operations, and Project operating conditions.* When high spring flows stabilized and declined, there were hints that SSC levels when pumping (yellow and gray) were higher than the ambient river SSC levels (blue dots)…CRWC doesn't have an explanation for a mechanism that would cause higher SSC levels when pumping than is in ambient river levels, other than erosion caused during pumping, but it may be worth additional thought.	See response to comment CRWC-3.
CRWC-5	Suspended Sediment Monitoring - *Patterns and trends observed in relation to flow, Vernon operations, and Project operating conditions.* Other than Table 4.2.2-3, there is no analysis of SSC levels compared to the number of units pumping and generating. Better analysis is needed, showing 1-4 units pumping (only 2 units pumping is shown for a single date), and 1-4 units generating (1-3 units are shown, each on a single date) and concentrations when idle (only a single date is shown). The analysis should include multiple dates, separated by season.	As part of the various modeling efforts undertaken by Alden, SSC levels as compared to the number of units pumping or generating were analyzed. The Alden reports included as appendices to the final report include discussion pertaining to this.
CRWC-6	Sediment Management Techniques Explored - *Physical model testing of exclusion structure* In Section 2.5.3 of the October 2016 Alden Report, it states, "Based on discussions with GDF Suez the target model sediment concentrations shown in Figure 2-12 were identified. At a river flow of 70,000 cfs, a suspended sediment concentration of about 400 mg/L was targeted." As the report points out, a flow of 70,000 cfs has a recurrence interval of 5-10 years (page 7) and the target suspended sediment concentration of 400 mg/L is significantly higher than observed values in the river (page 12). CRWC is unclear why so much effort was put into modeling a high flow event that occurs relatively rarely, and at a concentration not representative of typical conditions. The motive was not stated. Most of the physical model test runs were based on 70,000 cfs. When they ran the test at 40,000 cfs, they used an SSC concentration much lower than observed results. One wonders what the other objectives of the project were.	The purpose of the model was to investigate the benefits of a proposed modification at reducing sediment entering the intake. The proposed design was a sill wall which conceptually limits flow entering the plant to that in the top of the water column. The most conservative testing condition is at the high river flows. At high river flows the sediment exclusion sill is the least effective, providing a conservative estimate of the amount of sediment that might be excluded. While it is desirable to operate the model with a realistic sediment concentration, the actual sediment concentration in the model is not critical. The model was used to compare sediment entrainment with and without the modification. Reductions are given as a percentage not in absolute terms.
CRWC-7	Sediment Management Techniques Explored - *Physical model testing of exclusion structure* The Background section in the October 2016 Alden Report states, "The upper reservoir has experienced chronic sediment accumulation; however, the rate of accumulation appears to have increased in part due to an operational change in the reservoir management… Historically, the reservoir level varied between a high of about 1,000 feet and a low of about 920 feet. More recently the reservoir low water level was increased to 938 feet." CRWC is curious about this statement, since the original license mentioned a low of 938 and this, to our knowledge, has been the license limit of lower reservoir level for the history of the project, other than during temporary amendments.	FirstLight understands that, under former ownership and prior to the required divestiture in 1998 of the generating assets owned by Northeast Utilities, the Project's upper reservoir was operated for brief periods of time outside the licensed reservoir operating limits but within the approved designed storage capacity. These variances, of which FERC was aware, did not cause the lower reservoir to exceed its FERC prescribed maximum or minimum operating levels. Since transfer of the license to Northeast Generation Company in 1999, operations of the upper reservoir at its designed storage capacity have occurred only as authorized by the Commission under temporary license amendments.
CRWC-8	Proposed Sediment Management Measures CRWC recommends FirstLight prepare an addendum to Study 3.1.3 that contains the following details: • protocol to follow during future dewatering events. • levels (or approximate levels) of sediment accumulation in the upper reservoir that would trigger either targeted hydraulic dredging or dewatering and maintenance. If this is not possible, state a maximum number of years between maintenance activities. Note: CRWC asked about this at the study report meeting, and we were told that the information was in the Alden 2014 report. After close read of this report, we believe sediment accumulation trigger levels were not discussed in this report. • FirstLight should specify which technology will be consistently used for future bathymetry surveys (i.e., multi-beam echosounder surveying) so that years can be compared. • FirstLight should identify how much storage capacity it has in the upper reservoir area for dredged sediments, and what the plan is for future disposal/storage options. • Schedule for implementation of plan. • FL should clarify what operational change in upper reservoir management has increased the rate of sediment accumulation, as mentioned in the October 2015 Alden Report.	In regard to the bulleted recommendations: • Bullet 1: Refer to the response to comment USEPA-1 regarding the development of protocols. • Bullet 2: The dewatering protocols to be developed by FL will provide additional information pertaining to this comment. • Bullet 3: It is FL's intention to use a multi-beam echo-sounder for future bathymetry surveys • Bullet 4: The dewatering protocols to be developed by FL will provide additional information pertaining to this comment. • Bullet 5: FL intends to provide the dewatering protocols to MADEP, FERC, and USEPA by 6/30/2017. • Bullet 6: See response to comment CRWC-7.

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

Commenter	Comment	Responses
USFWS-1	Reach 5: HEC-RAS 1-D Model In its Study Plan Determination (SPD), FERC recommended that FL collect mean column and benthic velocity data at representative transects at three calibration flows in Reaches 4 and 5 to validate mean column velocities and any simulated benthic velocities. In the report, FL states that Acoustic Doppler Current Profiler (ADCP) data were collected in 2016 from seven representative transects in Reach 5 to determine whether the theoretical velocity relationship reasonably approximated the conditions in the area. FL does not specify what calibration flow(s) the ADCP data were collected under, but does acknowledge that, due to equipment limitations, the ADCP unit was not able to collect accurate benthic velocity data. Rather than opting to use a different velocity meter that does have the capability of collecting benthic velocity, FL decided to analyze different models to determine which one provided the best approximations of benthic velocities in Reach 5. Based on the information provided in the report, it does not appear that FL performed the validation as required in the SPD. We recommend that FL collect empirical benthic velocity data from at least 5 of the 15 transects in Reach 5 and compare them to the modeled velocities.	The February 21, 2014 SPD recommended collection of mean column and benthic velocity data in reaches 4 and 5 to validate simulated mean column and benthic velocities. FL has not collected these data. Our understanding of this recommendation was that velocity data collection would occur as part of a detailed Reach 5 analysis (task 2b and 3 in the RSP), if FL determined that level-of-effort was necessary. The first phase of the mussel approach (task 2a) was intended to be a screening analysis, based on the existing model that is calibrated to water surface elevation (WSEL) data but not to transect-specific velocity data (mean column or benthic). The first screening analysis, submitted as part of the October 2016 report, was based on 15 transects located throughout reach 5 that were at or near historic mussel survey locations. The transect locations were chosen based on stakeholder input to best represent historic mussel survey sites with varying levels of state-listed mussel abundance (including no abundance). To improve the screening-level analysis accuracy, FL has collected substrate data at 16 transects in Reach 5 and new bathymetry at 11 of those 16 transects. Fifteen of these 16 transects line up closely with the October 2016 report's 15 reach 5 mussel transects; minor adjustments were made to some transects to better line up with historic mussel survey locations, plus one new transect. Five of the 16 transects had relatively recent and higher-resolution bathymetry data which did not require collecting new bed elevations. The 11 transects that did require new bathymetry data (seven transects collected in July 2016, four more collected in November 2016) were surveyed using an ADCP that allowed FL to collect bed elevation and water velocity (mean column and velocity profile) data simultaneously. As discussed with NHESP and USFWS on a 1/4/2017 conference call, FL is not aware of any equipment or methods for collecting benthic velocities (defined as water velocities ~3 inches above the bed) for a non-wadeable river like this on a reach-wide scale at the number of flows and transects that have been requested. While there are methods for collecting near-bed benthic velocities by using a handheld or weight-mounted acoustic Doppler velocimeter (ADV) for small-scale studies, we do not believe it is feasible using these methods to collect reach-wide benthic velocity data in the Reach 5 study area. FL has proposed to estimate benthic velocities using a log-law velocity profile equation. FL did use the ADCP data to collect water velocity data within a foot or two of the riverbed, and was able to use the water column velocity data that were collected to validate the proposed log-law velocity profile equation. FL has laid out a methodology in the next response (see USFWS-2 and Attachment A-Study 3.3.1) that will elaborate on how the existing velocity data will be used to validate the screening-level hydraulic model. Attachment A (Study 3.3.1). also describes the timing of when different datasets (substrate, bed elevation/water velocity) were collected at each transect.
USFWS-2	Mussel Habitat Analysis FL states that the parameters of depth, velocity and substrate were selected to determine habitat suitability of cross sections within Reach 5 for three State-listed species of freshwater mussels. As noted in our comments on Study 3.3.16, we have concerns with the omission of shear stress (SS) and relative shear stress (RSS) as parameters to use in the habitat suitability analysis. Should the supplemental analysis we requested for Study 3.3.16 suggest it is worthwhile to include SS and RSS, we recommend that FL re-run the Reach 5 analysis with those additional parameters.	FL will perform an enhanced screening level analysis of shear stress parameters at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017. The meeting minutes and approach outlined by FL will be provided to USFWS and NHESP and are included as Attachment A (Study 3.3.1). FL will seek feedback from the USFWS and NHESP before finalizing this approach. FL proposes to complete the screening level analysis and file it with FERC on 4/3/2017.
USFWS-3	Mussel Habitat Analysis Another concern with the mussel habitat analysis is that FL assumed the substrate was medium sand throughout the area. By making the assumption that all substrate was suitable, depth and benthic velocity were the primary drivers in the analysis. However, that assumption also could have the effect of overestimating the actual quantity of suitable habitat which in turn could mask the impact of flow and/or project operations on habitat suitability. At an Instream Flow Study meeting held on December 2, 2016, FL informed stakeholders that, based on feedback it had received during the October 31, 2016 Study Report Meeting, it had collected substrate data at additional transects located in proximity to known yellow lampmussel *(Lampsilis cariosa)* beds. This supplemental information will be used to update the project effects analysis.	FL heard this concern expressed at the October 31, 2016 meeting and hence mobilized a field crew in November 2016 to collect transect bathymetry and substrate mapping at four additional transects to supplement the previous work. Now that more detailed substrate data have been obtained by FL in Reach 5 (collected in July 2016 and November 2016), FL will apply the HSC for all species and lifestages separately when performing additional screening level analysis at transects in Reach 5 as noted in the response for USFWS-2.
USFWS-4	Mussel Habitat Analysis A third concern is that FL created two groups of mussels and HSI criteria curves for each group based on similarity of depth and velocity criteria: one for yellow lampmussel juvenile, Eastern pondmussel *(Ligumia nasuta)* juvenile and adults, and tidewater mucket *(Leptodea ochracea)* juveniles, and the other for yellow lampmussel and tidewater mucket adults. As we noted in our comments on Study 3.3.16, FL should provide an explanation for not adhering to NHESP's recommendation to not use a composite HSI for all three species and both life stages. On the contrary, NHESP stated that habitat modeling should be conducted separately for each species and life stage.	As presented in Tables 3-1 and 3-2 of the Delphi report (Study No. 3.3.16), the binary HSC scores were presented separately for both adult and juvenile lifestages of the three Massachusetts state-listed mussel species. The HSC for several species and lifestages were composited for the analysis in the IFIM Report because the only difference in the criteria was substrate for yellow lampmussel juvenile, Eastern pondmussel juvenile and adults, and tidewater mucket juveniles. In the IFIM report, it assumed that all substrate in Reach 5 was suitable for all species and lifestages, so composite HSI were used. As noted in the response to USFWS-3, FL will apply the HSC for all species and lifestages separately when performing additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call

Commenter	Comment	Responses
		on January 4, 2017 (see USFWS-2).
USFWS-5	Mussel Habitat Analysis In the Revised Study Plan (RSP), FL proposed that "using the binary HSI criteria...determine if any binary HSI thresholds are not met under a range of modeled operating conditions anywhere in study reach 4 or 5."Based on the narrative in this section of the report, it appears that project effects were only assessed at the 15 transects where ADCP data were collected by FL. Given that mesohabitat was mapped for all of Reach 5 and that the hydraulic model also covers all of Reach 5, it should be possible to run both steady state and dual flow analyses for the three mussel species within Reach 5. These analyses would provide additional information relative to the overall quantity of suitable habitat and how much of that habitat persists between various base/peak flow combinations. Also, this section should acknowledge that project effects will be analyzed using both steady state and persistence modeling for State-listed mussels within Reach 3.	FL will perform additional screening-level analysis at the Reach 5 transects , as discussed with USFWS and NHESP during a conference call on January 4, 2017 (see USFWS-2). The additional screening-level analysis will be based on the 16 transects with detailed substrate data, as described in Attachment A (Study 3.3.1). At a December 2, 2016 stakeholder meeting to discuss the IFIM study and specifically what steady state and flow pairs to evaluate persistent habitat in Reach 3, NHESP noted that the yellow lampmussel was not assessed in Reach 3. At that meeting, stakeholders provided FL with a list of flows to evaluate and species/lifestages to assess (including yellow lampmussel), which FL will conduct and provide as an addendum to this study. FL proposes to file the addendum on 4/3/2017. Minutes from the December 2 meeting are located on FL's website (http://www.northfieldrelicensing.com/Lists/Document/Attachments/389/120216_IFIM_Meeting_Minutes.pdf).
USFWS-6	Habitat Time Series (Reach 4) FL states that the habitat time series analysis was done by merging the habitat versus discharge relationships for all target species and life stages with the Montague USGS gage hourly flow data to yield habitat time series for Reach 4. While the output portrayed in Figure 5.5.4-1 shows habitat versus time at a sub-daily time step, the actual output curves provided in Appendix J were at a monthly time step. Monthly habitat duration curves are not helpful in discerning impacts of a daily peaking operation on habitat, as fluctuations in habitat are greatly masked. The curves should represent habitat versus time on a sub-daily time step for representative seasonal periods. In the report, FL acknowledges that habitat time series analysis has yet to be conducted for Reach 3. An addendum will be provided at a later date containing the Reach 3 results. The comments we provided for the Reach 4 analysis also apply to any curves generated for Reach 3.	As USFWS notes, habitat duration curves were developed in Reach 4 using hourly flow data at the Montague USGS Gage for the period January 1, 2000 to October 1, 2015 (plus intervening inflow) and converting the flow to habitat using the WUA vs flow curves derived from the steady state analysis in Reach 4. The computed WUA values were subsequently converted to monthly WUA duration curves. USFWS notes that the habitat duration curves are not helpful in discerning impacts of a daily peaking operation on habitat. At a stakeholder meeting on 12/2/2016, FL/stakeholders discussed the form and format for habitat time series. At that meeting it was agreed that FL would identify a week within each season to develop the habitat versus time plots. for existing (baseline conditions) by selecting one week in calendar year 2002—this is the year for which the operations model has already been developed (note that the operations model is on an hourly time step so the plots will show habitat changing every hour). FL would compute the time varying habitat for the spawning life stages of shortnose sturgeon, shad, juvenile yellow lampmussel, adult yellow lampmussel and sea lamprey in addition to darter, juvenile dace, deep-fast guild, deep-slow guild. FL agreed to provide results (habitat vs time) to stakeholders for review and comment and recognized that other scenarios/species plots may be requested. Minutes from the December 2 meeting are located on FL's website (http://www.northfieldrelicensing.com/Lists/Document/Attachments/389/120216_IFIM_Meeting_Minutes.pdf). FL recognizes that habitat time series analysis has not been completed in Reach 3 and will be included in addendum along with the information discussed in the above paragraph. The addendum will be filed with FERC by 4/3/2017.
USFWS-7	Reach 1-Left Channel It would be helpful to have a figure showing the location of the cross section where the headpin and tailpin loggers were located. Reach 1-Center Channel Similar to our comment in Section 6.1.1.3, we request that a figure be included showing the locations of the five cross sections where velocity data were collected.	See Attachment B (Study No. 3.3.1) for the requested figure.
USFWS-8	Habitat versus Discharge Relationships Reach 3 State-listed mussels have yet to be analyzed. The results of that analysis should be reported in an addendum.	See USFWS-6. FL will also assess yellow lampmussel in Reach 3 as part of the addendum to be filed with FERC by 4/3/2017.

USFWS-9

Tables 6.2.4-1 through 6.2.4-3 of report

The way data are presented in the tables is confusing. For example, a maximum Weighted Usable Area (WUA) of 2,021,880 square feet is identified for American shad *(Alosa sapidissima)* spawning/incubation at a flow of 5,000 cfs, yet the persistent habitat table (H-9) shows that at a bypass flow of 5,000 cfs and Cabot Station operating at 2,500 cfs, there is 1,988,201 square feet of spawning habitat. These same minor discrepancies appear to carry throughout the tables. FL should explain why the values differ between the steady state and persistent habitat analyses.

The difference in WUA and persistent habitat at a given flow is due to a difference in how each is calculated. This relates to the difference between WUA and quality habitat, as persistent habitat is calculated by looking on a node-by-node basis and determining which nodes are consistently calculated as ‘quality’ over a range of flows. Our definition of ‘persistent habitat’ could also be more explicitly called ‘persistent quality habitat’. The difference between WUA and quality is described below.

A node’s WUA is calculated as the node’s combined habitat suitability (CS) multiplied by the nodal area (i.e., the river area encompassed by each model node), for each species/life stage at each flow. A node’s CS can range from 0 (no habitat) to 1 (ideal habitat), or any value in-between. For example, if a given node has a CS of 0.6 and a nodal area of 100 ft^2, then the nodal WUA is 0.6 *100 ft^2 = 60 ft^2. If that node had a CS of 0.15, then the nodal WUA is 0.15 * 100 ft^2 = 15 ft^2. The sum of the nodal WUA values equals the reach-wide WUA.

Quality habitat is defined as a node with a CS ≥ 0.5, as stated in the RSP. To simplify the analysis, nodes were defined as either quality (if CS ≥0.5) or not quality (if CS < 0.5). If a node’s CS = 0.4, it is marked as a 0 (not quality); if a node’s CS = 0.5, it is marked as a 1 (quality). Nodal quality habitat was calculated as the quality flag (either a 0 or a 1) multiplied by the nodal area. Using the same example nodes as above, if the CS = 0.5 then it is quality (marked as a 1) and the nodal quality habitat equals 1.0 * 100 ft^2 = 100 ft^2; if the CS = 0.15 then it is not quality (marked as a 0) and the nodal quality habitat equals 0 * 100 ft^2 = 0.0 ft^2. If the node had a CS = 0.9 then it is also quality (marked as a 1) and the quality habitat similarly equals 1.0 * 100 ft^2 = 100 ft^2. The reach-wide quality habitat is calculated as the sum of all nodal quality habitat values.

Table 1 below shows the difference between the two calculations. Because of the different calculation methods, the total WUA and total Quality Habitat values can be (and often are) different. Total quality habitat may be more or less than the WUA at the same flow, depending on the distribution of the CS values.

Table 1: Example WUA vs. Quality Habitat calculation for a given species/life stage at a specific flow.

Node	Nodal Area (ft^2)	Combined Suitability	WUA (ft^2)	Quality?	Quality Habitat (ft^2)
1	100	0.2	20	No (0)	0
2	100	0.3	30	No (0)	0
3	100	0.4	40	No (0)	0
4	100	0.5	50	Yes (1)	100
5	100	0.6	60	Yes (1)	100
6	100	0.7	70	Yes (1)	100
Total	**500**	**N/A**	**270**	**N/A**	**300**

Persistent habitat is defined as a node being ‘quality habitat’ between a range of flows. The intent is to identify consistently high quality habitat over a defined flow range to address peaking impacts. If, for example, we wanted to determine persistent habitat for a Cabot flow range between 4,000 cfs and 6,000 cfs (assuming a constant bypass flow), we would look at whether a node was considered ‘quality’ for the entire flow range. Table 2 below shows a sample calculation. We also required a given node to be ‘quality’ for both modeled Deerfield flows in order to be considered persistent habitat.

Commenter	Comment	Responses

Table 2: Example WUA vs. Quality Habitat calculation for a 4,000-6,000 cfs Cabot flow range for a given species/life stage at a specific bypass.

Node	Nodal Area (ft^2)	CS @ 4,000 cfs	CS @ 4,500 cfs	CS @ 5,000 cfs	CS @ 6,000 cfs	Quality @ 4,000 cfs?	Quality @ 4,500 cfs?	Quality @ 5,000 cfs?	Quality @ 6,000 cfs?	Persistent from 4,000-6,000 cfs?
1	100	0.4	0.5	0.9	0.8	No	Yes	Yes	Yes	No (0 ft^2)
2	100	0.5	0.5	0.5	0.5	Yes	Yes	Yes	Yes	Yes (100 ft^2)
3	100	0.6	0.8	0.8	0.45	Yes	Yes	Yes	No	No (0 ft^2)
4	100	0.9	0.9	0.8	0.6	Yes	Yes	Yes	Yes	Yes(100 ft^2)
5	100	0.1	0.9	0.8	0.4	No	Yes	Yes	No	No (0 ft^2)
6	100	0.9	0.7	0.4	0.6	Yes	Yes	No	Yes	No (0 ft^2)
Total (ft^2)	**500**	**340**	**430**	**420**	**335**	**400 ft^2**	**600 ft^2**	**500 ft^2**	**400 ft^2**	**200 ft^2**

In summary, the WUA values reported in Tables 6.2.4-1 through 6.2.4-3 are calculated using a different methodology than the persistent habitat values in Appendix H. This method was used on other projects (Delaware River mussel analysis, Conowingo Dam IFIM analysis) that this study plan was modeled after.

Commenter	Comment	Responses
USFWS-10	Mussel Habitat Analysis (Reach 5) We request that, for each transect, FL provide the HEC-RAS model output tabular data showing depth, benthic velocity, substrate and suitability for each interval along the transect for each flow and backwater condition analyzed. Each of the 15 transects was placed in an area where mussel surveys had previously been conducted. Those mussel surveys provided qualitative assessments of substrate, yet FL chose to assume sand substrate throughout Reach 5. FL should include transect-specific substrate data to the extent it is available.	FL will perform additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1). FL proposes to complete the screening level analysis and file it with FERC on 4/3/2017. Tabular data will be provided in an appendix to the screening level analysis.
USFWS-11	Mussel Habitat Analysis (Reach 5) As noted in our comments on Study 3.3.16, the NHESP has recommended not grouping the three State-listed mussel species into two categories (or "criteria"); rather, each species and life stage juvenile and adult) should be analyzed separately.	FL will apply the HSI for all species and lifestages separately when performing additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1). FL proposes to complete the screening level analysis and file it with FERC on 4/3/2017.
USFWS-12	Mussel Habitat Analysis (Reach 5) Likewise, our comments on Study 3.3.16 noted that there was no supporting documentation justifying the exclusion of SS and RSS as habitat parameters to include in the analysis.	All of the email correspondence with panelists is included as Attachment A (Study 3.3.16) in the responses to comments on Study 3.3.16.
USFWS-13	Mussel Habitat Analysis (Reach 5) For the qualitative categorization of project effects, FL used intervals that were unequal and subjective (e.g., "minimal" and "low" effects were at 10 percent intervals, whereas "moderate" through "severe" effects were at 20 percent intervals). FL should provide a justification for its selection of intervals or, in consultation with NHESP, develop a new interval categorization system.	FL plans to present transect-by-transect suitable areas (% suitable vs. flow) in the addendum. If the addendum uses interval categorizations to report results, FL will consult with NHESP for a new interval categorization system.
USFWS-14	Mussel Habitat Analysis (Reach 5) While inclusion of spring flows in the analyses is useful as a point of comparison, results should be viewed in the context of the duration and periodicity of these high flow events. Relative to daily fluctuations that occur due to project operations, a flow of 38,600 cfs occurs less than 10 percent of the time on an annual basis. Additionally, the hydrograph ascends and descends from that flow gradually, affording mussels an opportunity to react/adjust appropriately (e.g., burrow down into the substrate). Fluctuations in relevant hydraulic parameters happen more abruptly and more frequently as part of daily project operations.	Habitat suitability including SS values will be analyzed under various flows within the operational limits of the Turners Falls Project, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1). FL proposes to complete the screening level analysis and file it with FERC on 4/3/2017.
USFWS-15	Mussel Habitat Analysis (Reach 5) For the comparison of yellow lampmussel abundance with modeled effects, FL should clarify whether abundance relates to total number of mussels found or the catch per unit effort (CPUE) of mussels. Given that survey effort was variable with respect to number of observers, time spent surveying, and length of survey area, CPUE would be a better metric to us.	The initial report referred to total number of mussels found at each site in Reach 5, and were categorized based on recommendations from NHESP based on qualitative abundance (high, med, low, etc.). Mussel abundances is reported as CPUE in surveys conducted by HG&E and can be used in future analysis of Reach 5.
USFWS-16	Mussel Habitat Analysis (Reach 5) In addition to the analyses FL undertook, as identified in Section 5.5.2 above, we recommend that FL run both steady state and dual	FL will perform additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A

Commenter	Comment	Responses
	flow analyses for the three mussel species within Reach 5 in order to provide additional information relative to the overall quantity of suitable habitat and how much of that habitat persists between various base/peak flow combinations. Currently, project effects have been evaluated only at the 15 transects identified. This does not meet the RSP objective of determining if any binary HSI thresholds are not met under a range of modeled operating conditions anywhere in study reach 4 or 5.	(Study 3.3.1). FL proposes to complete the screening level analysis and file it with FERC on 4/3/2017. The new screening-level analysis will include steady-state and dual flow analyses.
USFWS-17	Mussel Habitat Analysis (Reach 5) We understand from the water level logger data as presented in Study 3.2.2 that the farther away from Cabot Station discharge, the more moderated project-induced flow fluctuations are (Figure 1). Likewise, the more upstream from Holyoke Dam one gets, the less the backwater influence from that dam (which also would act to moderate flow perturbations). Table 6.2.6-2 suggests a general trend of increasing operational flow effects with decreasing distance to the project. The most upstream transect was located at River Mile (RM) 106.344, approximately 3 miles downstream of the Route 116 Bridge in Sunderland, Massachusetts (which is the beginning of Reach 5; Rainbow Beach is at RM 94.298). There also appears to be a general trend of decreasing yellow lampmussel abundance with decreasing distance to Cabot Station. All of these factors suggest a need to quantitatively assess all of the habitat within Reach 5 to better understand the impact of project operations on the quantity of suitable habitat under steady state and base/peak flow conditions. In addition, because freshwater mussels are relatively sedentary organisms, FL should assess the rate of change to habitat suitability within Reach 5 over the course of a peaking cycle during representative time periods (e.g., spring, summer, fall) based on distance from the Route 116 Bridge (e.g., every RM from Route 116 to Dinosaur Footprints). These rates should then be compared to the burrowing capabilities of the target mussel species.	Based on the impoundment-wide surveys for HG&E, yellow lampmussels occur at variable densities from the Holyoke Dam to near the Mill River confluence, with highest densities in the reach from Brunelle's Marina to Mitches Marina. During surveys conducted over the last 20 years, yellow lampmussels have not been found farther upstream than the Mill River confluence. In FERC's 2/21/2014 study plan determination, it addressed the rate of change analysis. FERC indicated that this analysis was not necessary as we are not aware of any mussel-related rate-of-change thresholds or criteria, nor has MADFW or others proposed any methodology to determine these thresholds. It is also unclear how such an analysis, if a threshold were defined, would be used to inform flow management decisions.
USFWS-18	Habitat Time Series (Reach 4) As noted in our comments under Section 5.5.4, we do not believe that converting habitat versus time curves to monthly habitat duration curves is appropriate. The objective of this type of analysis is to assess how project operations affect target species/life stage habitat at the relevant time step. In this case, because Turners Falls Project operates as a daily peaking facility, a daily time step is appropriate. FL should generate curves that represent habitat versus time on a sub- daily time step for representative seasonal periods. Likewise, habitat time series should not be restricted to certain life stages. One of the benefits of this type of analysis is the ability to understand how temporal changes to the quantity of suitable habitat could impact any particular life stage. For instance, a theoretical habitat time series curve for juvenile fallfish in Reach 4 under typical August flow conditions would show nearly 8 million square feet of habitat during base flow conditions interspersed with dramatic drops down to 2 million square feet of habitat during peak generation. The frequency, duration and magnitude of those fluctuations have important implications on intraspecific competition as suitable habitat becomes restricted/limiting. Output format and specific production runs for the Habitat Time Series analysis for Reach 3 were discussed at a meeting held on December 2, 2016. FL and the stakeholders agreed that FL would provide habitat versus time hydrographs (e.g., one week per month) for the current operating conditions using a typical water year (e.g., 2002) for the species and life stages used in the persistence and steady state analyses for that reach. Based on those results, stakeholders will be able to provide additional recommended run scenarios (i.e., using different water years and/or operational constraints) if needed.	As noted in USFWSs comment, the output format and specific production runs for Reach 3 were discussed at December 2, 2016 meeting. FL agreed to provide habitat versus flow hydrographs on an hourly time step for one week for typical operating conditions using a typical year (in this case 2002 since the operations model was developed for this year).
USFWS-19	Discussion: Reach 5 FL states that its decision to assume all substrate was sand resulted in conservative benthic velocity calculations, but notes that variability of substrate across transects and within the reach would affect mussel distribution. While not previously presented in the report, FL then describes coarse-scale substrate survey data it says were collected during the 2016 ADCP surveys (transects from RM 88.5988 to RM 92.9704) as consisting primarily of sand. FL hypothesizes that substrate may become a more limiting factor in upstream areas of Reach 5. Substrate data from upstream areas of Reach 5 do exist. As noted in our comments under Section 6.2.6, FL collected mesohabitat data (including substrate characterization) as part of the subject study. In addition, the Holyoke Gas and Electric mussel reports (Tighe & Bond 2006; 2010; 2014) contain qualitative substrate characterizations. Those data sources indicate that sand is the dominant substrate up to approximately RM 105. FL goes on to cite a conclusion from Study 3.3.16 relative to SS and RSS being most relevant for mussel habitat at high flows. We have responded to that argument in our comments on Study 3.3.16. While we will not reiterate those comments herein, we do note that in the analysis provided by FL's consultants in Study 3.3.16 to support its contention that only high flows are important, the SS and RSS values were based on a mussel size of 2 inches or larger. This size range does not cover juvenile mussels. Because	Now that more detailed substrate data has been obtained by FL in Reach 5, FL will apply the HSI for all species and lifestages separately when performing additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1). FL proposes to complete the screening level analysis and file it with FERC on 4/3/2017.

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	juveniles are smaller, they would require less flow to reach a RSS threshold. Therefore, it is possible that flows within the operational control of the project would exceed threshold RSS values for juveniles, which would reduce the likelihood of mussel settlement and/or result in scouring juveniles off of sediment. We recommend that FL broaden the RSS analysis to account for smaller particles (i.e., juvenile mussels). FL assumes that State-listed mussels may be absent from transects in the upstream areas of Reach 5 due to factors independent of the operational effects modeled, such as the movement patterns of host fish limiting dispersal. We maintain that it is premature to draw conclusions, given that FL has yet to comprehensively assess mussel habitat in the context of project operations throughout Reach 5.	
USFWS-20	<u>Appendix B - Reach 1 - Right Channel - Single Transect Model - Habitat Versus Flow Relationships</u> It is unclear why, in the graphs of WUA versus flow, the x-axis stops at 4,000 cfs, given that: (1) the Reach 1 curves for Transects 10 and 11 (Appendix C) go up to 7,500 cfs; (2) the Reach 2 curves go up to 10,000 cfs; and (3) the bypass flow range evaluated for the persistence analysis in Reach 3 extended to 5,000 cfs.	4,000 cfs was the highest modeled flow for Reach 1-Right Channel. The hydraulic model results were not deemed reliable for flows exceeding 4,000 cfs.
USFWS-21	<u>Appendix F - Reach 4 - Habitat Versus Discharge Relationships</u> It is unclear why the x-axis has flows well beyond the operational capacity of the project. We recommend that the figures only graph flows from 0 cfs up to 20,000 cfs (or 30,000); that way, it would be easier to see what flows correspond to what WUA in the flow range controlled by the project.	FL proposes to revise the figures as requested and file them with FERC on 4/3/2017.
USFWS-22	<u>Appendix J – Reach 4 – Habitat Time Series Results – Monthly Habitat Duration Curves</u> The graphs in this section portray monthly habitat duration curves. For daily peaking projects, monthly habitat duration curves do little to inform how habitat changes over the course of a peaking cycle. FL should redo the figures to show habitat on the y-axis, and time (either daily or weekly) on the x-axis, by species/life stage for each reach for a representative time period (e.g., a week in late May/early June for shad spawning). In order to capture a range of conditions, the analysis should be run for a representative "wet," "dry," and "average" water year.	See USFWS-18.
NMFS-1	<u>Appendix E</u> Figures E-1, E-2 and E-3 display WUA and percent of maximum WUA results for spawning and incubation, juvenile and adult life stages of American shad, respectively. The overall trend of these results is that for a given Cabot Station flow, increasing flows in the bypass reach increase the total amount of usable area for American shad of all life stages in Reach 3. These results do not display at what flow the maximum WUA is achieved.	Tables 6.2.4-1 through 6.2.4-3 display the flow at which the maximum WUA is achieved for Reach 3.
NMFS-2	<u>Study Modification Request</u> Based on the observations of spawning sea lamprey (Relicensing Study 3.3.15), we request that FirstLight update the velocity and depth Suitability Index (SI) curves for spawning sea lamprey (Relicensing Study 3.3.1). Because direct observations were made on spawning sea lamprey and sea lamprey developing their redds on the mainstem Connecticut River and four of its tributaries, we conclude that these observations are the most recent and most geographically applicable observations for development of SI curves for this species and life stage. By using updated SI curves, we can more accurately determine the impacts to sea lamprey spawning habitat in the maps and graphs that are generated for this species and life stage. This study does not require field work. Rather, our request is that FirstLight use newly generated data from one study to inform another.	The sea lamprey HSI values used to develop suitable habitat mapping were not consistent with our findings during the 2015 study period. Lamprey spawning habitats assessed during this study consisted mostly of cobble dominated substrates and depths outside of the range used to map suitability. However, it is outside of the scope of this study to revise or quantitatively modify the HSI curves. Observational data collected in this study can be used to interpret IFIM results for Sea Lamprey.
MADFW-1	<u>Habitat Time Series (Reach 4)</u> FirstLight (FL) states that the habitat versus discharge relationships for all target species and life stages analyzed were merged with the Montague USGS gage hourly flow data to yield habitat time series for Reach 4. The example, Figure 5.5.4-1, shows habitat versus time at an hourly time step, however, the actual output curves provided in Appendix J are at a monthly time step. Monthly habitat duration curves are not helpful in discerning impacts of a daily peaking operation on habitat. The curves should represent habitat versus time on a sub-daily time step for representative seasonal periods. In the report, FL acknowledges that habitat time series analysis has yet to be conducted for Reach 3. The Reach 3 analysis should likewise represent habitat versus time on a sub-daily time step for representative seasonal periods.	See USFWS-18
MADFW-2	<u>Reach 5: HEC-RAS 1-D Model</u> According to Section 5.3.4, in Reach 4 FL collected mean column velocity at a single calibration flow (5,988 cfs) but did not collect mean column velocity at low and high calibration flows (2,318 cfs and 14,844 cfs). Additionally, it appears that FL did not collect benthic velocity data at any of the three calibration flows in Reach 4. According to Section 5.4.5, and additional information provided at the October 15, 2016 study report meeting, in Reach 5 FL collected data from seven transects to determine whether the theoretical velocity relationship reasonably approximated the conditions in the area. FL collected velocity profiles at one relatively low calibration flow, but did not specify the magnitude of this flow. FL acknowledged that data from the bottom 10% of the water column (or from 0 to 12" above the substrate) was not evaluated because the ADCP could not measure benthic velocity accurately. In the absence of field collected benthic velocity data, and rather than using a velocity meter with the capacity to accurately measure	See USFWS-1

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	benthic velocities, it appears that FL applied a logarithmic model to data collected from the lower 35% of the water column (but excluding the bottom 10%) to simulate benthic velocities. It appears that FLs field methodology represents a variance from the Revised Study Plan (RSP) and the FERC SPD (dated February 21, 2014; p. B-11 and B-12), which stated that FL should "*collect mean column and benthic velocity data at representative transects at all three calibration flows in reach 4 and 5 to validate mean column velocities and any simulated benthic velocities.*" The SPD continued that "*this validation effort should ensure velocity data, including other dependent hydraulic parameters such as shear stress, are accurate through the project's operational flow range and provide reliable information to conduct our environmental analysis.*" Therefore, the Division requests that FERC direct FL to collect empirical mean column and benthic velocity data at all three calibration flows at representative transects in Reach 4 and 5, as directed. Results, and a discussion of those results, should be included in a revised report submitted for public review and comment. All raw data, including both field measured and simulated velocities, should be provided in editable spreadsheet format (Microsoft Excel or similar).	
MADFW-3	Mussel Habitat Analysis- Shear Stress and Relative Shear Stress: FL states that the parameters of depth, velocity and substrate were selected to determine habitat suitability of cross sections within Reach 5 for three state-listed mussel species. In Study Report 3.3.16, FL states that it would use shear stress (SS) and relative shear stress (RSS) as constraints or limiting factors in the final habitat analysis; however, it does not appear that these parameters were included in the mussel habitat analysis in any way. As noted in our comments on Study Report 3.3.16, we have significant concerns with the omission of SS and RSS as parameters in the habitat suitability analysis and the lack of data or literature to support such an omission. The Division recommends methods for modeling and incorporating SS, including developing SS thresholds from the literature, and recommends further consultation with the Division, other stakeholders, and the Delphi Panel (see comments on Study Report 3.3.16). Should the supplemental analysis requested in our comments on Study Report 3.3.16 find that it is worthwhile to include SS, we recommend that FL re-run the Reach 5 analysis.	FL will perform additional screening level analysis of shear stress parameters at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1). FL proposes to complete the screening level analysis and file it with FERC on 4/3/2017.
MADFW-4	Mussel Habitat Analysis-Substrate: Each of the 15 transects in Reach 5 was placed in or near an area where mussel surveys had previously been conducted. Those mussel surveys provided qualitative assessments of substrate, yet FL elected to assume that all substrate in Reach 5 consists of medium sand. The Division agrees with USFWS comments that by making this assumption, depth and benthic velocity became the primary drivers of the FL's analysis. Additionally, differences in substrate within and across sites may contribute to differences in mussel abundances and/or the extent of suitable habitat. Therefore, FL's assumption could overestimate the actual quantity of suitable habitat, which in turn could mask the impact of flow and/or Project operations on habitat suitability. At the IFIM meeting held on December 2, 2016, FL confirmed that updated sediment and bathymetry data had been collected from mussel transects and that these data would be used to update IFIM modeling. The Division appreciates FL's collection of additional data collection but reiterates that this level of data collection is necessary for all transects being used to model mussel habitat; therefore, we request that FERC require FL to collect sediment and bathymetry data at all mussel transects used for modeling.	FL heard this concern expressed at the October 31, 2016 meeting and hence mobilized a crew to collect transect bathymetry and substrate mapping at the same transects to supplement the previous work. Now that more detailed substrate data has been obtained by FL in Reach 5, FL will apply the HSI for all species and lifestages separately when performing additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017. FL proposes to complete the screening level analysis and file it with FERC on 4/3/2017.
MADFW-5	Mussel Habitat Analysis- HSI Groupings: As noted in our comments on Study Report 3.3.16, the Division agrees with USFWS comments that FL's proposal to create two groups of mussels based on similarity of depth and velocity criteria is not supported by the data. The Division recommends creating three groups based on empirically derived SS thresholds, as further outlined in our comments on Study Report 3.3.16.	See USFWS-4. The mussel criteria will be looked at separately as part of an enhanced screening-level analysis.
MADFW-6	Mussel Habitat Analysis- Qualitative Categorization of Effects: FL used intervals that were unequal and subjective (e.g., "minimal" and "low" effects were at 10 percent intervals whereas "moderate" through "severe" effects were at 20 percent intervals). At the October 31, 2016 study report meeting the Division raised concerns regarding the qualitative categorization of Project effects and stated that there was no biological or data-driven justification for the categories. FL should provide a justification for its selection of intervals or, in consultation with the Division, USFWS, and other stakeholders, develop a new interval categorization system based on percent of suitable habitat available at a given flow (steady state) as well as the percent of persistent habitat across flows (dual flow). The Division also notes that, in concept, any categorization should be biologically based and should consider life history, population size and trends, and other parameters on a species by species basis. Preliminarily, the Division's performance standards for permitting the Take of a state-listed species are outlined in 321 CMR 10.23 of the Massachusetts Endangered Species Act (MESA) (MGL c.131A).	FL plans to present transect-by-transect suitable areas (% suitable vs. flow) in the addendum. If the addendum uses interval categorizations to report results, FL will consult with NHESP for a new interval categorization system.
MADFW-7	Reach 3 Habitat Suitability Analysis: In Reach 3, and per consultation between FL, the Division, and FERC representatives on May 15, 2014, FL must collect hydraulic data and evaluate Project effects on Yellow Lampmussel and its host fish using methodology described in the Modified Revised Study Plan (MRSP). FL agreed to apply any DELPHI-developed habitat suitability criteria for Yellow Lampmussel to Reach 3, and to conduct 2-D modeling of habitat persistence based on these suitability criteria. Study Report 3.3.1 provided no information regarding the status of FL's screening level assessment for Reach 3, although at the October 31, 2016 study report meeting FL indicated that this work needs to be completed. The Division reiterates the need to conduct a screening level assessment for Yellow Lampmussel in	See USFWS-6 and USFWS-8.

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	Reach 3, but recommends that FL only conduct this assessment *after* the assessment methodology has been refined per Division comments on Study Report 3.3.16 and as provided herein. Once a mutually agreeable assessment methodology has been developed, we recommend that FL's assessment of habitat availability and persistence in Reach 3 use scenarios identified during the December 2, 2016 IFIM study report meeting.	
MADFW-8	Mussel Habitat Analysis (Reach 5) The Division is concerned by FL conclusions of mussel habitat modeling as presented at the October 31, 2016 study report meeting. These include the following: FL concluded that "*flow conditions within operational parameters at Turners Falls Dam do not appear to be correlated with State-Listed mussel presence/absence or abundance.*" As noted in the USFWS comments, there appears to be a general trend of decreasing Yellow Lampmussel abundance with increasing proximity to Cabot Station. However, it appears that FL is utilizing absolute mussel abundances reported by HG&E. As noted by USFWS and confirmed in our review of the data, field survey methods and level of effort for mussels in Reach 5 were not standardized between 2005, 2009 and 2013 surveys with respect to number of observers, time spent surveying, length/area of survey, and survey methodology. Therefore, comparing absolute abundance across sites is an inappropriate measure of mussel population numbers. According to the RSP, FL proposed to use the catch per unit effort (CPUE) method to qualitatively assess mussel species abundance, which estimates density at each site using the number of mussels found per species per square meter of survey area per unit time. CPUE would be a more accurate and standardized metric to use in this analysis.	Based on the impoundment-wide surveys for HG&E, yellow lampmussels occur at variable densities from the Holyoke Dam to near the Mill River confluence, with highest densities in the reach from Brunelle's Marina to Mitches Marina. During surveys conducted over the last 20 years, yellow lampmussels have not been found farther upstream than the Mill River confluence. The initial report referred to total number of mussels found at each site in Reach 5, and were categorized based on recommendations from NHESP based on qualitative abundance (high, med, low, etc.). Mussel abundances is reported as CPUE in surveys conducted by HG&E and, to the extent this metric is reported by HG&E, can be used in future analysis of Reach 5.
MADFW-9	Mussel Habitat Analysis (Reach 5) FL also noted that "*mussels [are] absent from seemingly suitable areas under a variety of flows*" and that "*mussels [are] present in areas where typical spring (April) river flows can result in low suitability.*" As noted in our comments on Study Report 3.3.16, the Division believes that by excluding SS from the analysis – despite SS being identified by Delphi Panelists, stakeholders, and published literature to be critically important to mussel distribution – FL's assessment of mussel habitat suitability was fundamentally flawed. Areas of habitat that are suitable based on substrate and depth may not be suitable due to elevated SS levels. Additionally, use of annual high spring flows are inadequate to understand Project effects on mussels because this approach does not consider mussel phenology, recruitment of juveniles, and Project alteration of flows during summer months (see comments on Study Report 3.3.16).	FL will perform additional screening level analysis of shear stress parameters at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1).
MADFW-10	Mussel Habitat Analysis (Reach 5) FL proposed an alternative hypotheses that other potential factors – including dispersal and successful colonization, SS during high flow events, and distribution of suitable substrate – may affect mussel distribution and abundance in the CT River independent of Project operations. The Division believes that, except for seasonally high flows unrelated to the Project, these alternative hypotheses are in fact directly related to Project operations. In particular, and regarding dispersal and successful colonization, juvenile settlement and colonization is the mussel lifestage most sensitive to SS. By creating elevated benthic velocities and SS levels during the summer months, Project operations may affect the ability of juveniles to settle and successfully colonize suitable habitat (see comments on Study Report 3.3.16). Regarding SS during high flow events, in our comments on Study Report 3.3.16 the Division noted that higher SS may be tolerated by adult mussels during typical spring high flows through adaptation. However, if juvenile recruitment is significantly reduced due to elevated SS during the summer months, mussels may not be able to colonize otherwise suitable habitats and the viability of existing populations may be compromised. Regarding distribution of suitable substrate, FL posits that the distribution of suitable substrate is not affected by Project operations. However, the Division notes that the Delphi Panel found a wide range of suitable substrate for all three state-listed mussels in the Project area. The distribution of substrate from the Turners Falls Dam downstream to the Holyoke Dam Impoundment is driven by two processes: erosion and deposition. Erosional processes are a function of hydrodynamics including SS and shear velocity, which are affected by the alteration of flows. Deposition is also related to geomorphic and hydrodynamic processes, including velocities, depth, and the amount of sediment input. The Turners Falls Dam directly affects these processes through alteration of flows and by intercepting sediments from farther upstream.	Species distributions are driven by multiple factors that operate on different spatial and temporal scales. Some of these factors might indeed be affected by Project operations. It is beyond the scope of this study to quantitatively assess all of the factors that might affect species distributions, or the relative importance of natural versus anthropogenic influences on these factors. Based on the additional analyses that will be completed, some of the hypotheses proposed by NHESP can be addressed, within context that recognizes the limitations of the model inputs and outputs, and the potential effects of factors not directly tied to Project operations.
MADFW-11	*Rate of Change:* The Division agrees with USFWS comments that although inclusion of spring flows in the analyses is useful as a point of comparison, results should be viewed in the context of the duration and periodicity of these high flow events. Relative to daily fluctuations that occur due to Project operations, a flow of 38,600 cfs occurs less than 10 percent of the time on an annual basis. Additionally, the natural hydrograph ascends and descends from that flow gradually, affording established mussels an opportunity to react/adjust appropriately (e.g., burrow down into the substrate). Fluctuations in relevant hydraulic parameters happen more abruptly and more frequently as part of daily Project operations. Because freshwater mussels are relatively sedentary organisms, FL should	See USFWS-17. FL will perform additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017. The analysis will not include a rate-of-change assessment, as FERC had previously determined that FL did not have to conduct such an assessment.

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	assess the rate of change to habitat suitability within Reach 3 and 5 over the course of a peaking cycle during representative time periods (e.g., spring, summer, fall). These rates should then be compared to the burrowing capabilities of the target mussel species.	
MADFW-12	*Assessment of Whole Reach:* In the RSP, FL states that "*using the binary HSI criteria…determine if any binary HSI thresholds are not met under a range of modeled operating conditions anywhere in study reach 4 or 5.*" Based on the narrative in this section of the report, it appears that project effects were only assessed at the 15 transects where ADCP data were collected by FL. Given that mesohabitat was mapped for all of Reach 5 and that the hydraulic model also covers all of Reach 5, the Division agrees with USFWS comments that FL should quantitatively assess all of the habitat within Reach 5 (as well as Reach 3) to better understand the impact of Project operations on the quantity of suitable habitat under steady state and base/peak flow conditions. These analyses would provide additional information relative to the overall quantity of suitable habitat and how much of that habitat persists between various base/peak flow combinations. Also, and consistent with the presence of relic, adult Yellow Lampmussel shells found throughout in Reach 4 over the last 40 years, it may also become appropriate to assess Project operations within Reach 4 *if* the revised mussel suitability analyses indicate potential Project affects in Reaches 3 and 5.	FL will perform additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017.
MADFW-13	*Steady-state vs. Persistent Habitat IFIM Analysis:* The Division has identified eight (8) steady state flow scenarios (Table 2), and seven (7) dual flow persistence scenarios (Table 3) to be modeled at each transect in Reach 5. Table 2 identify lifestages for all species to be tested at a given scenario, based on methodologies incorporating SS (Criteria 1-3). The Division requests that outputs of the IFIM analysis are consistent with the Division's comments on Section 5.5.4 and 6.2.9, to include tables and graphs of time series curves at a sub-daily time step for representative seasonal periods. Further, the time series should incorporate suitability of both lifestages at appropriate seasonal scales (see comments on Study Report 3.3.16).	FL will perform additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1).
	Request for Additional Data: FL conducted two analyses: mussel habitat suitability as it relates to flows both within and outside the control of the Project, and mussel abundance as it relates to the effects of different model scenarios on suitability. Both analyses rely on data collected at 15 transects located within Reach 5. Figure 5.5.2-1 is a schematic portraying how the data were analyzed and Table 6.2.6-1 is a table summarizing the results of that analysis. We request that, for each transect, FL provide the HEC-RAS model output, tabular data showing the depth, benthic velocity, substrate, calculated bed SS, and suitability for each interval along the transect for each flow and backwater condition analyzed. This information could be included as an additional appendix to the report and electronically in an editable spreadsheet format.	Tabular data will be provided in an appendix to the screening level analysis.
MADFW-14	Tables 6.2.1-1, 6.2.2-1, 6.2.2-2, 6.2.3-1, 6.2.4-1 through 6.2.4-3 and 6.2.5-1 The way data are presented in the tables is confusing. A graph with the percentage of Max habitat available as flows increase is much easier to understand. This analysis was done for reach 4 (6.2.5 Figures F1- F10).	Tables 7.1.1.1-1, 7.1.1.2-1, 7.1.1.2-2, 7.1.2-1, 7.1.3-1, 7.1.3-2, 7.1.3-3, and 7.1.4-1 show the percent of maximum habitat over the range of operational flows at the Project.
MADFW-15	Habitat Time Series (Reach 4) As noted in our comments under Section 5.5.4, we do not believe that converting habitat versus time curves to monthly habitat duration curves is appropriate. The objective of this type of analysis is to assess how project operations affect target species/life stage habitat at the relevant time step. In this case, because Turners Falls Project operates as a daily peaking facility, a daily time step is appropriate. FL should generate curves that represent habitat versus time on a sub- daily time step for representative seasonal periods. Likewise, habitat time series should not be restricted to certain life stages. One of the benefits of this type of analysis is the ability to understand how temporal changes to the quantity of suitable habitat could impact any particular life stage. For instance, a theoretical habitat time series curve for juvenile fallfish in Reach 4 under typical August flow conditions would show nearly 8 million square feet of habitat during base flow conditions interspersed with dramatic drops down to 2 million square feet of habitat during peak generation. The frequency, duration and magnitude of those fluctuations have important implications on intraspecific competition as suitable habitat becomes restricted/limiting.	See USFWS-6.
MADFW-16	Appendix B It is unclear why the x-axis stops at 4,000 cfs, given that (1) the Reach 1 curves for Transects 10 and 11 (Appendix C) go up to 7,500 cfs, (2) the Reach 2 curves go up to 10,000 cfs, and (3) the bypass flow range evaluated for the persistence analysis in Reach 3 extended to 5,000 cfs.	See USFWS-20.
MADFW-17	Appendix F It is unclear why the x-axis has flows well beyond the operational capacity of the Project. We recommend that the figures only graph flows from 0 cfs up to 20,000 cfs (or 30,000); that way it would be easier to see what flows correspond to what WUA on the lower end of the curve.	See USFWS-21.
MADFW-18	Appendix J The graphs in this section portray monthly habitat duration curves. For daily peaking projects, monthly habitat duration curves do little to inform how habitat changes over the course of a peaking cycle. FL should redo the figures to show habitat on the y-axis and	See USFWS-6.

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	time (either daily or weekly) on the x-axis, by species/life stage for each reach for a representative time period (e.g., a week in late May/early June for shad spawning). In order to capture a range of conditions, the analysis should be run for a representative "wet", "dry" and "average" water year.	

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

Commenter	Comment	Responses
CRWC-1	*General Comments:* 1. The report identifies the Montague receiver as part of the lower river spoke. Discussions with all stakeholders, prior to the release of the report, noted, with agreement of all, that Montague was within the project. That fish detected at Montague had arrived at the project. 2. Tabular data should be presented for the numbers of fish at important locations (Montague, tailrace, entering Cabot ladder, exiting ladders, at base of dam, at upper end of the canal, in the Cabot forebay, etc.) and associated passage statistics including total project passage efficiency. 3. Additional tabular data should include but not be limited to: number of hours fish are in the tailrace and number of entries by hour, time spent by fish at the base of the dam, time spent in the canal prior to Gatehouse passage, time spent in the impoundment prior to downstream passage (both routes), time spent in the canal during downstream passage. 4. The terms survival, transition, recapture, attraction are at times confusing (e.g. Cabot attraction, Spillway attraction are unclear as to whether that means entry of close proximity). These should be clarified. 5. For all state tables and charts, the number of fish represented should be included. 6. Adjust numbers of fish detected by eliminating 'fish' that were spurious detections (e.g. Holyoke released fish only detected in the canal or with few detections at a single location that has a high proportion of spurious detections). 7. Heat maps that include bypass flows should be limited to 7,500 cfs to understand in better detail the potential effects of manageable flows as opposed to flows beyond control by the project	1. The Holyoke to Montague model assessed the movement of fish from Holyoke through the project. However, Montague was left as its own receiver rather than grouped with the project receivers, which consisted of all receivers within the project area. The model still assessed transition between Montague and the lower river, and between Montague and the project. FL will construct a Cormack-Jolly-Seber (CJS) model, which is the best representation of the proportion of fish arriving at the project and will group Montague with all other project receivers. The model will show bottlenecks between individual receiver groups along the project. 2. (also answers number 3). Given the number of comments and requests for additional information, FL will file a single addendum with FERC on 4/30/ 2017. As part of that addendum, tabular data will be provided and referenced to each section. 3. See answer 2 4. The MSM analysis provides the conditional probability that a fish has survived, transitioned and was recaptured at a receiver given that it was alive and present at another receiver at a previous point in time. We cannot partition out any of the separate probabilities from this result. Therefore, this probability says that a fish survived from t to t + 1 in that it was alive in both time steps, transitioned from receiver i to receiver j in that it moved between them, and was recaptured at receiver j at time t + 1. When we refer to attraction, we are actually referring to this conditional probability and note that a fish was alive and present within the tailrace (or spillway) and was then alive and present within the ladder. In regards to Cabot and Spillway ladder attraction, fish were attracted if they were alive and present in any of the receivers that make up a ladder at time t + 1, conditional to them being alive and present in any of the receivers that make up the tailrace (or spillway) at time t. It is the transition between receivers that inform our belief in attraction. When we put attraction in the context of operations we can see how this conditional probability changes with respect to changing operations. As flow increases, this probability may increase or decrease. 5. Data will be provided in tabular format in the addendum 6. FL will assess Holyoke released fish recaptured in canal. 7. Updating the heat maps will just change the axes and not the data. FL is not proposing to update them.
CRWC-2	*3.2 Study Design and Methods* *1.* The report states that the fishways were operated in the normal method with one foot differentials at the entrance. Does this apply to the old entrance to the Gatehouse ladder?	1. The Gatehouse ladder was operated as normal with a 1-ft differential at the primary (new) entrance. This operation results in a differential greater than 1 foot at the old entrance.
CRWC-3	*Table 4.2-3* 1. The number of detections at T1, T2, and T3 should be included. T3 is considered as the arrival at project location.	1. These data will be provided in an addendum.
CRWC-4	*4.4 Mobile Tracking and Evaluation of Mortality* 1. Mortality determined from receiver detections for a prolonged period of time with no subsequent location up- or downstream should be included. 2. Route specific mortality should be reported (e.g. x number of fish pass through the units and y number died).	1. As stated, due to the limitations of the Lotek receivers ability to detect a mortality signal when scanning multiple frequencies, FL used mobile tracking for mortality assessment. 2. FL will assign mortality if a fish does not move from a receiver location for the remainder of the study or is last recaptured at a receiver downstream (or upstream) of project passage and never detected again. If a fish is classified as mortality, the first detection at the fish's terminal receiver will be used as time of mortality.
CRWC-5	*4.5 Data Reduction* 1. How were single detections evaluated for validity? Fig 4.5-2 would seem to indicate that all single detections were false.	1. If a pulse detection history within +/-5 pulse intervals is empty (e.g. 00000100000), it was classified as a false positive detection. Single heard detections within +/- 5 pulse * scan rate intervals at a receiver will always have this string, and was removed from analysis.
CRWC-6	*4.6.1 Holyoke to Montague* 1. It is not clear how hours in the state table relate to individual fish movement as it appears to group all fish. For example, there were 514 hours when fish remained at the Canoe Club, but was this one fish or 25 fish, and if it was many fish, what was the distribution of hours? 2. The report needs to define the "project". Previous discussions, with all stakeholders, defined arrival at the project as detection at Montague. It should not be included with T1 or T2 as lower river.	1. FL will provide a breakdown in an addendum. The tabular summary will include the number of fish present. 2. See discussion above about Montague receiver (CRWC-1).
CRWC-7	*4.6.2 Montague Spoke* 1. Tabular numbers of fish at Montague, moving to Smead Island, the tailrace and the bypass will enhance the understanding of fish behavior at this location. 2. Fish likely made multiple attempts moving upriver from Montague and this should also be noted. Time spent at Montague should be evaluated including the effect of flow and diel period. 3. Some fish moved from Montague to the bypass (Conte discharge) without being detected at Smead Island or the tailrace but are not discussed in the text. Others were detected at the tailrace far field antenna for a brief period indicating movement through that area, but not a "stop" at the tailrace. It is not clear which category these fish fell in: tailrace or bypass. They should be included in the Montague to bypass category. For these fish, the time of detection at the tailrace.	1. FL will provide tabular data in an addendum. 2. Time-to-event analysis can be used to understand the effects of project operations in a Montague-to-anywhere else model. This information will be provided in the addendum. 3. Fish detected within T5/T6 were considered to be within the tailrace. Fish subsequently recaptured at T15 are considered to have entered the bypass reach. For those fish that transition from Montague to the bypass (T15) without being recaptured in the tailrace T5/T6 are considered to have transitioned to the bypass reach.

Commenter	Comment	Responses
CRWC-8	*4.6.3 Cabot Ladder Attraction* 1. Tabular data for numbers of fish in the tailrace, entries into the ladder, range/distribution of entries by fish, time from first detection in the tailrace to entry, number of hours fish were in the tailrace would provide context to movement probabilities. 2. "The state table counts 137 forays into Cabot ladder, with 120 from the tailrace, 8 from downstream receivers and 9 from the bypass reach. This number of forays differed from the sum of the number of forays per fish according to the raw recapture data." (Quote from pg. 4-55). How and why they are different should be explained.	1. FL will provide tabular data in an addendum. 2. FL will provide an accounting of fish removed for the MSM analysis because they did not meet data requirements and assumptions.
CRWC-9	*4.6.5 Bypass Reach* 1. Again, tabular data would assist understanding movement in the bypass reach: how many fish moved to either side of Rawson Island, how many fish passed each side and how many failed, what were the times fish spent in the east side, how many fish passed Rawson Island undetected and what were the flows associated with success or failure in passing.	1. FL will provide tabular data in an addendum.
CRWC-10	4.6.6 *Spillway ladder attraction* 1. Figure 4.6.6-2 describes fish approaching the spillway ladder by time of day. It is unclear if approach means 'in the proximity of' or 'enters the ladder.' For the limited number of fish in the pool below the dam, 144 'approaches' seem high. 2. Paragraph 5 says 11 dual tagged fish made at least one attempt on Spillway ladder (entered?) and in the next paragraph it says, "In total, 34 dual tagged fish made at least 17 successful attempts into the spillway ladder from the spillway,…". This seems contradictory or confusing. 3. A more complete analysis of the time from the first Montague detection to the first detection at the dam T-19 & T20 should be done to assess delay associated with finding and entering the spillway ladder. 4. During different periods of the study Station #1 operated or did not. Bypass flow is earlier described as spill plus Station #1. For the Spillway ladder attraction model it is not clear what flow is used in Tables D-1.6-1, D-1.6-2 and the histogram of bypass flow. For analysis of entry into the bypass or passage at Rawson Island including flow from Station No. 1 is appropriate. For entry into the Spillway ladder it is not.	1. The dipole antenna (T30) was considered part of Spillway Ladder. This receiver could have picked up fish within the spillway. It was used as the entrance antenna for the ladder in conjunction with P21 and P22, which had poor receiver detection rates. FL will construct two models in an addendum, one with and one without T30 as part of the ladder and compare the results. 2. Agreed, FL will confirm and address if necessary in an addendum. However, the 11 dual tagged fish are fish recaptured at Montague, which had a low number of recaptures for fish that used the bypass and/or arrived at Spillway. See next comment. 3. The low number of recaptures for bypass oriented fish at Montague precluded a more thorough analysis because the entrance criteria given by the Stakeholders was too strict. FL will group the Montague receiver with the lower bypass receivers adjacent to the Cabot Tailrace (T5, T6, T11, T15). The last detection at these receivers will be used as entry to the bypass reach for bypass oriented fish. This model will be addressed in an addendum alongside a Cormack-Jolly-Seber model which will show the proportion of fish migrating up to specific points within the bypass, this model will show the "bottlenecks" within the bypass reach. 4. The Spillway Attraction model only included upper bypass receivers (T12E, T12W, T16, T19 and T20) and only included spill from the dam as the operational flow. Receivers T12E and T12W were included in the analysis due to low number of recaptures at T16.
CRWC-11	*4.6.7 Spillway Ladder Efficiency* 1. Spillway ladder entrance efficiency for both dual and PIT only tagged fish is stated as 91.5%. It is unclear how this is derived. Ladder entrance efficiency is generally the number of fish that enter divided by the number available/in close proximity (detected in this case by T19 or T20). Since PIT tagged fish cannot be detected in the pool, they cannot be used in calculating a measure of entrance efficiency. A table of fish in the pool below the dam the fish that entered, and the number of attempts would be appropriate. 2. Overall ladder efficiency is the number of fish that pass, divided by the number of fish available. Again, as PIT tagged fish are not 'available', overall ladder efficiency can only be calculated with dual tagged fish as opposed to internal efficiency which can use PIT tagged fish. Tabular data of PIT and dual tagged fish would better describe the performance of the ladder.	1. Ladder entrance efficiency was derived in the manner presented in the comment. The number of fish available to pass was the number of dual tagged fish recaptured at T19 and T20, plus the number of PIT tagged fish known to have been in the region because they were recaptured somewhere within the ladder. The number of PIT tagged fish present within the spillway and not detected within the ladder is unknown. 2. PIT tagged only fish were included in the CJS model for Spillway Ladder. The overall efficiency of the ladder is the product of the internal efficiencies. The standard assumption for a CJS model is that survival probabilities between recaptures are independent, therefore if we want to know the overall efficiency we take the product of all receivers. One could take the overall number of successful fish and divide that by the overall number that attempted the ladder, and compare the product of the internal efficiencies and find that the numbers match or are very close. Tabular data in an addendum will compare these products.
CRWC-12	*4.6.8 Upstream Migration through the Canal* 1. An analysis of the telemetry database shows only 6 dual tagged fish passed the Cabot ladder making a total of 56 dual tagged fish for canal upstream movement. Of those 22 were detected at T22 (downstream of gatehouse). Four fish that came up the Spillway ladder were also detected on T22. It is unclear if the detections at T22 were if the fish dropped into the canal or when they were in the Spillway ladder not, but they cannot be considered as fish that moved from the lower canal to the head of the canal.	1. The queries created for the upstream migration model did not include fish known to have passed Spillway Ladder. It only contained fish known to have passed Cabot Ladder or those released directly into the canal. Therefore the MSM and Time-to-event model only included fish from these two cohorts and the results are only representative of them.
CRWC-13	*4.6.9 Gatehouse Ladder* 1. Gatehouse ladder efficiency should be calculated as the number of fish passed / number of fish available (detected at T22).	1. Gatehouse ladder entrance efficiency included those fish recaptured at T22 and PIT tagged only fish recaptured within the ladder. The overall ladder efficiency was calculated as the product of each individual receiver specific survival probability. FL will provide a comparison of both approaches in an addendum.
CRWC-14	*4.6.10 Upstream Migration through the TFI Impoundment* 1. Movement and delay times at Northfield Mountain Pumped Storage Facility ("Northfield") for all operating conditions should be more fully detailed. The report states for upstream movement past Northfield there was some delay and milling at the intake. The numbers of fish, project operation status, and their respective delays should be provided along with analysis.	1. FL will provide tabular data in an addendum as well as address concerns with operations.

Commenter	Comment	Responses
CRWC-15	4.6.11 *Downstream Migration through the TFI Impoundment* 1. Impoundment-released fish that were detected at Shearer or Stebbins Island and then moved downstream should be included in the analysis. 2. A more complete analysis of delay at the Northfield intake, including specifics as to delay and the effect of operations on that delay, is needed.	1. FL will incorporate these fish into an overall CJS model of downstream arrival. FL will not include impoundment released fish that were recaptured at Shearer Farms during their upstream migration and did not subsequently come back down. 2. FL conducted time-to-event analyses for time-to-escape Northfield Intake. In a procedure analogous to multiple-regression modeling, operations and diel cues were incorporated as predictors in a stepwise procedure. Each model was assessed for goodness of fit. Neither operations nor diel cues reached the significant threshold (per appendix D-2.11), therefore the interpretation of any rates would be suspect because we are not ensured the model is correct. FL does not recommend interpreting hazard ratios from these models that did not pass goodness of fit.
CRWC-16	*4.6.12 Downstream Migratory Route Choice at Turners Falls Dam* 1. In addition to impoundment-released fish and TransCanada fish, FirstLight fish that passed into the impoundment should be included in the evaluation of downstream route. 2. Downstream route choice and delay by route should be analyzed in relation to flow to the canal, to spill and the number of fish available under different conditions. 3. Delay at the dam should not include impoundment released fish that move downstream within 24 hours of release.	1. FL used presence at any impoundment receiver (T26, T27, T25, T24 and T23) as the starting state for the multi-state model of downstream route selection. However, for the purposes of time-to-event modeling, this will complicate measures of delay because not all fish are recaptured at all sites. If we start the clock at the lower impoundment 'gate' at T23, we may find that not all fish were recaptured, thus we do not know when the clock starts for those not recaptured. Left truncation may not work because we cannot assign an arbitrary start time, we would only know when the animal experienced the event (choice of route) and nothing about when they started. If all release cohorts are to be used in the analysis, FL will identify the receiver that had the highest rates of recapture to maximize sample size. 2. FL will address route selection in relation to operations in an addendum referenced to the section. FL will query out impoundment released fish that moved downstream within 24 hours of release. . 3. FL will remove fallback fish from analysis
CRWC-17	*4.6.13 Downstream Migration through the Canal* 1. Multi-state Markov has 86 fish "moving through the telemetry subnetwork" and Time to Event uses 98 fish. An explanation as to why different numbers were used would be helpful. 2. The second paragraph states that 28 fish transitioned from the Cabot forebay to the tailrace but the fifth paragraph says 37 passed from the forebay through the turbines (pg. 4-88). This is confusing. 3. The sixth paragraph on page 4-88 states, "Fish at the Downstream Bypass were most likely to be detected next at the Cabot Forebay, though the probability of next detection decreased with increases in flow (93% at 25th percentile flow decreasing to 97% at 100th percentile flow; …" It seem like the probability is increasing when it goes from 93 to 97%. 4. Last paragraph on page 4-88 says that fish passed quickly through the downstream bypass while the text on page 4-89 (2nd paragraph) says that there was a large delay for fish using the downstream bypass. How are these reconciled?	FL will revise this section as part of the addendum according to methods of Therneau et al. 2016 (see footnote 2), which outlines a method for time to event analysis within multi state and competing risks frameworks. They state "a common mistake with competing risks is to use the Kaplan-Meier separately on each event type while treating other event types as censored," this is what was applied and the reason for figure 4.6.13-4 summing to an overall proportion > 1.0. Therneau et al. (2016) outlines a method for dealing with competing risks in relation to each other. Therneau et al. propose that interpretation of hazard ratios (coefficient describing amount of delay that occurs when a covariate changes) can be assessed with separate Cox Proportional Hazard regressions because each rate (hazard ratio) depends only on the transition from which it originates and the event which it enumerates, and that rates are instantaneous quantities that depend only on the set of subjects who are at risk at a given moment. Therefore, the analysis is two-fold. Time-to-migration fate based on Therneau's suggested methods, and a set of Cox models that derive hazard ratios for operations and other predictors for each separate route of passage.
CRWC-18	*Discussion and Conclusions: Upstream migration* 1. The 2nd paragraph says, "Fish preferred to move into the Cabot Tailrace during times of low flow," while the 3rd paragraph says, "Attraction to the Cabot ladder increased as Cabot discharge increased, suggesting the discharge from the powerhouse provides attraction flow." These statements appear to be contradictory.	1. This paragraph will be updated in an addendum referenced to the section to further explain fish movement into and within the tailrace.
CRWC-19	*Summary* 1. Though just over half of the fish released at Holyoke were detected, a better metric for fish reaching the project is the number of dual tagged fish detected at the project (94) divided by the number detected (154) or detected at Rt. 116 or above (116) to account for post tagging effects. In that case, movement to the project would be 61.0% or 81.0%, respectively.	1. The least biased estimate of project arrival would come from a CJS model that simply described the proportion of animals that arrive at each receiver (or group of receivers) from release at Holyoke to recapture all the way up to the Spillway. Bottlenecks occur where animals spawn and turn back, exit the reach through another route of passage (Deerfield or Cabot Ladder) or where they die. The model will not be able to differentiate between each fate. While simple in its application, the CJS will give the stakeholders the least biased proportion of animals arriving at the project and the spillway and identifies potential problem locations. Fall back fish will be removed from analysis.
MADFW-1	*General* *1.* The Multi-state Markov approach (MSM) applied throughout is somewhat novel and quite challenging to interpret or understand its meaning. There are several reasons for this, and the result may be to obscure rather than explain patterns of movement. A major problem is that the 'states' among which fish transition are set to too fine a scale (movements between each antenna?). This reduces many important movements (e.g from Montague into the bypassed reach), instead calculating rates of movement into areas about which we are less intrinsically concerned (e.g. movement behind Smead Island). Perhaps the data can be reinterpreted to show fish movement to the relevant waypoints over given flows and time.	1. See response to USFWS-1.
MADFW-2	*General* In some cases output of time-to-event analysis is provided. This analysis has been used by the Conte Lab in past radio/PIT tag studies at the TF ladders and power canal. This method often seems much more revealing of underlying patterns than the MSM approach. The time-to-event analyses measure rates of movement, much like the MSM models do, but with the added advantage of a continuous time axis. I would prefer to see the entire study analyzed in time-to-event, competing risks framework. The MSM approach may be able to be manipulated to address this concern. Regardless which (or both) method is used, the context of movement rates under various and varying environmental conditions should be the focus of this study. This context seems to me to have been largely lost in all of the details	As discussed in the response for CRWC-17, a recent article from Therneau et al. (2016) described the correct method for applying time-to-event analysis with competing risks, which produces the probability that a fish is in a state at a specific time that sums to 1.0. Environmental cues and project operations were considered for all models except the CJS. FL will construct a CJS model of arrival for the stretch of river between Holyoke and the Spillway as it provided the least biased assessment of project survival. Tabular data and a table to detection histories will accompany the overall CJS model.

Commenter	Comment	Responses
MADFW-3	*General* FL should compare dual tagged fish passage with PIT only, to determine the degree of difference between the two tag types by tagging cohort. The data show evidence of differences in results between PIT only and dual tagged shad, possibly attributed to the additional procedure of a radio tag insertion and that tag's presence. There should be some discussion of immediate and long-term tagging effects how they would manifest in the data. There should also be some investigation of radio tag loss using data of known and missed radio detections in relation to PIT reader detections of dual tagged fish. The consideration of tag loss in a tagging study should be reported and incorporated into analyses as appropriate.	The performance of PIT tagged fish can be compared with dual tagged fish using a CJS model, however the resolution of the PIT system will make comparisons between technologies difficult. All fish were released at Holyoke, and some of those PIT tagged only fish were recaptured in the Cabot Ladder, and some at the Spillway Ladder. If PIT tagged only fish passed either of those ladders, they could be recaptured again at Gatehouse Ladder. Meaning we only have two recapture locations and 1 release location for either route (Spillway vs Cabot). A CJS model will be constructed to compare the performance of either tagging method at the ladder.
MADFW-4	*General* Finally there is a general lack of contextual analysis throughout. Data and observations are presented as a list of facts. But these facts occur in a broader context, and many similar studies have already been performed on this project. The observations need to be compared with previous work, and the report should more carefully explain how the new information improves and/or alters our understanding of the dynamics that drive shad movement and migratory success/failure throughout the Turners Falls projects.	FL will provide a comparison with past studies in an addendum referenced to the section.
MADFW-5	*4.1 Spillway ladder PIT and radio antennas.* These should have been checked daily and fixed as needed. The PIT systems can be challenging, but the radio antenna was almost certainly an oversight problem. The absence of reliable fish entry data for Spillway marks a key failure in this study. Percent of dual tagged fish that made it from Holyoke to the "Project Area" (42%). This percentage should be based on known upstream migrants. The report should enumerate immediate migratory failure (fall back due to tagging and handling), and how this varied with release date. It would also be helpful to have summary tables of % of migrants that made it to Redcliffe and to T2 (Rt 116) by release date. Dual tagged study fish, captured, handled, tagged and released at Holyoke provide the basis for determining rates of movement including percent arrival to the Turners Falls Project. PIT tagged only fish cannot be used to determine the proportion of shad that reach the project area. The capture, handling, tagging, and tag presence on adult American shad are all know to manifest in tagging-related effects on the study fish, including "fallback" behavior, when tagged fish drop back and remove themselves from the monitored study group in the defined study area. This study released a total of 215 dual tagged shad at Holyoke. However, the fixed monitoring stations (lower most site Red Cliffe followed by RT116) and mobile tracking surveys (Holyoke to Cabot), never detected 51 tags of the 251 released tagged shad, producing a "fallback" rate that in theory may be as high as 23.7%. The results provided in Study 3.3.6 (Impact of Project Operations on Shad Spawning…") indicated that in 2015 all documented spawning occurred well upstream of RT 116 (that was the downstream boundary of that spawning survey). Therefore it is a reasonable expectation that the "undetected tagged fish" (n=51) may be considered the upper end of a potential fallback figure for study fish. The radio tags detected in the report is noted as n=164. Using the KA database, a reported total of 109 dual tagged shad (Holyoke) were detected at the Montague Wastewater receiver site and/or, other further upstream located receiver sites.	Fall back will be assessed in an addendum referenced to the section. A CJS model as described in response to **CRWC-19** would provide the least biased assessment of project arrival. This will be provided in the addendum along with tabular data and detection histories. After controlling for fall back fish that could bias detection and recapture at T1 and T2, the proportion of fish arriving at the project would be the product of the probability of survival between release and T1, the probability of survival between T1 and T2, and the probability of survival between T3 and the receivers considered 'the project'. FL did not use PIT Tagged only fish to determine proportion of shad reaching project area, FL only used dual tagged fish.
MADFW-6	*4.2 Shad Tagging, Release and Reach Recapture* The report concludes that because there were no detections in the upper reservoir- therefore there was no entrainment. This all depends on being able to detect entrained fish. Were the droppers fixed to the bottom, or floating on the surface? Surface droppers would be likely to miss fish. Please elaborate on the location of the droppers and on how detection was tested.	Table 3.2.1-1 of Study Report 3.3.2 describes the receiver station deployed at the Upper Reservoir (T31) and Appendix A of Study Report 3.3.2 describes the calibration and testing procedure, although a figure for Station T31 results was inadvertently omitted. A new figure (Attachment A, Study 3.3.2, Figure A-18) has been included herein that depicts the location of the test tag and results. The in-water droppers were suspended mid-depth using 8-lb. downrigger weights.
MADFW-7	*Table 4.2-1* As stated previously it would be helpful to see the % arrival at Redcliffe, Sunderland, and Montague for each of the Holyoke releases.	See response to **MADFW-5** for description of least biased CJS estimate.
MADFW-8	*Table 4.2-3* Should include the number of dual tagged fish detected at the Montague receiver as that provides important context for the other upstream receiver detections. As was discussed above, we contend that detections at the Montague receiver are fish arriving at the project area. The data support this, with n=109 dual tagged shad reported as detected at Montague compared with n=106 dual tagged shad reported detected at any upstream receiver locations.	FL will provide the tabular data in an addendum referenced to the section.
MADFW-9	*4.3 Project Operation, Discharge and Environmental Data* Project operation data should be presented in cubic feet a second (CFS), not megawatts. It is impossible to compare project operations in megawatts to dam spill, treatment flows, canal flow and river discharge all reported in CFS. We are interested in a consistent metric of CFS, however it might be informative to keep the megawatt values and place them on a second y-axis. (Same for figures 4.3-1,4.3-2 through 5)	FL will update figures in an addendum referenced to the section.

Commenter	Comment	Responses
MADFW-10	*4.6.1* It would be useful to have 2D plots of dual tagged fish receiver detection histories with time on the x-axis and receiver location (or logical receiver grouping locations) by river kilometer on the y-axis. Fixed station receiver, mobile tracking, and PIT reader identification can each be assigned a unique symbol on the plots, which would help to explore the tagged fish movement histories and their timings. As an example, live fish, moving downstream post spawn, are believed to make very directed and timely progress. Given limited energy reserves, at the end of their spawning, these movements and their rates should be more completely presented as we suspect they will further inform question on reported survival data, as an additional observation to tag signal rates. A 3D plot that partially addressed this was provided on page 3-30, but is difficult to interpret without being able to rotate the figure. A 2D set of tagged fish plots would be helpful in describing patterns of movement, rates, fates, and project locations, with the actual data. These plots should include clearly known fish fates when available (left study area –out-migrating or died), which can also be noted with another unique symbol code on the plots. Only Montague should be included in the 'staging' state, unless Montague had poor detection, in which case you might have to include downstream. The issue is that you might have some fish that were not staging, and were instead spawning.	FL will provide the figures in an addendum.
MADFW-11	*4.6.1-2* It would help to see the denominators here to give a better sense. These could be presented in just the diagonal cells.	The number of fish available within each state will be provided in tabular form in an addendum referenced to the section.
MADFW-12	*4.6.2-2* Not clear what's going on. 13 escapes by 11 fish or 8 escapes by 11 fish? We request that throughout this report, any references to # of forays, or # of events, or # of transition that the number of tagged fish attributed to such an action be clearly noted with those reported actions. Currently, throughout the report, the use of number of foray, transitions, and events are qualified by the fact a single tagged fish can have a range of 1 to numerous observations (forays, transitions) that need to be considered in the interpretation of the results. For example, the MSM models may show dozens of transitions for one state to another but the actual sample size of fish available and used for those measures, can lead to wide confidence limits, and may have additional implication in data interpretations. This is even spelled out in the report text. The understanding of these sample sizes should not be left unknown but clearly reported to place the data and analyses provided in additional context that is not presented consistently in the current report.	The number of fish used in each analysis will be presented in tabular format in an addendum referenced to the section.
MADFW-13	*% of fish that transitioned from Montague to Cabot.* Again, this is not really what is interesting to us. Instead you should be showing how long it takes them to arrive at Cabot Tailrace at these various flows. The fact that some go somewhere else first is misleading as it suggests that they do not subsequently arrive at Cabot. Instead you should treat arrival at Cabot as the event of interest. Fish are candidates for arrival until they move up the bypassed reach, downstream, or up the Deerfield River (those are censoring events, as is an absorbing state for fish that disappear).	Time to arrival at Cabot from Montague was assessed with the time to first foray. Deerfield River was not absorbing as fish were found to have escaped.
MADFW-14	*Heat Map Figures 4.6.2-3 through 4.6.2* These figures suggest that there was a uniform distribution of conditions. For example, was there a condition with 1000 cfs from Cabot and 15000 through the bypassed reach? Likewise how about 10000 cfs at Cabot and 20000 down the bypass? Given the non-uniform range of actual conditions, is there any reality to the dome shape we see relative to bypass flows or if that is just an artifact of graph.	Probabilities at extreme ends of either flow scale are affected by sample size and confidence intervals are included in the report. FirstLight constructed the heat maps using the best MSM model, which incorporated flows from the bypass reach and Cabot station. FirstLight used the model to predict transition probabilities at the full range of flows.
MADFW-15	*4.6.3.2* The analysis is contingent on a state having changed, but remaining within the ladder is a key behavior, and it is the rate of transition that we care about. I don't see how you can calculate that without dealing with the 'staying' issue. Perhaps a multi-state time-to-event problem.	This probability and rate of movement will be solved simultaneously with Therneau et al.'s (2016) method, see response to **CRWC-17.**
MADFW-16	*4.6.3-2* Time of arrival for dual tagged fish at the Cabot ladder- Please compare this with the tailrace arrival data.	Fish behavior will be assessed with new model, see response to **CRWC-7.**
MADFW-17	*4.6.3-5 and 6* Cabot ladder first Foray- Please provide similar plots for re-entry.	Figure 4.6.3-5 is for time to first Cabot foray from Montague while 4.6.3-6 is for movement between the tailrace and ladder, which incorporates all events, including first forays and re-entries from the Tailrace.
MADFW-18	*4.6.6* Because of the poor coverage, both at #1 station and at Spillway entrance I am very skeptical of these data and analysis.	Recapture anywhere within the ladder prompted a state transition. All spillway ladder receivers (including the entrance dropper T30) were grouped into a single state, transition into just one of the receivers means transition into all.

Commenter	Comment	Responses
MADFW-19	*4.6.7* I do not believe this because of the antenna outages. Need to resolve that issue.	Spillway ladder entrance efficiency was taken as the proportion of fish recaptured at the entrance (P21, P22 and T30) over those fish known to be within the Spillway, which was the number dual tagged fish recaptured at T20 and T19, the number of PIT tagged only fish recaptured anywhere within the spillway ladder, and the number of dual tagged fish recaptured within the ladder but not within the spillway. The only cohort of fish that cannot be accounted for are the number of PIT tagged only fish that were within the spillway area and not subsequently recaptured within the spillway ladder. If we only take into account dual tagged fish because that is the only complete census of individuals present within the spillway, we would reduce the number of observations in the model, and it will lose precision. Regardless, the CJS model noted very low rates of recapture at the spillway entrance (P21, P22 & T30) at 37.9%, which resulted in considerably wide confidence intervals of the entrance efficiency between 69.5% and 100%. The CJS mark recapture estimate is the least biased estimate because it adjusts survival for the rate of recapture at each telemetry station. Grouping the entrance into a superstation (P21, P22 and T30) would reduce bias from downtime at P21 and P22. Detection histories with and without T30 will be presented in tabular format. In regards to **USFWS-6**, a multi-state release recapture model with two states for the entrance pit array (P21 and P22), can assess the entrance rate when the receivers were known to be down vs when they were known to be operational. The results of three mark recapture models will be compared; model 1: CJS mark recapture with T30, model 2: CJS mark recapture model without T30, model 3: multi state release recapture (MSRR) with two entrance states (P21, P20 and T30 on vs off).
MADFW-20	*4.6.8* Canal passage data is basically useless because of loss of new entrance antennas and no antennas at the old entrance. The only real use would be the rate of movement upstream for fish that were released to the canal as compared with those that ascended the ladder and/or fell back into the canal after ascending Spillway, and possibly the within-canal movements, which are interesting.	FL disagrees and proposes a CJS model of the canal showing the proportion of fish to arrive at each subsequent upstream station. Passage into Gatehouse Ladder will be assessed as the survival between T22 and the receivers that make up Gatehouse Ladder (P31, P32, and P33). The model will assess survival from the location of release (Cabot Ladder or Cabot Canal release cohort) and T13, between T13 and T14, between T14 and T18, between T18 and T21 (this will have drop off due to station No 1 and fallback), between T21 and T22, between T22 and the ladder, and between the ladder and the impoundment. The new model will be presented in an addendum referenced to the section along with the detection histories of all fish used in the model in tabular format.
MADFW-21	*4.6.12* 1. It is stated that as flow increased study fish movement increased to downstream sites, with values reported. It is important to note that the higher flows occurred later in the study season, and it is unclear what effect the time of year actually played in influencing the reported downstream movement. All adult shad eventually move downstream -independent of flow. More analyses to consider the auto-correlation of downstream movement with time/duration of migration, as a variable vs. higher flows should be done. 2. A State Table (see 4.6.8-2) displaying transitions is omitted and should be included for this component of the study as in previous components. Additionally the number of tagged fish that comprise the “hour of exposure” should be included adjacent to those values to place them in some context. 3. This section should include table with the number of available downrunning fish encountering the dam and/or gatehouse, by release cohort (including TransCanada) and their assigned fates that can be linked to a passage route. 4. This area requires a time-to-event analysis to determine if there is any delay upon reaching this project area and to examine the effects of flow and flow routing (bascule spill CFS relative to Gatehouse CFS) on the fish route of choice. The ratio of flow to Gatehouse vs. spill would be a useful analyses relative to route and in addition to the straight flow value analyses may consider if a threshold value(s) exist for route choice. This will inform an area of project effects given the choice and importantly outcomes (fate alive or dead for route taken) that needs to be analyzed.	1. Tests for autocorrelation was not in the study plan. 2. A state table will be provided in an addendum referenced to the section. 3. Release cohort was not added to the model as a predictor, a revised model can incorporate this variable so that we can determine if route of passage choice is dependent upon where and when it was released. 4. Time to event analysis within the multi-state and competing risks framework will be presented in an addendum referenced to the section.
MADFW-22	*4.6.13* This section is confusing because of the mixed use of numbers of tagged fish reported in the text. A table should be included that shows the number of tagged fish available starting, the number known to pass by either Cabot Units, Bypass Sluice, unknown passage route, or not passed and their respective percentages relative to the available total and also in subgroups. This section should include information on the fates of tagged fish that can be assigned as alive or dead from mobile tracking based upon the number of known tags using the bypass, the number using the Cabot units, and the combined overall passed by either (which would include the unknown route). Survival rates, based on the complete study period should be reported as these determined values are key study objectives for project effects and the impact to outmigrating shad that are located in the canal.	Tabular data will be provided in an addendum referenced to the section. See response to **CRWC-1**
MADFW-23	*5 Discussion, Downstream migration* There is no mention anywhere in the Discussion section on the topic of project effects on mortality. The report needs to more fully address and develop the data reporting, analyses, and results on this study objective. It is important that the Discussion Section provides a good review of these findings given that different project operations may favor different migration routes which may in turn have different outcomes on survival through the project.	The report assessed project induced mortality with a catch curve analysis. CRWC provided arbitrary metrics in their comment letter, however FL feels the best way to assess project induced mortality is with separate CJS models for each route of passage. The models will be simple, with only 3 stations necessary. The release station will list all fish known to successfully attempt a particular passage route. The first recapture occasion is the receiver, or group of receivers directly adjacent to the exit receiver and the second recapture occasion is any other receiver in the network. FL will address this in the addendum.

Commenter	Comment	Responses
MADFW-24	*Summary* We strongly disagree with the statement that "less than half" the American shad lifted at Holyoke approach the Turners Falls Project. This statement is misleading, and we believe incorrect, based solely on the number of shad captured, handled, processed, and double tagged, and then released at Holyoke in relation to upstream detections. The previous comments note the lack of consideration for fallbacks from the initial release group sample that result in an unknown level of bias in this estimate.	Once controlled for fish that fell back, a CJS model as explained in response to **CRWC-19** would provide the least-biased assessment of project arrival because it accounts for recapture rate at the receivers that make up the project. Tabular data along with detection histories will be provided in the addendum.
NMFS-1	*Goals and Objectives: Evaluate attraction, entrance efficiency and internal efficiency of the Gatehouse ladder* This objective was partially accomplished. One of the stated objectives was to evaluate the entrance efficiency of the Gatehouse ladder. Based on our understanding of Section 4.6.9 and Appendix D, the report does not provide this information. However the report does provide the probability of an upper canal fish being detected in the gatehouse ladder was 0.11, 0.12, 0.15, and 0.00 at the 25%, 50%, 75%, and 100% canal flow, respectively. Study results estimated the overall efficiency of the Gatehouse ladder at 76.9%. This is similar but lower than the historical average from 1999 to 2002 of 83% (Sullivan 2004). Section 4.6.9 does not provide a time-to-event analysis of fish that encounter the ladder.	FL will construct a CJS model of the upstream migration through the canal, through Gatehouse ladder and into the impoundment, with findings included in an addendum. The model will track the fate of fish released into Cabot Canal and those fish released at Holyoke that passed Cabot Ladder. Entrance efficiency will be assessed between T22 and the Ladder in the upstream canal CJS model. Time to pass gatehouse ladder was not completed due to issues at P34Z. FL will provide time-to-Gatehouse passage from the first detection at P31 to last detection at P33 and from the first detection at T22 to the first detection at P31 in an addendum referenced to the section. The first model will give us the overall time spent in Gatehouse Ladder, while the second model will give us the overall time spent attempting to enter the ladder.
NMFS-2	*Goals and Objectives: Identify migration delays resulting from operation of the Turners Falls Project* 1. This objective was partially accomplished. Sullivan (2004) provided a median transit time for the Holyoke impoundment of 5.8 days ranging from 23 hours to 32 days. This equates to a median ground speed of approximately 10 kilometers per day (km/day) during migration through the Holyoke impoundment. The FirstLight study reported a median transit time for the Holyoke impoundment of 9.7 days suggesting a ground speed of 5.9 km/day. The slower transit time exhibited by the FirstLight study fish may be a result of dual tag effects, though multiple environmental cofactors may affect transit time. One such factor is the timing of release which was not evaluated in the study. There were two distinct release periods: one in the beginning and one near the end of the migration run. The FirstLight study quantified the delay at the Cabot ladder entrance by a first foray model from the Montague station. Median daylight transit time to enter the Cabot ladder was 7.55 hours. Median night transit time to enter the Cabot ladder was 148.0 hours after detection at Montague. Figure 4.6.3-5 suggests that more flow down the bypass channel reduces delay during the day and the night. Once in the ladder, the first fish remained in the ladder up to an additional 30 hours before successfully passing. The report did not include median time to passage in the ladder. 2. The first foray model from the Montague station to the spillway ladder calculated the median transit time of 94.4 hours (3.9 days) with wide confidence intervals due to a low number of fish. The median transit rate in the bypass was 1.5 km/day which is substantially lower than baseline (Holyoke impoundment). Because the Markov State Model (MSM) showed that Deerfield fish only transitioned to either Montague or Cabot Station, the slow bypass reach transit rate is likely a result of project operations at Cabot Station. Once in the ladder, successful passage required up to an additional 10 hours. 3. After passing the Cabot ladder and entering the power canal, fish experienced hydraulic conditions that impact migration behavior. First, fish were observed milling in the forebay, lower canal and log sluice for up to 48 hours. Second, fish were attracted to the Station 1 forebay where they remained for up to 14 hours. Third, during high canal flows, upstream migrating fish would fall back to the lower canal to find velocity refuge. The median overall mitigation time in the power canal was 23.1 hours with a maximum of 10 days. 4. The poor performance of the P34Z array led to the time-to-event analysis not being completed to determine the length of delay within the Gatehouse fishway. We agree that the probability of entry to the Gatehouse ladder is for upstream migrating shad in the power canal is very low and is on the order of 11-15%.	1. FL did not assess time-to-project migration with respect to release cohort. The transit time of 9.7 days is the time at which 50% of the fish experience the event, meaning half are shorter, and half longer. FL proposes a CJS model to assess the proportion of fish arriving at the project after controlling for fall back, see response to **CRWC-19**. 2. The first foray from Montague station will be updated in an addendum referenced to the section to include the last recapture from stations within the Montague area (T3, T11, T5, T6) and arrival within the spillway (T19, T20). FL was asked to strictly limit the individuals used in this assessment to those that departed T3 with subsequent arrival at the spillway ladder, this reduced the number of observations below the method's ability to tease out effects due to operations of the project. By grouping receivers we will increase the sample size and produce informative statistics with the caveat that time to event may be biased if the last detection within the Montague group is at T3 in Montague and not T6 in the Cabot Tailrace. 3. FL proposes a CJS model of the upstream migration through the canal, which will pinpoint bottlenecks and potential problem areas, see comment for **NFMS-1**. 4. This interpretation of the MSM statistics is incorrect, the success of every transition from T22 is only 11- 15%. The state table indicates that fish transitioned from T22 , 123 times, with 15 of those transitions into Gatehouse Ladder. A complete picture of the entrance efficiency will result from the overall proportion generated from the upstream CJS model, the creation of the expected number of visits table (MSM output describing the total number of forays into the Ladder), and the success rate of all forays leaving T22 (11 - 15%). FL will update the section in an addendum referenced to the section.
NMFS-3	*Goals and Objectives: Determine route selection and behavior of upstream migrating shad at the Turners Falls Project under various spill flow levels* This objective was partially accomplished due to one of the pit tag receivers not functioning during the entire period of the study. Shad were observed migrating during the day and spawn at C-4 night as they migrate upstream. The data from this study indicate that project operations affect route selection of migrating fish.	The entrance PIT antennas will be addressed in a multistate release recapture to assess entrance when antenna array was down vs up; see response to **USFWS-3.**

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<tr><th>Commenter</th><th>Comment</th><th>Responses</th></tr>
<tr>
<td>NMFS-4</td>
<td>
Goals and Objectives: Evaluate migration through the Turners Falls Impoundment (TFI)
1. This objective was partially accomplished. During times of no NMPS operations (Table D-1 7-2), the baseline condition for downstream movement of upstream obligated shad from the NMPS station and the DS NMPS station is shown in the table provided below (Table C-1).

Table C-1. Summary of downstream movement of upstream obligated shad without operations
<table>
<tr><th></th><th>DS NMPS</th><th>NMPS</th></tr>
<tr><td>Day</td><td>7%</td><td>83%</td></tr>
<tr><td>Night</td><td>31%</td><td>84%</td></tr>
</table>

2. Pre-spawned adults will continue to migrate upstream until spent, so at the middle telemetry stations (DS NMPS & NMPS) downstream movement is most likely a result of project operations or comprised of spent adults when compared to the baseline condition. The probability of a fish moving in the downstream direction from the middle stations is shown (Table C-2). The nighttime pumping data (Table D-1 7-1 of the report) showed that downstream movement from the NMPS intake was not effected by project operations. However, downstream movement from the DS NMPS increased from baseline suggesting an avoidance behavior.

Table C-2. Summary of the probability of a fish moving in the downstream direction that is detected at one of the receivers in the Turners Falls headpond
<table>
<tr><th>Pumping Flow</th><th>DS NMPS</th><th>NMPS</th></tr>
<tr><td>25%</td><td>14%</td><td>84%</td></tr>
<tr><td>50%</td><td>19%</td><td>84%</td></tr>
<tr><td>75%</td><td>25%</td><td>83%</td></tr>
<tr><td>100%</td><td>31%</td><td>84%</td></tr>
</table>

3. MSM data was not provided for next state probabilities for daytime pumping, which did occur (Figure D-2 10-1). During discharge (Tables D-1 7-3 & D-1 7-4 of the report), the MSM data show that as generation increases, the probability that a fish moves in the downstream direction increases as well (counter to an obligate upstream migrating shad). The effect is more pronounced at the DS NMPS station, but full generation does have an effect on the probability of fish moving downstream from the intake area (Table C-3).

Table C-3 Summary of chances of being detected downstream of NMPS Intake and at the NMPS Intake.
<table>
<tr><th rowspan="2">Generation Flow</th><th colspan="2">Daytime</th><th colspan="2">Nighttime</th></tr>
<tr><th>DS NMPS</th><th>NMPS</th><th>DS NMPS</th><th>NMPS</th></tr>
<tr><td>25%</td><td>9%</td><td>83%</td><td>35%</td><td>85%</td></tr>
<tr><td>50%</td><td>9%</td><td>83%</td><td>35%</td><td>86%</td></tr>
<tr><td>75%</td><td>11%</td><td>83%</td><td>40%</td><td>88%</td></tr>
<tr><td>100%</td><td>21%</td><td>92%</td><td>57%</td><td>98%</td></tr>
</table>

4. The FirstLight study did not clearly show the effect of project operations on potential delay of upstream migrating shad. Figure D-2 10-2 shows two Kaplan-Meier curves representing night and day that have time on the x-axis and proportion attracted on the y-axis. The associated text implies that the y-axis should represent the proportion of fish that pass the intake in the upstream direction. Also, as shown in Figure D-2 10-1, night and day does not necessarily reflect project operations. While, it is important to consider diurnal changes as a cofactor in this analysis, understanding the effect of project operations is necessary. Therefore, Kaplan-Meier curves should be developed for project pumping, generating, and no operations.

5. The FirstLight study does not show a MSM analysis for downstream migrating shad in the Turners Falls impoundment. The study determined the median delay caused by attraction to the intake (~6 hr – exact number not reported) and the median transit time (25 hr) past the intake (Figures D-2 11-2 & D-2 22-3). A baseline value was not provided for comparison.
</td>
<td>
1. No response required.
2. No response required.
3. No response required.
4. FL provided thorough statistical results in an appendix to the report and found no effect with operations.
5. See CRWC-15 for a description of the CJS model for downstream movement within the impoundment. The model will be provided in the addendum along with tabular data and detection histories of fish used in the analysis.
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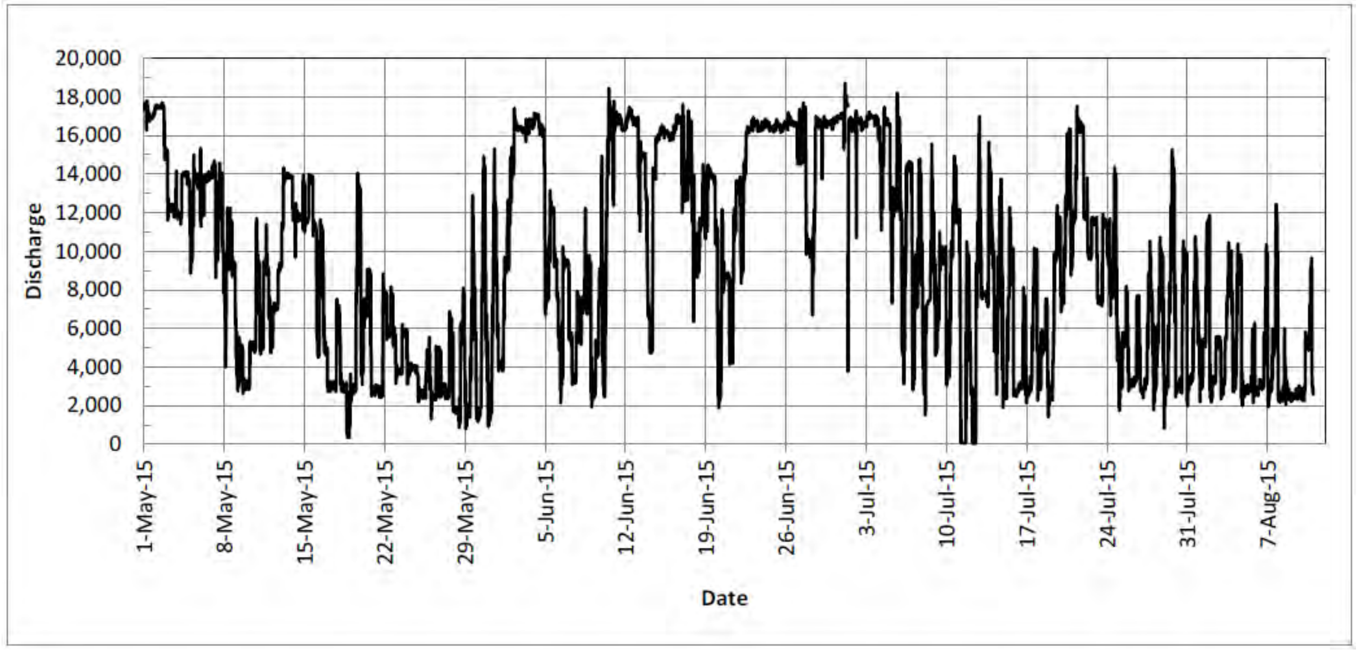
</tr>
</table>

Commenter	Comment	Responses
NMFS-5	*Goals and Objectives: 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* 1. This objective was partially accomplished. The overall canal passage rate was 82% including entrainment with a median transit time of 23.1 hours. As flow in the canal increased, transit time decreased. 2. The data from this study indicate that Station #1 causes a median delay time of 14 hours for upstream migrating adults. The report does not make it clear whether entrainment in Station #1 was evaluated. This study stated the log sluice bypass efficiency was 45% in paragraph 2 on page 4-88 and then stated the log sluice bypass efficiency was 52% in paragraph 2 on page 4-89. We recommend these data be clarified. 3. Our review of the MSM analysis determined that extensive milling behavior in the forebay occurs, thereby increasing delay for downstream migrants.	1. No response required. 2. 14 hours for those fish attracted to the Forebay, not all fish are attracted to Station No 1. Some will migrate by without entering the Forebay area at all. 3. No response required.
NMFS-6	*Goals and Objectives: Estimate downstream passage route selection, timing/delay, and survival at Turners Falls Dam* This objective was partially accomplished. The probability of downstream migrating fish through the canal was 74% and over the spillway was 26%. However, the report does not make it clear how project operations contributed to the derivation of these probabilities. A regression model was used to determine daily mortality rates. Unaffected reaches exhibited a loss of 1% of fish/day. The Bascule gate, the Gatehouse/Cabot, the gatehouse/log sluice routes all exhibited a loss of 3% of fish per day. The FirstLight study states that passage routes through Cabot Station and the log sluice are better than the Bascule gate route with mortality rates of 2% and 1%, respectively. We recommend clarification regarding how these calculations account for the increased mortality in the canal.	Project operations was not assessed for this model, see response to **CRWC-16.** Mortality within the canal was not considered, this is the daily rate of mortality for those fish known to have migrated through a specific route.
NMFS-7	*Section 4.6.5 Bypass Reach* This section discusses results of fish movement through the bypass reach. This section (as well as Appendix D section 1.5) omits several pieces of information. Foremost, the results discussion should include the number of tagged fish detected in the bypass reach during each flow release scenario. The results should discuss rates of movement and transit time a fish that experienced 6,300, 4,400, 2,500 or 1,200 – 1,500 cfs.	The stakeholders requested the bypass analysis to limit the fish used in the analysis to those recaptured at Montague and then subsequently recaptured within the spillway ladder. This limitation reduced the sample size to an amount where we were not able to understand project operations. FL will change the entrance criteria of the model to those recaptured within the Montague area (T3, T5, T6, T11, T15 and Cabot Ladder) and those recaptured within the Spillway (T19 and T20) and the Spillway Ladder. The findings will be included in the addendum.
NMFS-8	*Section 4.6.6 Spillway Ladder Attraction* The results of this spillway ladder attraction indicate that passage performance in this ladder is not providing safe, timely and effective passage for American shad. The MSM results demonstrate that among fish detected at the base of Turners Falls dam are poorly attracted to the existing ladder, with entrance rates ranging from 41% to 65% (6,226 cfs and 2,569 cfs respectively). The Kaplan-Meier curve for Figure 4.6.6-3 suggests that after approximately 96 hours (4 days) only 50% of the fish detected at Montague made a foray into the spillway ladder entrance. However, the report does not account for the role of Cabot Station in leading to these transit time delays. These data also demonstrate that the spillway ladder does not support safe, timely or effective passage.	Cabot discharge does not affect fish transitioning from the spillway to the spillway ladder. Those fish are not exposed to Cabot flows while they are in the bypass.
NMFS-9	*Section 4.6.7 Spillway Ladder Efficiency* The PIT data from this study suggests that the spillway ladder has an overall efficiency of 32.7% when entrance efficiency is included and 36% when entrance efficiency was not included. These data indicate that the existing ladder is not providing safe, timely and effective passage for shad. These results also indicate that the existing ladder is not sufficient for meeting management goals on the mainstem Connecticut River.	No response required.

Commenter	Comment	Responses
	Section 4.6.8 Upstream Migration through the Canal This section makes no mention of the hydrology within the canal and how fish in the canal are subjected to rapid increases and decreases in flow. Based on our review of the data provided, in some instances, discharge increased or decreased by more than 12,000 cfs in one hour (Figure C-1).  **Figure C-1. Discharge in the power canal during the 2015 shad study** While Figure 4.6.8-2 shows the portion of fish attracted to the Gatehouse fishway entrance under the 25%, 50% and 75% exceedance flows, neither these figures nor the associated text make reference to the aforementioned rapidly fluctuating hydrology. The report makes no mention as to whether upstream migration is more likely to occur when flows are increasing or decreasing, or if rates of upstream passage are more likely to occur on the rising or receding limb of the hydrograph. We recommend these flow fluctuations be considered in the analysis. The report mentions that "considerable milling occurred between the lower canal, Cabot Forebay, and the downstream bypass area…..Fish take as long as 48 hours to leave the Forebay area." This result indicates a significant delay in the forebay as a result of project operations.	FL will incorporate rate of change into the competing risks analysis (see comment: **CRWC-17**). Tabular data showing the number of animals to arrive at each station along with detection histories will be provided in the addendum.
NMFS-10	*Section 4.6.11 Downstream Migration through the TFI Impoundment* The report states that 75% of the study fish were detected below the NMPS intake within 100 hours, which is over four days. This result suggest that at least 25% of the downstream migrating fish are delayed by more than four days, consequently, the project is not providing safe, timely and effective downstream passage.	No response required.
NMFS-11	*Section 4.6.12 Downstream Migratory Route Choice at Turners Falls Dam* The report makes no mention of the variability in flow that occurs on the Connecticut River. Rapid fluctuation in flows in the canal render the median canal flow 6,223 cfs uninformative in terms of understanding migration cues. The detection probabilities reported provide no information on the range of flow splits that occur. Table D-18-2 only presents results for all flows. We recommend this table present results based on the flow quantiles listed in Table 4.6.12-1.	See comment **CRWC-16.**

Commenter	Comment	Responses
NMFS-12	*Study Modification Request* We believe the requests we are making can be achieved with existing data that has been collected. At this time, we are not requesting any additional field work. FirstLight has indicated that another round of studies will be submitted on March 1, 2017. As such, the requests we are making will not cause a delay in the schedule. 1. We request an analysis examining why the spillway ladder passed 88% of the fish that the Cabot ladder passed during the 2015 upstream migration season when, on average, the spillway ladder passes 27% (Sullivan 2004). Given that the flows that were released down the bypass during this study were significantly higher than previous years, we recommend the report include an analysis of this significant change. 2. In order to achieve the objective to identify migration delays resulting from operation of the Turners Falls Project, we request the following analyses or clarifications: • an evaluation of the reasoning behind the slow transit time and the potential dual tagging effects; • the median transit time to passage in the Cabot ladder; • the median transit time of fish that leave the Cabot tailrace and transition up the bypass and compare that to the reported transit time from Montague to the spillway ladder; • provide the median time to passage in the Spillway ladder; • baselines transit times for downstream migration to serve as a basis for comparison; • a time-to-event analysis that addresses the delay that occurs for upstream migrating fish that encounter Station 1 tailrace flows in the bypass; and • presentation of the delay that occurs in the bypass that is presented in the same way as it is for the canal and delay times should correspond with flow down the bypass. 3. In order to achieve the objective to determine route selection and behavior of upstream migrating shad at the Turners Falls Project under various spill flows can we request a more detailed accounting of the number of fish in the spillway ladder, when they were in the ladder, and what the spill conditions were when they entered the ladder. 4. In order to achieve the objective to evaluate migration through the Turners Falls impoundment we request: • The study show the Kaplan-Meier curve for proportion of fish passing the intake during times of pumping, generating and no operation • The analysis includes a baseline condition for transit time to evaluate the effect of project operations on migration behavior and potential for migration delay. The report should state a natural or baseline downstream migration rate, which could be obtained from downstream migrating fish from Turners Falls to Holyoke.	**1.** See **CRWC-10** **2.** Tabular data representing transit times, arrivals and forays will be provided in report. Regarding time to event analysis for fish experiencing spillway flows, bypass analysis will be conducted. See **CRWC-10** 3. Detection histories and tabular data will be provided in the addendum. 4. As stated, FL assessed movement within the impoundment in relation to operations. If flow was not a significant predictor, it was not reported.

Commenter	Comment	Responses
USFWS-1	*GENERAL* Overall the study is an impressive effort, coupling a thorough design concept with extensive and sometimes novel methods for analyzing a very complex dataset. For the most part the conclusions seem to be supported by the data. Often, however, it seems that these conclusions were limited in scope and did not necessarily take into account the breadth of information that the data afforded. Attachment A provides detailed comments on the study report. Below are summary bullets of overarching concerns: 1. The report frequently uses obtuse and confusing language. For example, the term 'survive' is often used when what is really meant is 'arrive', and 'transition' is used instead of 'move'. Language should be simplified and clarified throughout to reduce unnecessary jargon. 2. There is a general lack of contextual analysis throughout. Data and observations are presented as a list of facts, yet these facts occur in a broader context and many similar studies have already been performed on this project. The observations should be compared with previous work and the Consultant should more carefully explain how the new information improves and/or alters our understanding of the dynamics that drive shad movement and migratory success/failure throughout the Turners Falls project. 3. Throughout our comments we highlight the need to have associated tabular data presented to put the narrative text and figures portraying different analytical results in context. In particular, for the MSM analyses, providing the data in this format will aid in understanding exactly how many individual fish were detected at each location relative to the probabilities of a fish transitioning from one "state" (i.e., location) to another. 4. An underlying concern is that FL did not account for apparent "fallback" in many of the analyses. The Service's position is that fish that were not detected at receivers upstream or in mobile tracking, should be reported and considered in that specific context for analyses. This effect of handling and tagging has implications for determination of reported values, such as arrivals to management areas of interest, such as the Montague receiver. 5. In general, the number of Holyoke tagged fish (excluding those never detected at receivers upstream) is small enough that it would not be onerous for FL to provide individual plots (2D) of their movement histories using both fixed and mobile tracking records (and assigned fates in cases of mobile tracking data). These plots would enable holistic assessment of the data and aid in putting the MSM and time-to-event results in context. Similarly, the two other release groups and individual plots of fish movement histories and fates should also be provided. 6. Although we do not object to FL providing passage route mortality as a daily rate, we ask that the data also be analyzed and reported as a straight percent mortality in order to provide consistency with other studies conducted by FL (e.g., Study 3.3.7) as well as related TransCanada studies. These data should be presented in tabular formats for the three release groups in relation to broader study area movements and also in more refined detail for more specific components, including within project (e.g., canal), and through project study areas (e.g., dam spill, Cabot, bypass/sluice).	1. As part of the addendum, FL will provide a glossary at the beginning of the text and will define their statistical meaning so the reader understands context of the modeling, what the term quantifies, and what its limitations are. 2. FL will discuss the results in the context of previous work in an addendum referenced to the section. 3. FL will account for fall back after all cohort releases. Those fish released, but never recaptured will be removed from all analyses. 4. FL will provide tabular data in an addendum referenced to the section. 5. **MADFW-10** made the same request, 2D plots showing time on the x-axis and RKM to river mouth on y-axis (as measured with a GIS) will be produced for all fish released at Holyoke and subsequently recaptured. 6. FL has received guidance in the form of comments on how to assess mortality using at-a-receiver and receiver-receiver detection logic rather than identifying a mortality pulse out of a pattern of missed to hit detections. However, FL feels that applying a complicated series of conditional logic statements to assemble a list of fish that we think may have died is difficult and prone to error due to the size of the dataset, complexity of the conditional logic, and potential unforeseen special exceptions and scenarios that come with over 16 million lines of data. To reduce the potential for error and costly debugging, FL will construct a simple 3 occasion (1 release, 2 recapture) CJS model to assess route specific post-passage survival. FL will assign mortality to those fish that pass a structure and are recaptured, but do not transition to another location within 48 hours.
USFWS-2	*3 Methods* The text refers to Table 3.2.1-1 which describes receiver locations and related details. We question Station No. 1 tailrace receiver's (Tl6) ability to actually detect tags the full width of the river channel based on the extremely limited tag detections (two fish), the number of tagged shad known to have migrated past this area, and the reported test tag detection power reading shown on page A-12, Figure 10. The reported receiver "power readings" for test tags in that figure rapidly decline within a short distance from the Station No. 1 discharge from 100 to as low as 70s (a very weak tag signal), over a distance of approximately 130 feet. The wetted distance from the station antenna to the far bank is approximately 730 feet. Based on this information it is highly unlikely that tagged fish could be detected across the full width of the river. Given this tag detection limitation, as provided by field measurements, we believe it is inappropriate to represent this antenna as a "gate" antenna and request that that it not be characterized as a full coverage antenna in the report.	Receiver T16 was not assessed as a gate antenna in any models because of the low rates of recapture.
USFWS-4	*3.3.5 MSM Modeling* Define what is meant by time dependent covariates are assumed to be 'piecewise'. Does this mean that if an animal stays in one state for an extended period during which covariates are changing you adjust them to some mean value? This is an important element that should seek to ensure a hazard "rate of transition" is constant within the interval, and covariate values are fixed within the interval. The section includes describing "forays" which will require details when that term and its associated values are reported later to, note specifically the number of fish involved, the mean and median number of forays per fish and maximum number of forays.	It was a typo and should have been **time-varying** and constant over the measurement interval. Thus we can only assume that flow remains constant over a 15 minute interval. This allows the hazard to change with time while ensuring that the hazard remains constant within the interval.

Commenter	Comment	Responses
USFWS-5	*3.3.6 Cox Proportional Hazards Regression* In reference to the use of alpha 0.05 for significance of the model, under the AIC there is no need to restrict evaluation of parameters to the 0.05 level. The model as a whole needs to be considered. Variables with low confidence can have associated caveats, but should not be ignored, especially if the SE of the estimate is relatively small (e.g. producing a value of 0.1).	FL was assessing overall goodness of fit before comparing models with the AIC. If a model was never fit, it was not compared with AIC scores. FL did not perform a likelihood ratio test between two nested models. Regardless, FL will report the omnibus likelihood ratio goodness of fit, hazard ratio coefficient, standard error and p-value for all models. However, caution will now have to be taken by stakeholders in their interpretation of the model results. If the model was not fit (omnibus statistic $p >> 0.10$), nor were coefficients significant ($p >> 0.10$) interpretation of any model or coefficient should be treated with suspicion because the probability of committing error is much larger.
USFWS-6	*4.0 Results* The narrative states "the mark recapture CJS procedure accounts for receiver detection rates and produces an unbiased estimate of survival." This is not true. CJS assumes uniform detection probability. It does not allow for variability with respect to time. In fact, known down times should be controlled for in a CJS model. In Perry et al. 2012, there is a mention of a multi-state CJS model, where the states would be discrete time periods (i.e. controlling for periods of receiver outages). The application of discrete time periods as states in multistate CJS model is also presented and described in Plumb et al. (2012). This will still be biased, but it will be less biased than the approach described here. What will result is a bias with the estimates of entry higher than they actually were, due to artificially deflated the probability of detection.	FL grouped poor receivers with better performing receivers to reduce this bias. By grouping receivers together, recapture at one means recapture at all. Regardless, FL will produce a multi-state model with known down and up times for the receiver(s) in question and compare results. See response to **MADFW-19** for further explanation.

<table>
<tr><th>Commenter</th><th>Comment</th><th>Responses</th></tr>
<tr><td>USFWS-7</td><td>4.1 Receiver Reliability and Missing Fish
Dual tagged study fish captured, handled, tagged and released at Holyoke provide the basis for determining rates of movement and percent arrival to the Project area. The capture, handling, tagging, and tag presence on adult American shad are all known to manifest in tagging-related effects on the study fish, including "fallback" behavior, when tagged fish drop back and remove themselves from the monitored study group in the defined study area. A total of 215 dual tagged shad were released at Holyoke. However, the fixed monitoring stations (Red Cliffe and RT 116) and mobile tracking surveys (from upstream of Holyoke Dam to Cabot Station), never detected 51 of the 251 tagged shad, producing a "fallback" rate that in theory may be as high as 23.7 percent. This potential rate falls within reported ranges of "fallback" occurrences in a review of studies reported in Frank et al. 2009. The results provided in Study 3.3.6 (Impact of Project Operations on Shad Spawning) indicated that in 2015 all documented spawning occurred well upstream of RT 116 (which was the downstream boundary of that spawning survey). We do not agree that any undetected fish can be assumed healthy, proceeding upstream, and only migrating to areas downstream of RT 116, avoiding all detection in mobile tracking and at the Red Cliff stationary antenna.

The Service's position is that the "undetected tagged fish" (n=51) may be considered the upper end of a potential fallback value for study fish. A total of 164 radio tags were reported detected. Using the KA database, a reported total of 109 dual tagged shad released at Holyoke were detected at the Montague Wastewater receiver site and/or receiver sites located further upstream; therefore, the percentage of viable dual-tagged shad released at Holyoke that approached the Turners Falls Project may range as high as 109 of 164, or 66.5 percent. Only three of the 109 tagged shad detected at Montague Wastewater were not subsequently detected at any upstream receiver locations. A field study on fallback behavior from radio-tagged anadromous fish, details these concerns and approaches for its consideration in these types of studies (Frank et al. 2009).

A similar approach for determining fallback rates should be applied to other tagged fish release groups that would include the TFI and Cabot release groups that had many opportunities for downstream fixed receiver detections. The upstream release groups (TFI and Cabot) observed fallback should be presented and described with tabular and graphical (movement plots) data. Fallback can be defined by some limited time-frame (e.g., less than 24 hours) during which tagged fish made rapid downstream movements and never fully recovered a detected consistent upstream movement pattern.

This telemetry study also provides clear and consistent evidence of differences in results/fish performance between PIT only and dual tagged shad, possibly attributed to the additional procedure of a radio tag insertion and that tag's presence (Table 1). While the additional information obtained from radio tagged fish is valuable, these tag effects should be taken into consideration when interpreting results.

Table 1. Comparison of reported fishway entries for dual tagged and PIT only tagged shad at Spillway and Cabot ladders. The number of fish from each these cohorts detected as successfully passing Gatehouse ladder is also shown for comparison. This comparison assumes no difference in the survival/tagging effects between the two tag type groups.
<table><tr><th>Release group</th><th># Released</th><th># detected entering Cabot of Spillway, PIT antennas only used (% of released)</th><th># detected passing Gatehouse, from number detected as entering Cabot and or Spillway ladders</th></tr><tr><td>Holyoke Dual Tagging*</td><td>215</td><td>40 (18.6%)</td><td>9 (22.5%)</td></tr><tr><td>Holyoke PIT ONLY</td><td>218</td><td>67 (30.7%)</td><td>21 (31.3%)</td></tr></table>*since we cannot determine if there was differential survival and/or fall back by tag type, we used the total number released for first ladder entry as a percentage. The comparison for Gatehouse eliminates this question with known starting sample size values.

Tag loss should be calculated using data from known and missed radio detections in relation to PIT reader detections. These results then should be reported and incorporated into analyses. For example, if there is a 15 percent radio tag loss rate, the results describing percentage arrival to an area (such as the Upper Bypass) should be adjusted, or at least the adjusted value should also be reported.</td><td>FL will account for fall back fish in an addendum referenced to the section.

FL will attempt to quantify tag loss in the addendum.</td></tr>
<tr><td>USFWS-8</td><td>4.2 Shad Tagging, Release and Reach Recapture
Table 4.2-3 should include the number of dual tagged fish detected at the Montague receiver as that provides important context for the other upstream receiver detections. As discussed at the Study Meeting, the Service contends that detections at the Montague receiver are fish arriving at the project area. The data support this conclusion, with 109 dual tagged shad reported as detected at Montague compared with 106 dual tagged shad reported detected at any upstream receiver locations.</td><td>FL will provide tabular data in an addendum.</td></tr>
</table>

Commenter	Comment	Responses
USFWS-9	*4.3 Project Operation, Discharge and Environmental Data* Figures 4.3-lthrough 4.3-5 all show generation in megawatts (MW) on the y-axis. We request that these figures show discharge (in cfs) instead of MW of power.	FL will update these figures in an addendum.

USFWS-10

4.4 Mobile Tracking and Evaluation of Mortality

1. Mobile tracking was noted as the method for determining mortality of study fish. The data reported in Appendix C needs further analyses and reporting to improve the level of detail for project related effects (both within and through) and mortality. Specifically, the reported data show one of three possible assignments: time of release and last known detection alive (left study area); first time detected mortality (died); or remained in the study area. The designation "remained in the study area" for six fish that averaged 51.5 days in detection period length is questioned by us. We assume these fish have died, based on the reported periods of time for those fish assigned as "left the study area" in direct comparison to those reported as died. Fish identified as "died" averaged 40.0 days, compared with fish that "left study area" averaging a presence of 21.0 days (Table 2). Fish identified as "died," requires further clarification so that the first recorded time that the fish is identified as a mortality, is confirmed as the date used for its fate "assignment" date.

Table 2. Mobile tracking data on radio tagged fish mortality based on data provided in Appendix C.

Release Dual Tag Fish	Sample Size	Mean # of Days in Project Area	Standard Deviation
Died in Study Area	95	40.0	10.9
Left Study Area	78	21.0	12.3
“Remained” in Study Area	6	51.5	6.3

* ANOV A, P <0.001, pairwise all pairs are significantly different (P<0.05): Holm-Sidak

2. The data on shad mortality must be more completely described, examined and reported in tabular formats. Each of the three release group cohorts (Holyoke, Canal, TFI) and the TransCanada (TC) fish cohort, should be examined and described from their most upstream attained location, and their fates as assigned (died or left study area) by their release/origin cohort, for potential differences among study areas and project area uses/routes. These data should also be examined in the aggregate for key areas such as known downstream approach direction and use of either the Turners Falls Dam (TFD), Bascule spill or Canal and the corresponding fates of fish utilizing each route (e.g., within project, through project). Similar analysis, fates and rates would include spill/passage at the dam and passage via the Cabot Station units. This information cannot be easily obtained from appendices B and C and the larger database files.

3. Additional data reporting in tabular format and with additional analyses are required to clearly show, of the tagged fish known to be in the Canal, what percentage never left the canal (died), or did exit the canal by the routes available; Cabot Units, Bypass/Sluice, or Station 1.1 Two different numbers of tagged fish moving downstream in the canal (n= 86 or 98) are reported in the text, which become confusing with later text. We want the report to be clear in defining the percentage route assignment for those of a known passage route that as percentages sum to 100% and their resultant fate (live left, died), which must be the reported basis for the proportion that used for example in the lower canal, either the bypass/sluice Cabot Units as the two primary Canal passage options. Station 1 results should also be incorporated as the third option for fish to exit the Canal. Through project passage data should be comprised of fish that actually passed through project, for consideration of project passage effects.

4. The presented inclusion of "within project effects" (i.e, those fish never leaving the canal) merits its own distinction and should not be intermingled, as they are distinctly different management considerations and project effect considerations. Including the "unknown" values (passed downstream by unknown route) needs more careful consideration and should not be aggregated with the "knowns". The "unknown" tags do not provide clear route assignment and fate, but may be presented in a separately defined aggregate analyses for "through project" numbers and survival. The same concern relates to the tagged fish that never left the canal, which was reported later on page 4-88 to be n= 19 fish. Those fish never leaving the Canal are not part of the "through project" downstream passed shad and it is inappropriate and misleading to include these 19 fish in the denominator in the calculation of the number and % passage rate calculations. Using the reported tag values on page 4-88, (MSM based n=86) to appropriately determine the "effect" of Cabot Station, one would reduce the 86 by the 19 fish that never left. This results in a denominator of 67 tagged fish that were reported as emigrating "through project" not "within project", 28 of which (42 percent) were entrained into Cabot Station Units. The Bypass/Sluice had 39 tagged fish detected as passing (39 of 67, or 58 percent). This denominator could be further reduced by subtracting out those fish (n=4) whose through-project route could not be assigned. The matter of actual mortality via these routes must be clearly described in tables and with summary analyses and % rate value assignment. This information cannot be easily obtained from Appendices B and C and the larger database files. Delay associated with the project may occur on both the upstream and downstream migration. In relation to downstream movements, the delay that is noted for a substantial portion of the

1. The first instance of mortality during mobile tracking is the time of mortality, subsequent mortality detections were removed from analysis. FL has received guidance in the form of comments on how to assess mortality using at-a-receiver and receiver-receiver detection logic rather than identifying a mortality pulse out of a pattern of missed to hit detections. However, applying a complicated series of conditional logic statements to assemble a list of fish that may have died is difficult and prone to error due to the size of the dataset, complexity of the conditional logic, and potential unforeseen special exceptions and scenarios that come with over 16 million lines of data. To reduce the potential for error and costly debugging, FL proposes a simple 3 occasion (1 release, 2 recapture) CJS model to assess route specific post-passage survival. The release cohort will only be those animals known to have successfully passed via a particular route because they were recaptured at an exit receiver after being recaptured at an entry receiver. The first recapture occasion is the list of adjacent receivers. FL will list adjacent receivers in an addendum referenced to the section, however they can be identified with the network seen in Figure 3.2.1-10. For example, animals known to have passed downstream via the Cabot Powerhouse were first recaptured at T8 and subsequently recaptured at T5 or T6 within the Cabot Tailrace. The release location is T5/T6 and the first recapture occasion is the T15/T3 adjacent group. Presence at either receiver means the fish immediately survived passage because it was recaptured in an adjacent receiver. We have to assume that the fish moved under its own power. Note, bi-directional movement is possible, which means that fish can be recaptured within the bypass reach after passing downstream via the Cabot Powerhouse. By identifying all possible adjacent receivers, we can expand the search group for the first recapture occasion and improve recapture rate. Presence/Absence within the first adjacent group will assess immediate project survival. Uncertainty in this estimate will look at the rate of recapture at the next receiver. The second recapture location is anywhere else upstream or downstream of the adjacent group. The survival between the first and second recapture locations are of little interest because we cannot separate mortality from recapture without another adjacent set of receivers. Detection histories for those fish that die as a result of direct injury during project passage are ‘100’, where the first occasion is 1 because the fish was present and known to have passed a particular route. The second occasion is 0 because it was not recaptured at an adjacent receiver. The third occasion is also 0 because it was not recaptured anywhere else. This history (‘100’) suggests passage related mortality because it was not recaptured anywhere other than directly adjacent to the structure conditional on passing. Explanatory power may be gained by expanding the number of adjacent receiver groups. If the receiver-receiver analysis proposed herein is too ‘fine-grained’ FL would like guidance on receiver grouping. FL can also apply an arbitrary time limit on the analysis, however they suggest guidance from the stakeholders. The benefits of using the model proposed herein removes arbitrary conditions and reduces the assessment of project induced mortality to presence/absence. We will reduce the problem to two questions; was the fish present at an adjacent receiver, and was the fish present in the receivers adjacent to that? We would also reduce the bias in our estimate of mortality, and produce an estimate with uncertainty. The detection histories of all fish will be provided.
2. Tabular data will be provided in an addendum referenced to the section. (also answer for #3)
4. FL will conduct the following analyses for the canal emigration. A CJS model describing the probability that a fish emigrating through the canal will reach the next downstream antenna grouping. The overall canal efficiency is simply the product of each individual canal receiver. The CJS model will include release cohort as a predictor variable and means to control for release effects. The benefits of using the CJS model is that we can identify bottlenecks within the canal, and simply construct our ‘through project’ rates as the product of arrival probabilities. The CJS model can assess the overall canal passage survival, but cannot differentiate between passage route. Therefore, a multi-state/competing risks model comparing each passage route is also required. Therneau et al.’s (2016) method allows us to compare passage routes within a competing risk framework while allowing the within-a-state probabilities at time to sum to 1. Lastly, rate of movement (overall canal time-to-passage regardless of route, time-to-powerhouse and time-to-sluiceway) will be assessed with separate Cox Proportional Hazard regression models. The resulting hazard ratios will be presented in tabular format.
5. Assessing post mortality drift was not in the study plan.

Commenter	Comment	Responses
	tagged shad located in the lower Canal needs to be more closely examined and the "overall" total canal period must be reported. Specifically, what is the effect of being delayed in the canal? A comparison of the fates of tagged fish that move more quickly through and exit the canal should be compared to those that spend more extensive periods of time in the canal and their subsequent fates (left study area or died, and where). The report notes that of fish at the Cabot forebay, 50 percent passed in less than 23 hours (page 4-89) but there are no further data or statistics on those remaining 50 percent that are greater than 24 hours. Given the potential large numbers of upstream shad having to use the canal to outmigrate, a clear reporting of the "most delayed" proportion, e.g., ~ 75 percent value, in terms of time should be provided. Focusing on the reported value of "50%" minimizes the effects and concerns we have on this component of the study. If 25 percent of the population is expected to experience a much greater period of delay, as clearly indicated, that is important to fully describe in the report with additional text, values, and figures. Descriptive details on study fish, using plots showing individual fish arrival in relation to passing or remaining in the canal would be informative in considering the range of observed delay. Additional tabular data should be presented, broken into appropriate groupings. Based on the limited data presented, we do not have a complete understanding of the frequency, distribution, or magnitude of delay in the canal. The data can be presented in the aggregate for fish in the canal regardless of origin (as appears to be the case currently) as well as by release origin. There are potential differences that should be examined and data should be reported relative to release origin. We believe the breaking out of a "lower canal" and "upper canal" has use but does not address the "complete canal" as a single project area and that perspective for the study needs to be analyzed and presented. The delay periods (upper, lower, and complete canal) may be assigned based on time breaks for available data (tagged fish detection histories), a quartile approach may be used with some associated time breaks, or the use of the requested plot of entry time and time in the canal to exit or death (remaining) in the canal, to assign grouping breaks in a non-arbitrary manner. Comparing the survival results with a "time/delay" effect variable for amount of total time in canal (not segmenting on upper or lower canal) is important in assessing "through project" effects for those fish that are determined as passing downstream and those that remain in the canal as another comparison, in relation to determined fates. 5. There is an expectation that fish had a probability of dying and drifting for days following passage at the Bascule Gate, Cabot Station Units, or the Bypass/Sluice as examples, before having an opportunity for mortality detection with the weekly mobile tracking, and/or perhaps longer periods of time, based on potential variability in tag detection efficiency (tags at depth in deeper pools). The extent of this drift could be considered using the available data on first detection as a mortality and any subsequent detections of the same tag. River discharge also should be taken into consideration relative to movement of dead fish as well as deeper areas where fish mortalities may have settled. 1 ("Unknown" is not route but rather is a failure to detect, without ancillary data/analyses these may be pro-rated to either route or removed from use in the denominator to determine % route assignment).	
USFWS-11	*4.5 Data reduction* Examination of the provided database indicates some additional screening of false positives is needed. The effort and approach taken for this massive data set is appreciated by the Service. However, we suggest additional screening for those radio tags with very limited reported detection histories and/or that would have required a tagged fish to go undetected past numerous receivers. A few specific examples flagged include KA-SHD-0763, -0178, and -0163. These concerns were shared during a meeting with Kevin Nebiolo of Kleinschmidt on November 4, 2016. In response, Mr. Nebiolo stated the data would be reexamined for these occurrences.	FL will reexamine the data for these occurrences.
USFWS-12	*4.6.1 Adult shad migration and Emigration within Connecticut River* Some of our following comments will highlight the need throughout the report to provide information on the sample sizes of tagged fish that are utilized when quantified "transitions", "forays" or other analyses that are provided that may require the omission of some tagged fish known to have been present in the area of interest, because they do not meet model requirements for the analyses. This concern can be addressed by increased incorporation of tagged fish data tables that more clearly delineate the tag fish numbers. The current tables for release group detection provide tag fish numbers but do not address these finer scale questions such as if they are the same fish, or different fish, identified as moving from one area to another area (e.g., Smead Island Channel to the Cabot Tailrace). While we have probability rates for transitions through MSM analysis that compare movements among areas under different management/flow scenarios, we do not have a basic understanding of the number of tags in relation to these areas for the varied binned flow scenarios that feed these models.	FL will provide tabular data and an accounting for fish removed from analyses because model requirements were not met.

Commenter	Comment	Responses
USFWS-13	*4.6.2 Holyoke to Montague* 1. The report states that as flow increased, study fish movement increased to downstream sites. It is important to note that atypical higher flows occurred later in the study season, and it is unclear what effect the later timing of these higher flows played in influencing the reported downstream movement. It is possible that tagged fish present in-river for many weeks prior (time to pass at Holyoke unknown) may have been at a point of downstream movement initiation at that time, irrespective of river flow. Analysis of the data should consider potential auto-correlation of downstream movement and also note that these June flows were higher than average. 2. For analyses, it is noted that "staging" area assignments included Red Cliffe, Sunderland RTl 16, and Montague receivers. We would like to see analyses done with only Montague only data as the "staging" area relative to the subsequent "recaptures" (detections) at upstream sites noted as grouped into the "passing" state. Inclusion of the more downstream sites we believe complicates this analyses with unknowns. It is noted that "events may include multiple forays for fish." Researchers suggest the inclusion of a frailty term to address pseudo replication on that point. Additional text in this section speaks the likelihood "to experience the event" which can be more clearly stated as "moving upstream". 3. Table 4.6.1-1 Flow quantiles for MSM Downstream Model, would benefit from more description on how this was calculated. Researchers suggest a description of flow distribution for the chosen date bounds and then weighting for when live fish were present and actively moving upstream and/or in the "project" reach. 4. Figure 4.6.1-2 shows Kaplan Meier curves for the lower river. It is unclear if these are from Cox output. The report should identify whether these show the hypothetical scenario of a day or night that lasts 700 hours. *5.* For each of the following sections on study area segments, this report narrative should include a table of the number of fish available for each reach section. In addition, it would be useful to have 2D plots of dual tagged fish receiver detection histories with time on the x-axis and receiver location (or logical receiver grouping locations) by river kilometer on the y-axis, as mentioned earlier. Fixed station receiver, mobile tracking, and PIT reader identification can each be assigned a unique symbol on the plots, which would help to explore the tagged fish movement histories and their timings. As an example, live fish, moving downstream, are believed to make very directed and timely progress. Given limited energy reserves at the end of their spawning, these movements and their rates should be more completely presented to consider observations and make comparisons in project areas such as the immediate Gatehouse/Dam (arrival area), Canal proper, relative to other open reach areas, and the area of NMPS. Assessing the data in this manner could inform questions we have with the reported survival data. While a 3D plot was provided in Section 3 of the report, the figure is difficult to interpret. A 2D set of tagged fish plot movement histories, for each fish, would be helpful in describing patterns of movement, rates, fates, and project locations. These plots should clearly include known fish fates when available (i.e., left study area - outmigrating or died in area).	1. See comment **MADFW-21** 2. See comment **CRWC-1** for discussion on overall upstream movement model 3. The flow quartiles were generated by the dataset of flow experienced by fish used within the model. If more fish were present within a particular flow range (early vs late season), the quartiles may be biased towards the flows for which fish were present. The quartiles were not generated from the hydrograph representative of the duration of the study. FL will revise the quartiles so they are representative of the hydrograph and not weighted by fish presence. 4. Figure 4.6.1-2 is from the Cox output, which is why a 700 hour day exists. FL proposes to assess time to event within Therneau et al.'s (2016) competing risk framework and to discuss hazard ratios in tabular format rather than with a figure as the Cox output is confusing. 5. 2D plots of fish history will be provided in an addendum referenced to the section.

Commenter	Comment	Responses
USFWS-14	*4.6.3 Montague Spoke* 1. A table should be provided that summarizes the specific number of Holyoke release group fish detected at the Montague Spoke, Deerfield River, Smead Island West, Cabot tailrace, and Cabot ladder entrance. While the MSM is informative, the tabular data would provide information useful to understanding the summarized forays and to place the data in further context. 2. This section includes results of fish movement to the Smead Island under varied Cabot discharge and how once at Smead Island site transition probabilities to the bypass, increase with increased flow. The various percentages provided in this text are not fully explanatory given the available data. Specifically, how does time relate to these reported changes? A time-to-event approach should be applied here and would provide additional information on these changes in area detections in relation to time (rates) while accounting for the changing flow. We suggest an expansion of the time-to-event analytical approach to area not only limited to very near field project situations. Then it would be possible to provide K-M curves to show the rates of movement into each zone, controlling for other routes. Then it would be interesting to see a suite of K-M curves (cumulative incidence functions) that show the actual cumulative rates of transition in the presence of competing risks. 3. It is noted that the "majority of fish (74%) from Montague survived, transitioned and were detected ... at low flow ... " Additional use of existing data to examine how long it takes them to arrive at Cabot, under these various flows, would be most informative. The fact that some fish may go elsewhere, before subsequently arriving at Cabot is misleading. Instead one should treat arrival at Cabot as the event of interest. Fish are candidates for arrival **until** they move up the bypassed reach, downstream, or up the Deerfield River (those are censoring events). Each of the events of interest needs to be presented using a K-M complements and/or cumulative incidence functions. Ultimately what we want to know is the attraction to the tailrace and the rate of movement up into the bypassed reach, given that the fish are available. Then we can examine the flow treatment effects on those rates using Cox. *4.* The operations narrative is difficult to understand relative to within-day operations. For example, it is not clear why Cabot would have higher discharge flows at night given typical peaking operations, or why discharge values were as high as shown in the model run scenarios and plots (figure 4.6.2-4 as an example). We recommend providing more explanation in the text; if the project operated in an atypical manner in 2015 (reported same generation flows day and night) in comparison to previous 10 years that would be useful/necessary to know when assessing and interpreting the results. In addition, a more detailed operational figure with discharge in CFS would be helpful, as the currently provided figure doesn't allow for data time series that also shows the within day operations at a discernible scale.	1. Tabular data will be provided in an addendum referenced to the section. 2. (And 3) The suite of cumulative incidence curves produced by assessing each passage route event separately, while treating other events as censored produces some bias as shown in Therneau et al. (2016), and the reason for competing risk curves to sum to quantities greater than 1.0. FL proposes to treat competing risks within this framework. This addresses the USFWS third comment as well. FL produced competing time-to-event curves in section 4.6.13, the competing risk curves in Figure 4.6.13-4 assumed that fish were candidates for a route until they moved into one of them. This assumption produced curves that did not sum to 1. FL will revise this section according to Therneau. 4. FL will provide a description of operations for the duration of time fish in the model were present.

<table>
<tr><th>Commenter</th><th>Comment</th><th>Responses</th></tr>
<tr><td>USFWS-15</td><td>4.6.4 Cabot Ladder Attraction
In addition to summarizing the results of the MSM model, we request that FL provide a table showing the actual number of dual tagged shad available (Cabot Tailrace) to enter that ladder, the number of dual tags fish that do enter, and the number of PIT Only detected as entering. These tabular data can then be related to the Cabot ladder efficiency section. The narrative, as written, aggregates the number of Dual Tagged and Pit Only Tagged shad that attempted entry. It would useful to compare the number/rate (%) of entry by tag type relative to the number released and, in the case of dual tagged fish, the number available for that rate comparison. Tabular data should uniquely note any dual tagged fish not detected on the tailrace receiver but that were detected as entering Cabot Ladder. Because the definition of forays can mean a single tagged fish with one entry or a fish that made numerous repeated entries, clarifying the number of tagged fish available to enter and the frequency and timing of forays is important. In addition, a plot with individual/unique tags with the number of forays, by individual would more clearly depict the relative range of forays of individual tagged fish.
In text there are terms that continue to be used that unnecessarily complicate or confuse matters. The term "events" is apparently being referenced in text for "entry" at Cabot Ladder in some of the text in this section, the terms should avoid ambiguity and be clear. With respect to the time-to-event information, the definition of "event" (i.e., 114 ladder events) needs clarification. We request that throughout this report, any references to forays, events or transitions, include the number of tagged fish attributed to such an action. As noted above, the use of number of foray, transitions, and events are qualified by the fact that a single tagged fish can have a range of one to numerous observations (forays, transitions) that need to be considered in the interpretation of the results. For example, the MSM models may show dozens of transitions for one state to another but the actual sample size of fish available and used for those measures may lead to wide confidence limits that would have implications for data interpretations.
Figure 4.6.3-5 needs to have more detail to explain what the 25%, 50% and 75% values represent. Does that refer to discharge, and if so, from which location (Cabot or Bypass)? Were the fish that failed to enter censored? We would like to have retention time in the tailrace described and quantified. As presented here, it implies that retention was not the driver, but that instead there is something related to generation that stimulates fish to enter. We request the same plots for fish that re-entered for comparison. Figure 4.6.3-6 needs more detail on what the % values represent.
The text in this section states" ... Figure 4.6.3-7 shows that compared to fish approaching the bypass reach or turning back downstream, the relative rate of attraction into the Cabot Ladder was very high. While the overall rate of attraction into the bypass reach .... was relatively low ... "This text and the analyses it refers to are specific to tagged fish suitable for the MSM model in the Cabot Tailrace. It does not provide a broader perspective of available tagged fish that may also be available in the West Side of Smead Island, although it did include further downstream locations such as the Deerfield River. We request that tabular data be presented on the number of tagged fish available and or determined to be attracted to the bypass reach and assigned to the West Side of Smead Island.
Figure 4.6.3-7, the figures suggest there are numbers of fish that remain in the tailrace for> 100 hours what are some descriptive statistics on these fish. The tailrace detected group of fish would be logical for the more exploratory summary analyses for numbers and time spent, mean, median, min, max. How did you differentiate presences? Can we see departure based on the absence of data. Then the entry rates to the different reaches can be measured as time since departing the tailrace.</td><td>FL will provide tabular data in an addendum referenced to the section. FL will add tagging plan to the CJS model to explain differences between tagging methods
See comment USFWS-1, FL will standardize language.
See comment USFWS-13
FL will provide tabular data
FL will provide an examination of fish remaining in the tailrace in an addendum referenced to the section.</td></tr>
<tr><td>USFWS-16</td><td>4.6.4 Cabot Ladder Efficiency
It would be useful to have a table noting the number of dual tagged shad that entered the ladder and passed the ladder from the "available" tags as well as PIT only fish, showing the tabular data of available, entered, and passing, by cohort release group (Holyoke Dual and Holyoke PIT Only) and some summary statistics on how many attempts made (by some groupings based on the data). Our preliminary analysis of the entry and passage data for Dual Tagged versus PIT Only strongly suggests differences in performance; with radio tagged fish having consistently lower passage rates, as shown in our Table 1. These observations support the Service's contention that analytical results for radio tagged fish are influenced from a suspected handling/tagging/tag effects. Data from radio tagged fish are considered valuable but it is important to acknowledge cautions and potential concerns in interpretations of results.</td><td>FL will provide tabular data and the detection history of all fish used in the CJS model. FL will include tagging plan as a variable in the CJS model and compare probability of arrival at each subsequent station among different tag plans. AIC model selection and likelihood ratio testing will determine whether or not there was a difference between tag plans.</td></tr>
</table>

Commenter	Comment	Responses
USFWS-17	*4.6.5 Bypass Reach* 1. Given this reach's management interest, increased reporting of fish tag detections is required. A table reporting the number of dual tagged shad from the Holyoke release cohort available to move from either Cabot tailrace or West Side Smead along with a count of the number of tagged fish that are detected at each upstream receiver location will be useful to place other analyses in context. The text notes "fish moving through Rawson Island telemetry subnetwork incorporated 95 dual tagged fish." It is unclear if this is the same number of fish that were available to move through the network (i.e., the total number of tagged fish detected at Cabot Tailrace, Smead and Conte discharge). Further, as noted above, from the way results are presented, it is unclear where these tags are subsequently detected. Also, the data are then analyzed relative to "transitions" at an "hourly" exposure which may be influenced to an unknown degree by a few highly mobile fish. 2. We recommend that the data be analyzed to determine if there is a relationship between tag timing and fish performance, as this could have important implications on the interpretation of the results. Based on our review of the MSM models shown in Appendix D, (Table D-1.5-1) it appears that there is a high probability of tagged fish moving from one side of Rawson Island to the other side of Rawson Island and back again. As a result, the extent to which the rock dam is a partial barrier is reduced by the repeated probability/opportunities of such movements among areas and routes. 3. It is important to point out that the MSM probability models should not only be considered in the context of initial tag/fish probability of its transition options at one location at one point in time, in any given condition scenario. Rather, the probabilities and choices among "states" presented in the MSM models should be considered from the perspective of additive probabilities of repeated opportunities of movement. The Service contends fish have, and take, multiple opportunities to transition to upstream sites/areas in the natural river and do not simply vacate an area after a single upstream movement choice to a relatively small detection zone areas. This is perhaps best illustrated by repeated attempts, mostly associated with fishway entrance analyses. In the bypass reach, it can be somewhat confusing to consider the probabilities for "transitions" to the upstream areas, given the high degree of movement between defined sites (such as West and East side Rawson and the next downstream detection sites). If possible, model results should attempt to incorporate this additive probability of advancing. For example, when analyzing arrival from "Upper Bypass" to the base of the dam we would like Rawson Island area to be incorporated into the model rather than being broken out separately. 4. We also request that the Appendix D models and outputs include a table that lists the receivers that make up defined group areas. Analysis of the database indicates that a total of 23 dual tagged fish reached the base of Turners Falls Dam. If we use the provided total of 95 "available" in detection zones immediately below Rawson Island, 23 of the 95 fish (24 percent) of dual tagged shad reach the dam. This proportion is an example of the type of information that should be noted in the requested tabular summaries for tag fish advancement into areas of interest, such as available to enter the "bypass reach" in relation to "detected in tailrace" and "detected at the base of Turners Falls Dam." We note that detection at Rawson Island was potentially biased, as shad on the East side had a greater detection probability due to potential delays from the presence of the Rock Dam, whereas receiver data suggest rapid movements through the West Side detection zone. Additionally, the database indicates that 10 of the 23 dual tagged shad (43percent) that reached the base of the Turners Falls Dam were not detected at Rawson. This observation suggests the probability that the utilized data may have disproportionately overrepresented the tag detections and their associated value on the East side, influencing results regarding fish delay at the island. *5.* Additional descriptive summary analyses that examines when tagged fish were actually detected in relation to binned flow values (1,000 CFS, 2,000 ... 10,000CFS,>10,000) for study areas and reaches of interest would be informative. For example, the reported numbers of arrivals in relation to the binned flows to the base of TF Dam and movement from downstream locations (Smead and Cabot receivers) to Conte Tailrace. In addition, the MSM outputs consider fish movements under varying flow scenarios (Cabot vs. Bypass), but does not more fully explore how the data relate in a "ratio" approach for two flow levels. Actual tagged fish movements, from areas downstream of the bypass area entrance (Cabot Tailrace and Smead) should be considered for that ratio and response, both in actual data and model results.	1. FL will produce a CJS model describing the probability of arrival at the next upstream Bypass telemetry station as part of the overall Holyoke – Spillway CJS model (see **CRWC-1**). 2. Release cohort will be added as an explanatory variable in the MSM analysis, along with a variable describing the number of back-and-forth transitions between the east and west channel at Rawson Island. The probability of transition from the island to the spillway will be compared with those fish making a few back and forth transitions with those fish making many. 3. Rawson Island was not incorporated into the Upper Bypas state because T16 was not a gate. The model proposed in CRWC-1 will add context desired by USFWS. 4. FL provided receiver groupings within the report. Other stakeholder concerns will be addressed in the model proposed in **CRWC-1** to be provided in the addendum. 5. Fish are not exposed to Cabot flows while in the bypass reach. However, in reaches where they are (Montague Spoke and Cabot Tailrace), FirstLight provided heat maps which give probability of transitioning according to different flow scenarios

Commenter	Comment	Responses
USFWS-18	*4.6.6 Spillway Ladder Attraction* A tabular accounting should be provided for the number of dual tagged shad detected at Station No. 1, the Upper Bypass (base of dam T19 and T20), and Spillway Ladder entrance. The values reported in this section do not clearly correspond with the report's earlier summary table (4.2-3 on page 4-4) for Holyoke released fish. The text identifies 57 dual tagged Holyoke fish in the lower and upper bypass for MSM use; 11 dual tagged fish entering spillway at least once and 24 dual tagged recaptured in the lower bypass spillway, and spillway ladder. None of these reported values can be clearly linked to the dual tagged values reported in Table 4.2-3. The reporting of the correct values for dual tagged arrived and available at the base of the dam cannot be clearly determined from the information presented. This number is further qualified by our earlier contention that this rate of movement to the base of the dan1 is reasoned to be biased low due to "radio" tagging effects shown by comparison between the two study tag type groups. This caution would only reflect a portion of the tagging effects as the PIT only tagged fish were also handled, processed and tagged, but were seemingly less impacted relative to later measured fishway performance.	FL will provide tabular data in an addendum.
USFWS-19	*4.6. 7 Spillway Ladder Efficiency* As noted earlier, a table should be provided showing the number of fish available to pass by tag type and cohort release origin, as well as the number entering and advancing in defined segments and/or "survival/passage" to subsequent receivers. The reported receiver outages and the associated CJS associated biases, make the noted entrance efficiency seem highly questionable. The issue given outages needs to be resolved. As stated, "the results should be suspect given low rates of recapture at the spillway ladder entrance." At Cabot a high rejection rate was noted. If spillway had similar and they were undetected there would be large error here.	FL will provide tabular data in an addendum and create a series of release recapture models as discussed in response to **MADFW-19.**
USFWS-20	*4.6.8 Upstream Migration through the Canal* 1. The report states "from the forebay, fish may choose to transition upstream through the canal or to the downstream bypass entrance." We note that fish also have an additional transition option to pass into the tailrace via the turbines, which should be quantified by tag type and release group similar to the noted "bypass entrance." 2. A better quantification of canal delay for upstream migrating fishes is needed. The sample size of fish from each release group should be defined and their mean, minimum and maximum time spent in areas downstream of the upper canal receiver should be reported. Additionally, quartiles for mean times and a measure of variation should be provided in any downstream areas (in aggregate) of the canal. These data may be further broken into sub areas, identifying the fate of each fish relative to passing, remaining in canal (dead), or passing downstream (route and fates - may refer to later section on those). 3. Reference to the "state table" does not include information on the number of tagged fish comprising those observations. Each reported "state" should include the number of tags from both the Holyoke Cohort and the Cabot Cohort and the combined total, in tabular form for the reported downstream bypass and all the other reported locations. This additional information will place the current summary data in a more appropriate and meaningful context. An additional analysis should be reported for the number of tagged shad that were detected within a short time period (i.e., less than 24 hours) at receiver locations downstream of the Cabot Ladder exit with no upstream detections, to quantify "fallback" for that release cohort. A more thorough accounting of short-term fallback and fish that remained solely downstream of release locations should be provided. *4.* Figure 4.6.8-2, notes plots are for upstream canal passage, but is this really passage or movement? We must have this clarification as the axis title indicates this is movement to the upper canal radio receiver. Figure 4.6.8-4 notes time *to* escape the Cabot forebay under different flow regimes. Is the term "escape" only inclusive of fish moving upstream? Does it include fish that move to the sluice entrance? There are any number of options for fish escaping the forebay and it important to understand what the next choice was. It is also important to know if those choices were consistent across the three grouped flow regimes, or varied.	1. FL will provide transition proportions from the forebay through all routes. However, there was no PIT array at Cabot Station therefore we cannot assess by tag type. 2. See **CRWC-17.** 3. FL will remove provide tabular data and remove fallback fish from analysis. 4. FL grouped all routes from the forebay as escapement.
USFWS-21	*4.6.9 Gatehouse Ladder* As with the other project fish ladders, it would be instructive to compare tag type fishway results (dual tagged fish passage with PIT only), to determine the degree of difference between the two tag types performance, by tagging cohort.	FL will include tag type as a variable in the CJS model and will provide detection histories in tabular format.

Commenter	Comment	Responses
USFWS-22	*4.6.10 Upstream Migration through the TF lmpoundment* 1. In all other similar sections of the report an MSM State Table is provided (see page 4-74). We are unclear why this table is omitted from this study section and request its inclusion with the tabular data requested in other sections of number of tags (by release cohort) for the enumerated observations at each state, to place those observations in some context. 2. There should be a histogram that provides the sample size of tagged fish present in the NMPS study area in relation to both pumping and generation rates. How did study fish sample sizes vary relative to exposure for the range of operational conditions at NMPS in 2015. 3. For the time to event analyses, clarify if the attraction to the NMPS intake was only during generation or if there was any attraction during pumping. We request more discussion on the topic of delay as the text notes approximately 50% of the fish were able to escape within 20 hours. What does that mean for the balance of the delayed fish relative to their delay? Are the remainder, or 50%, of these delayed fish demonstrating a consistent rate of delay (and to what extent) or do their delays reflect a non-linear or skewed increase in the amount of delay in comparison to the 50% of the group that was described? Much more detail on the study fish experience and responses, for the full exposed sample group should be presented. Data that clearly show and account for all detected tags in and around NMPS should be presented to support the statements of no entrainment being detected. 4. The provided time-to-event analyses and figures is noted as only examining day vs. night in relation to "passing" of NMPS. We request time-to-event for varied pumping and generation analyses and resultant figures that would describe how varied operations effected study fish movement (or as described passage) past NMPS. This is an important examination of project effects that data are available for and should be provided and discussed in much greater detail. 5. Data on the number of dual tagged shad that were released, examined in terms of short-term downstream movement to either the Gatehouse or a bascule gate at the dam, should be provided. A period of less than 24 hours should be used to assess the fallback rate and the number and percent assignment of this fallback group to either downstream routes in relation to the number of tagged fish detected as moving upstream should be provided.	1. FL will include the state table in text and in the statistical results appendix and provide tabular data at the request of USFWS. 2. FL will enumerate sample size under different operational flow regimes. 3. The MSM analysis quantified attraction towards NMPS during pumping and generation. Then, time to event analysis assessed time to escape the intake area. FL found no relationship between delay and operations. 4. FL did conduct a full time to event analysis, please see response to comment **CRWC-15.** FL found that a model that incorporated flow was not fit. 5. FL will remove fall back fish from the analysis.

USFWS-23

4.6.11 Downstream Migration through the TF Impoundment

1. The Service requests the inclusion of a table for tagged fish from TC that were identified as available to pass the NMPS area, the number and percent detected at each receiver, and the fates of these fish. References to the number of events need to include the sample size of tagged fish that were used for those reported "events" statistics. The tabular data also should indicate the number of fish that "moved downstream" or "died" through this TFI section based on tag detection. The available information on TFI and TC released fish, relative to their downstream movements, routes taken, and ultimate fates should be presented in tabular form. Regarding fate, the Service's position is that if a fish is not moving over time, it should be assigned as "died."

2. The matter of delay and project effects at NMPS cannot be solely attributed to only study fish detected in the immediate NMPS intake detection zone. Fish are expected to be exposed and potentially influenced in their movements by the spatial extent of the NMPS flows in its generation and pumping mode, which extends well beyond the immediate intake area. The extent of this influence is dependent and related to in-river discharge and NMPS operations and can extend its flow field alterations for kilometers, both up and downstream. We request analyses that looks more broadly at the study fish available in the upstream and downstream areas, and explores the extent to which movements of all study fish in the study area (based on their assigned migratory direction) may be compared, contrasted and described for movement and time taken to advance (movement rates) or not. As noted on the upstream section analyses, figures and analyses that provide more detail to explain how project operations relates to the matter of movement delay should be provided. The currently provided figures only relate to day or night and does not include the available information on the time vary covariate of variable NMPS generation and pumping, which are of primary interest, as opposed to broadly comparing day vs. night.

3. Sixteen of the 20 fish (80%) from the TFI release group passing the "Gatehouse/Cabot Powerhouse" were reported dead. The definition of "Gatehouse/Cabot Powerhouse" needs to be better defined. As shown in Appendix C, it is unclear if this includes fish that died in the canal in front of Cabot Station or only those fish documented as having passed Cabot Station. In comparison, the Gatehouse/Bypass was used by only 6 TFI release group fish, with 100 percent of those assigned as dead. Again, it is unclear if these include fish that died in the canal or only those passing downstream through the bypass sluice. Below is an example (Table 3) of how the study objective on mortality determination should be presented using unfiltered field data, as opposed to log transformed catch-curve values/figures that use a "daily rate" metric. The Service would like to have a more integrated approach relative to the survival component of the study, which would begin in this upstream study section and be applied in all later section's results and discussions.

Table 3. Data from Appendix C for only TFI Release Cohort, illustrating summary presentation of obtained study objective data. The table is partially developed and would include additional rows/labels that would eventually allow for column sums to match in the bottom "total" row. Areas and or routes need to be more explicitly defined.

	Total	**Left Area (Alive)**	**Died**	***"Remained" (?)***
Bascule Gate	17	4 (23%)	12 (71 %)	*1 (6%)*
Gatehouse/Cabot Powerhouse	21	4 (19%)	16 (76%)	*1 (5%)*
Gatehouse/Downstream Bypass	6	0	6 (100%)	
Did not pass*	25	7 (28%)	18 (72%)	
Other options ... more rows				
Total	75	19 (25%)	54 (72%)	*2 (3%)*

*need clearer definitions, this is currently interpreted as fish never emigrating out of the Turners Falls Impoundment

In comparison to this TFI Release Group data, the Holyoke Release Group data shows that out of 75 fish identified in mobile tracking, 24 (32%) died in the study area, 50 (67%) left the study area, and one fish *"remained in study area"* (which we interpret as died). This simple partial comparison suggests some clear differences between these two release groups and their reported survival/mortality which should be more closely examined and discussed.

4. Each release group should have a mobile tracking survey summary table with the above information included to compare and contrast observations of routes fish took downstream and their corresponding fates, including a more comprehensive, all cohort summary table that would focus on the route choices and fates (aggregating release groups).

Response:

1. FL will provide tabular data in an addendum referenced to the section.

2. FL conducted time to event analyses and MSM analysis with operations in mind. If the results do not reflect operations it was because the model did not pass goodness of fit, or the model was not selected as having the lowest AIC score.

3. FL will provide tabular data on mortality.

4. FL provided a mobile tracking summary table in the appendix. FL will develop a table of fates by release cohort.

Commenter	Comment	Responses
USFWS-24	*4.6.12 Downstream Migratory Route Choice at Turners Falls Dam* 1. A State Table (see 4.6.8-2) displaying transitions is omitted and should be included for this component of the study as in previous components. Additionally, the number of tagged fish that comprise the "hour of exposure" should be included. This section should include a table with the number of available downrunning fish encountering the dam and/or gatehouse, by release cohort (including TC's releases) with relative percentages. *2.* This area requires a time-to-event analysis to determine if there is any delay upon reaching the dam and to examine the effects of flow and flow routing (bascule spill flow relative to Gatehouse flow) on the fish route of choice. The ratio of flow to these two routes would provide a useful analysis of route of passage and in addition to the straight flow value analyses may consider if a threshold value(s) exists for route selection. *3.* We do not disagree with the inclusion of a mortality rate using the given mobile tracking data but request that tabular data for downrunning fish and their assigned fates that can be linked to a passage route also be provided. Related studies at this project as well as other FERC hydropower projects commonly present mortality as a value (number determined dead/number available as %) rather than a daily rate. Therefore, we request that this tabular data on the tagged number of fish available and passing the Dam via spill along with the number assigned alive and detected as mortality, be provided to develop an overall mortality rate.	1. FL will provide tabular data in an addendum referenced to the section. 2. FL will assess time-to-passage route using the framework proposed in Theneau et al. (2016) so competing risks (canal or bypass passage and do not pass) sum to 1. FL will perform separate Cox regressions on each route of passage to understand delay as a function of project operations and report the hazard ratio (with standard error and significance values) in tabular format. The cumulative incidence curves for fish choosing each migratory route and Kaplan-Meier curve showing those fish remaining to pass will be graphed. 3. FL will assess mortality according to **USFWS-1.**

USFWS-24	*4.6.13 Downstream Migration through the Canal* This section is confusing due to the mixed use of numbers of tagged fish reported in the text. A table should be included that shows the number of tagged fish available starting, the number known to pass by either Cabot Units, Bypass Sluice, unknown passage route, or not passed, and their respective percentages. This section reports that 98 fish were detected in the canal but uses a lower value of 86 fish; with the latter value being used in data analyses. The report should discuss why 12 fish are not included in subsequent analyses if they entered the canal. Further, only 67 of the 86 fish passed the passed the canal, yet the report does not provide information on the status and fate of the 19 fish that did not pass. The currently reported values and rates of passage by route are based on a total of 86 tagged fish available in the canal. If, as the text states, four fish pass by an unknown route and another 15 fish do not pass, why is the percent passage assignment not based on the known available that passed by one of the possible routes out of the Canal? Given that 39 fish passed through the bypass sluice and 28 passed via Cabot, the total known passage by either of these two routes of is 67. This is the value that should be used as the denominator when calculating the percent passing each of those routes from the lower canal. This results in 58 percent of the fish using the bypass sluice (39 out of 67) and 42 percent using the Cabot Units (28 out of 67). These values should be included in the report. The Service would like to have a more integrated approach relative to the survival component of the study objectives as noted earlier. This section should include information on the fates of tagged fish that can be assigned as alive or dead from mobile tracking based upon the number of known tags using the bypass, the number using the Cabot units, and the combined overall passed by either route (which would include the four fish whose passage route was undetermined). Survival rates based on the complete study period should be reported as these address key study objectives for considering project effects and the impact to outmigrating shad that are located in the canal. Using the 96 fish available for time-to-event analyses referenced in Appendix D-50, a total of 80 made successful attempts into the bypass/sluice (PIT detection) or Cabot Tailrace. The Service recommends using the term "transition" rather than "successful attempts," given that "successful" has a certain connotation which is not appropriate in this context. Also, it should be noted that 16 fish did not make a transition, as they apparently remained in the canal, and are considered to be mortalities. For the 80 fish that made "successful attempts," it is unclear if those attempts are all unique or includes some fish making multiple attempts. Also, the report refers to 71 fish being detected in the tailrace or sluice, which differs from the 80 fish reported as making "successful attempts". This apparent discrepancy should be clarified. As requested in previous sections, a table that shows the number of tagged fish comprising the "attempts" should be included immediately adjacent to that statement. In order to address the study objective on delay, a more detailed accounting of the tagged fish detected as present in the canal for downstream migration and their time in the canal should be described in a table. These data should be related to the available data for downstream moving fish in the bypassed reach for comparisons. The time-to-event analysis is intended to consider time varying covariates, yet there is no mention of the covariates used. Further, it is unclear what Figure 4.6-13-2 is trying to portray; the legend does not state what 25%, 50% and 75% refers to. Even the title is confusing, as it suggests the graph shows time to downstream bypass arrival, yet the narrative indicates it shows time to pass either through the bypass sluice or Cabot Tailrace after entering the canal. It would be helpful to include canal flow in this analysis in order to ascertain whether time to pass via a given route was related to canal flow. The currently provided text and figures break this Canal project area spatially into two components: 1) from entry into canal to arrival at Cabot and 2) time to pass from "downstream canal". The same analysis should be run for the time of entry into the canal to the time of passage, without segmentation of the canal into two spatial components. The downstream canal model assessed passage efficiency of the Cabot bypass. The report states that 76 fish approached the bypass but abandoned it for other locations 716 times. A plot should be developed showing fish on x-axis and rejections on y-axis, to illustrate if the frequency of rejection follows some distribution or if only a small number of fish drive this result. The basic statistics (mean time, standard deviation, ranges, and quartiles; all time based with associated sample sizes) regarding delay/milling and for time to pass out of the canal (and those that did not) from first detection in forebay area should be provided. The Service agrees that shad exhibited a high degree of milling behavior with fish moving back and forth between the Cabot Station forebay/intakes and the entrance to the Bypass/sluice. These data indicate that shad are not able to find and utilize the Bypass/Sluice	See **CRWC-17**

Commenter	Comment	Responses
	in a timely manner (50 percent of the fish taking over 24 hours). A plot showing time taken to pass downstream (for each fish), will be useful to fully document the observed amount of time for all known passed fish. The report states that the Kaplan-Meier (KM) curves developed for the downstream canal model "illustrate low passage efficiency and large delay through the downstream bypass with fish abandoning the bypass." Additional discussion and tabular data to support the figures are needed, including: passage; delay (hours); time to pass (hours); and complete rejection (numbers and% relative to available). As mentioned earlier, the catch-curve mortality based estimates are of interest but are of limited management use in comparison to percent survival. The report must include a table of how many fish entered the canal (available), the number of fish that never left the canal, the number that were detected passing from the canal and their numbers and % by route and the fate (number and %) of those fish by known passage routes.	
USFWS-25	*4. 7 Turners Falls Fishway Passage* Because it is not reported in the text on page 4-66, we cannot easily ascertain the number of dual tagged shad that were detected in the "upper bypass" or at the base of the dam (and thus available to use Spillway Ladder) in comparison to the number of tags that do attempt entry, that is reported. This missing information is important, as we know the current ladder entrance was not designed to operate with the higher bascule gate spill treatments evaluated in 2015. We used the reported MSM probability values of fish that reached the "upper bypass" and attempted Spillway Ladder under high to low flow conditions to calculate a mean probability of 53 percent. Using this mean probability value, 2015 Spillway ladder counts, and the estimated ladder efficiency, we estimated the number of untagged shad reaching the base of Turners Falls Dam to be as high as 241,392 fish in 2015.	FL will develop a CJS model of the bypass reach using dual tagged fish. The model will examine the probability that fish will survive to a particular station. Ladder entrance efficiency will be assessed as the survival between the tailrace station and the ladder station. The ladder station will include all antennas within Spillway Ladder; this includes P21, P22, T30, P23TP, P24, and P25. The proposed release/recapture locations are: (1) the release location is Holyoke and will include detections from all fish released minus those identified as fall back fish, (2) the first recapture occasion is considered project arrival where a fish is either captured at Montague, Cabot (consisting of the tailrace T5 or T6 or anywhere within Cabot Ladder), Lower Bypass reach (T11 & T15) or the Deerfield river, (3) Rawson Island where presence in either channel is presence at Rawson Island, then (4) the spillway where recapture is noted with presence at T19 or T20, the (5) next recapture location is for a fish anywhere within the Spillway Ladder, the (5) next recapture occasion is the gatehouse ladder, and the (6) last recapture location is anywhere upstream of Gatehouse Ladder. FL notes that only dual tagged fish can be included in this model. FL will provide a list of detection histories in tabular format as well as a tabulation of the number of fish to arrive at each recapture location.

Commenter	Comment	Responses
USFWS-26	*5.0 Discussion and Conclusions* *Upstream Migration* 1. As noted earlier, the statements regarding the number of tagged fish that reached the Turners Falls Project area, as a percentage of the total released, must address the fact there are tagging related effects that result in "fallbacks" when conducting radio tagging studies. Also, as noted earlier, the effect of time relative to tag fish release dates needs to be considered in the analyses of atypical high flow events in June. Given that test fish were tagged and released primarily in early and mid-May, it is unclear if the high flows that occurred in June coincided with a normal transition from an uprunner to an outmigrating fish based on spawning condition and/or energy state expenditures. The results also show a substantial component of fish moving at night which was not previously known but should be mentioned here. The MSM models and heat maps illustrate the probability of movement between night versus day among select sites at and downstream of Cabot Station. 2. Rawson Island itself does not present a migratory hurdle, but the natural rock ledge on the eastern channel of the island appears to impede movement, but is complicated by a fish's ability to drop back and move up the other side of the island. We do not agree that the channel west of Rawson Island is a fish passage issue for shad to migrate through, particularly in light of the high proportion of tagged fish that went undetected past Rawson Island and the discarding of a large amount of receiver data from that site. The second to last sentence should be corrected, to finish the statement that fish passed "quickly" through the western channel. 3. There is no mention of project effects mortality in this section. Earlier, we noted the need to more fully address and develop the data reporting, analyses, and results on this study objective. The Discussion section should provide a review of these findings given the implications for differences in project routes used, frequency/magnitude of use/choices, and observed fates under various operational conditions that impact the extent of mortality on post-spawn outmigrants. *4.* We disagree with the statement that "less than half' the American shad lifted at Holyoke approached the Turners Falls Project. This statement is misleading and, we believe, incorrect, based on the number of shad captured, handled, processed, and double tagged, and then released at Holyoke in relation to subsequent upstream detections. Our previous comments note the lack of consideration of fallbacks from the initial release group that result in some level of potential bias. Further, using the provided study results on fishway passage efficiencies at Turners Falls (Cabot and Spillway), such a claim is not seemingly possible, given the determined poor study fish passage rates in relation *to* wild fish actually counted passing the first ladder facilities at Turners Falls in 2015 in relation *to* the number passed at Holyoke Dam/Lift.	1. FL will address fall back fish in an addendum referenced to the section. Time to event models of the lower river will include release cohort as a predictor. 2. FL will update the sentence in the addendum. 3. FL will provide an updated assessment of mortality, see USFWS-1. 4. FL will remove fall back fish and revise.

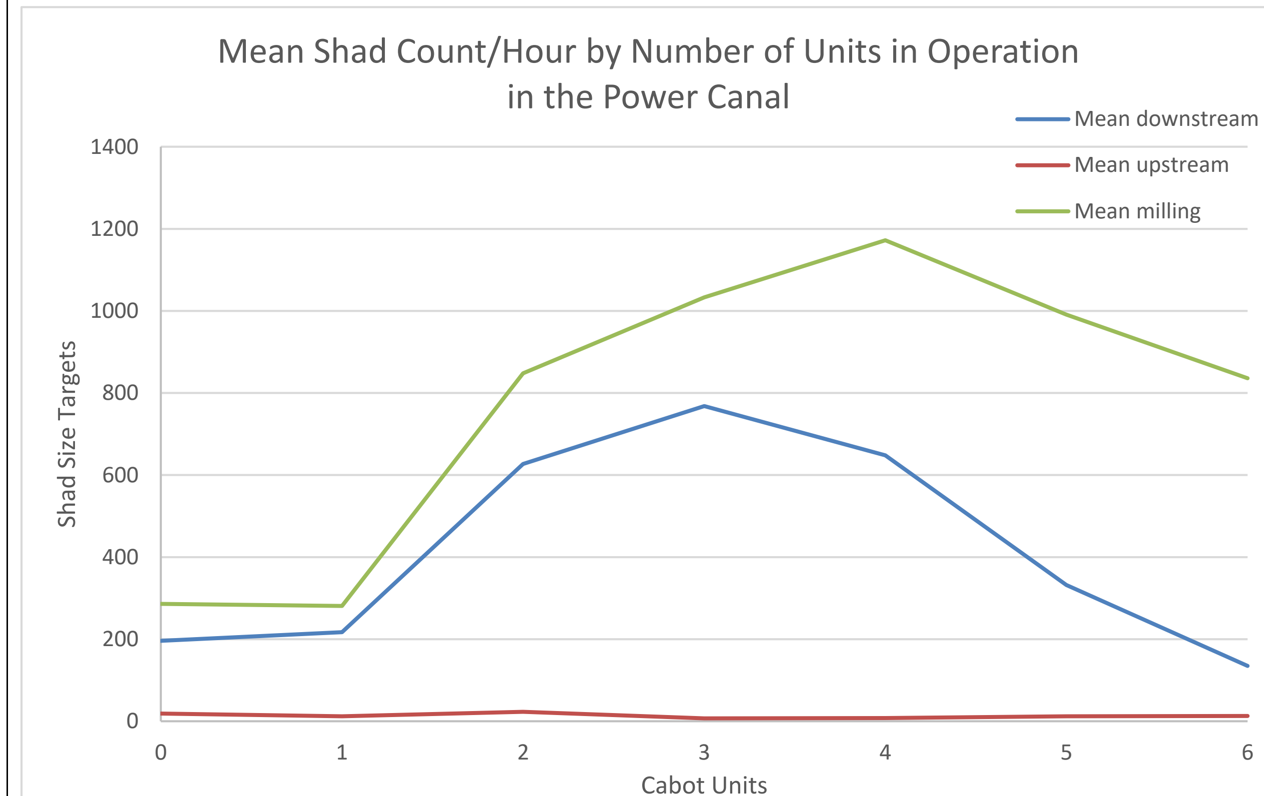
Commenter	Comment	Responses
USFWS-27	*Appendix D - Statistical Results* 1. The text notes," ... movement between states (location) in continuous time." Please clarify if the analysis relied on simply waiting for events to occur and called it a multinomial response. Typically, the MSM is done with a time step so time is discretized, not continuous. In addition, the text notes recaptures are defined within one hour period, so not continuous in this example and we note again recaptures are referring to detection. 2. The text notes transitions are assumed instantaneous. What happens if there are multiple transitions within a single hour? Does the clock re-start at each transition, or is it an astronomical clock? If astronomical, do we get multiple observations within an hour? This would not be recounting, but it would allow for individuals to be counted multiple times within an hour. 3. In the MSM tables there are zeros on the diagonal, which means the 'staying in place' option is omitted. This is acceptable for describing general movement patterns, but it would not be appropriate if quantifying covariate effects on movement. In that case, lack of movement is also very important and movement needs to be considered in that context. 4. In Figures D-1.3-1 and -2, the y-axis is referring to count of what units? Later similar figures have the same issue (e.g., Figure D-1. 7-1). 5. On page D-42 (Appendix D), it states " .... was 1.000 suggesting that Cabot Generation has no effect on risk of an event occurring." We believe this is inaccurate, as this only suggests the units were too small to register. Also, KCFS should be used instead of CFS. The report states, the first model was significant but we believe scale is being confused with significance. 6. Figure D-2.2-3 should include text noting the plots include flows. In D-2.3, Cabot Ladder Attraction, second paragraph, the use of four models are presented. These models should really be presented in table form. It would read best if you placed the tables in with the text so readers can quickly refer to them as they are explained. This is something that could be applied throughout the document. 7. In D-2.5, Spillway Ladder First Foray, for Figure D-2.5-2, this can be explained better. Is this time since departing Montague? Since arriving at Montague? We would want to see curves for entry into the bypassed reach at different flows. This is a fundamental quantity that is missing from your analysis and is of priority management interest. Entry should be from anywhere above Montague (but below the bypassed reach), i.e. do not censor for being in the tailrace. Or censoring could occur, but then also examine/report without censoring those fish. All of this will lead to a much more complete understanding of what is needed. 8. Figure D-2.8-2 suggests that at low flows passage we don't really expect to pass more than half the fish. It would be good to see this for arrival but also for passage (both from the forebay and from bypass nearfield). Turbine passage should also be shown. Figure D-2.8-6 seems to contradict some of what is in the text. It is more similar to what we have seen in previous studies, does this include non-obligate downrunners? Also are these only turbine passers? The following figures (D-2.8-7, set of three), doesn't mesh with the previous figures. We would like to have these data explained. Are they for all flows? Figures D-2.8-8, are unclear as to their basis and meaning. What is being reported and from what data? Figure D-2.9-2 requires more interpretation for clarification. The curves appear to be in relation to flow, and this suggests fish move downstream more rapidly in low flows.	1. Multi-state release recapture (MSRR) is performed with discrete time steps. The MSM analysis conducted here is in continuous time and uses data in the counting process style favored for use in survival analysis. Further, the multi-state modeling proposed by FL is an extension of survival modeling, just with more than two states and the ability to incorporate disease/recovery aspects into the modeling framework. This would arise when a fish attempts one route, but fails, returns to the original location and tries another route. The MSM also incorporates the assumption that transitions are Markov, meaning that the next state is dependent upon the current state. 2. The data format is the counting process style, which means the clock starts when a transition is made. 3. Lack of movement will be assessed in the downstream canal passage, turners falls dam route selection and ladder attraction models. 4. These figures represent flows experienced by fish in the model. Therefore counts are representative of an individual observation. See USFWS-13 5. FL used KCFS as values for generation. 6. FL will provide model results in tabular format. 7. This is time since departing Montague. See comment **CRWC-1** 8. Downstream canal model will be re-assessed see comment **CRWC-17**

Study No. 3.3.3 Evaluate Downstream Passage of Juvenile Shad (Interim Report)

Commenter	Comment	Responses
As noted in the cover letter, one of the juvenile shad study (Study No. 3.3.3) objectives is to determine the rate of entrainment of juvenile American Shad at the Northfield Mountain Project. In 2015, FirstLight deployed hydroacoustic monitoring equipment in the NMPS intake/tailrace to estimate the number of juvenile shad entrained as they emigrate past the Project. Unfortunately, milling was a major issue and no estimate of entrainment resulted from this effort. Radio telemetry was also used to estimate entrainment of the juvenile shad at the Northfield Mountain Project. However, poor tag retention and low survival of test fish, along with limited detection of test fish yielded questionable results. In its comment letter dated December 13, 2016, USFWS indicated that it is not appropriate to base an entrainment estimate on numbers of tagged fish detected in the upper reservoir due to potential tag loss upon entrainment. Given that hydroacoustics evaluation is not feasible at NMPS, and given the concerns with tag loss at NMPS, FirstLight proposes to base entrainment of juvenile shad at NMPS on a previous robust netting study conducted in 1992. Since the number of adult shad passing the Turners Falls Dam at the time of the study were similar to current passage numbers and that the Northfield Mountain Project operation was similar, FirstLight finds the previous entrainment study conducted in 1992 is still applicable today. Attachment A (Study No. 3.3.3) of the responsiveness summary includes a memo summarizing the entrainment estimate of juvenile shad at the Northfield Mountain Project from the previous study.		
USFWS-1	*3.1.1.3 Hydroacoustic Data Analysis at Cabot Station* Page 3-2, last paragraph: at Cabot, entrainment was assumed for targets tracked below elevation 160.26 feet mean sea level (msl). Fish above that elevation appeared to be milling (moving in multiple directions, not just towards the penstock). It is not clear if no fish above EL 160.26 msl were entrained, which could lead to underestimating entrainment.	The report states "*In addition, entrainment was assumed for those targets that were tracked to an elevation lower* ***than the top of the Cabot penstock at elevation 160.26 feet msl (NGVD 29),*** *as all fish below this elevation were observed to be moving into the penstock, while fish above this elevation appeared to be milling (moving in all directions).*". These fish were excluded from the estimate because regardless of their direction of travel they were physically excluded from entrainment by Project infrastructure as illustrated in Figure 3.1.1-2. It is important to consider that split-beam hydroacoustics provided data by which to enumerate and determine the direction of travel of targets over a discrete beam area. Targets moving in and out of the beam area cannot be quantified as individuals, which means if you counted targets above the top of the penstock elevation where they physically cannot be entrained they have the potential to be recounted when they are detected in a section of the water column where entrainment is possible and thus results in an overestimation. That is, targets observed above the elevation criteria are included in the entrainment estimate when they are detected below elevation 160.26 ft. msl but cannot be accounted for on an individual basis.
USFWS-2	*3.1.3.3 Hydroacoustic Data Analysis at NMP* 1. Data filter criteria included only using data for fish with a mean elevation of 172 feet msl for the duration it was tracked. The consulting group should provide its rationale for this criterion; it seems like a fish should be included regardless of how high in the water column it was so long as its last (or any) detection was below 172 feet msl. 2. Another filtering criterion applied to the data set was to exclude any fish that was outside of the 45 degree line as it moved between the transducer and the intake. The consulting group should clarify how fish are treated that do not adhere to the criterion for some, but not all, of the detections (i.e., fish that fell outside of the 45 degree line for some, but not all, of its detection history).	1. The elevation data filter criteria of 172 ft. msl is similar as explained above for Cabot station. The NMPS intake/discharge contains a structure that includes a skimmer wall constructed from solid concrete that physically excludes fishes from entrainment above that elevation. The intake/discharge structure is illustrated in Figures 3.1.3-1 and 3.1.3-2. 2. All fish moving toward the intake within a 90° swath (centerline +/- 45°, see figure 3.1.3-3) and below the bottom elevation of the skimmer wall were considered to be entrained. For any given detection history, the direction of travel was assigned based on the last vector observed. For example, if a target started in the direction of the intake but reversed direction away from the intake then the target did not meet the directional criteria and was excluded from the analysis. Likewise, those targets initially moving away from the intake and then reversed direction toward the intake were included in the analysis.
USFWS-3	3.2 Evaluation of Passage Routes (Radio Telemetry) *3.2.2 Tagging Methodology* The consulting group states that barbed No. 16 dry fly hooks were used to affix nano tags to test fish and mock tags to control fish. While the weight and approximate size of the mock tag were similar to the nano tag, Figures 3.2.2-2 and 3.2.2-4 clearly show differences in how the tag weight is distributed. Additionally, the control group was not introduced to a salted environment to maintain adequate levels of dissolved oxygen and minimize stress. Using dummy nano tags rather than the tin mock tags on the control fish and subjecting both groups to the same tank environment would have eliminated potential sources of variability in survival between groups. This approach should be used in the follow-up repeat of the study.	The use of tin bb weights was the best surrogate we had at the time of the study as no dummy tags were purchased. The control group was held in water pumped from the holding tanks and was subject to DO levels that were consistent with the water body in which shad were collected and well within tolerable ranges. Salt was added daily in an effort to reduce the effects of ion loss that occurs from stress, but was not stated in the report.
USFWS-4	*3.2.6 Canal Escapement during Drawdown (Radio Telemetry)* Nano-tagged fish were released at two sites within the canal on October 4, prior to initiation of the scheduled drawdown. Mobile tracking of tagged fish took place the following afternoon. Given that the intent of the assessment was to "gather information on the fate of juvenile shad in the canal as water is released for the drawdown event" (first paragraph, page 3-15), it is unclear why only a single tracking event occurred. At a minimum, mobile tracking should have taken place at least three times: immediately after completion of the drawdown, just prior to rewatering and after rewatering is complete and prior to station start-up. This would have allowed determination of the fate of fish that did not leave the canal during the drawdown (i.e., did they survive to rewatering?). Table 3.2.3-1: It does not seem necessary to provide the number of units pumping at NMPS for releases made in the canal or upstream of TF dam. Rather, the generating status of the canal units (at both Cabot and Station No. 1) should be provided.	An assessment of canal escapement during the drawdown was not a component of the study as detailed in the RSP. FL added this study component at the request of the agencies after the study plan comment period. The canal escapement evaluation was envisioned to rely upon both fixed telemetry and mobile tracking monitoring. Tagged shad were released immediately prior to the initiation of the drawdown. It was believed that the fixed radio monitoring stations located at the four primary routes of egress (i.e. Cabot Station, the downstream bypass, Station No. 1 and Gatehouse) would document canal escapement during the drawdown. The mobile survey, conducted the following day, would document those fish that remained in the canal after the drawdown. Should tagged shad survive the drawdown period and escape the canal during or after re-watering the fix monitoring stations would document their escapement. By relying on the fixed stations to document canal escapement, multiple mobile tracking efforts were not required. See Attachment B (Study 3.3.3) for Amended Table 3.2.3-1 Summary of Juvenile Shad Release Events

Commenter	Comment	Responses
USFWS-5	4.0 RESULTS *4.1.1 Cabot (Hydroacoustic)* Unlike in the upper canal or at NMPS, collection of hydroacoustic data was successful at Cabot Station. Based on this data, entrainment through Unit 6 was higher than Unit 1, even though Unit 1 was operated more frequently. Units 1 and 2 had lower than expected entrainment, given their frequency of operation. Unit 1 is run preferentially to promote attraction to the bypass. Analysis showed that entrainment increased as volume of water through Cabot Station increased. When the consulting group analyzed the data relative to diel periodicity, it found the lowest rates of entrainment between 0100 hours and 0900 hours. Using data presented in Figure 4.1.1-3, total entrainment between 2200 hours and 0400 hours (the time period identified to be when NMPS typically pumps) is approximately 20 percent. While the number of shad detected was higher from 1500 to 2100 hours, it is not clear whether the project was generating during this time period. In order to provide context for these results, the report should include operational data, by time of day.	Operation data for the projects is provided in tabular format at 15 minute interval in Attachment C (Study 3.3.3).

Commenter	Comment	Responses
USFWS-6	*4.1.2 TF Power Canal* The consulting group was unable to estimate run timing, duration and magnitude in the canal due to excessive milling behavior of targets. Based on Figure 3.1.2-3, the canal surface area in the vicinity of the split beam transducers was approximately 2,368 square feet. Using a minimum flow of 2,000 cfs and a maximum canal flow of 15,000 cfs, velocities would range from 0.84 feet per second (f/s) up to 6.3 f/s at this location. While milling could occur at lower velocities, milling would not be expected at the higher velocities that would occur during typical peaking operations. This section of the report should clarify whether there was an association between flow and target detectability. If milling did not occur under higher generation flows, could those specific data be evaluated to assess run timing, duration and magnitude?	Flow rate had no effect on the detectability of targets within the canal. Milling occurred under all operational flows observed during the study period from no generation to all six Cabot units as illustrated in the table and graph below. No further evaluation of run timing, duration and magnitude is possible.



# units (Cabot)	Mean Downstream (Power Canal)	Mean Upstream (Power Canal)	Mean Milling (Power Canal)
0	196	19	286
1	217	12	281
2	627	23	848
3	768	7	1033
4	648	8	1172
5	332	12	991
6	135	13	836

Commenter	Comment	Responses
USFWS-7	*4.1.3 NMPS Hydroacoustics* As identified in the report, hydroacoustic evaluation of NMPS was unsuccessful in meeting the study objectives. Absent these data, the consulting group uses Vernon downstream passage (telemetry) data to suggest that entrainment at NMPS is likely low because most fish passed Vernon between 1600 and 2300 hours, while NMPS does the majority of its pumping between 0000 and 0600 hours. The timing of downstream migration would make it unlikely for downrunning shad passage to pass NMPS while it is pumping. The Service believes this rationale is flawed for several reasons. First, Vernon Station is located at a dam, which is hydraulically different than the open river environment at NMPS. Fish may move/behave differently in these two environments. Second, the Vernon data is from juvenile shad that were captured, held, tagged with nano tags and then released only 0.5 mile upstream from Vernon, with most fish released between 1800 and 2000 hours (with only two of 15 releases earlier in the day: one at 1336 hours and one at 1609 hours). As such, these released fish may not represent the diel migration patterns of wild fish moving downstream from above the Vernon Project or NMPS. Third, as noted in the report under Section 4.1.1, entrainment increased as volume of water through Cabot Station increased, suggesting that fish movement is related to flow, so as NMPS pumps, it changes flows in the River upstream and increases flow into the project. Lastly, even passage data between Vernon and Cabot Station differ: 85 percent of tagged fish passed between 1600 and 2300 hours at Vernon, but over this same time period only 53 percent were entrained at Cabot. In addition to these factors, Vernon and Cabot stations typically operate in the early evening, while NMPS pumps later at night. Before drawing any conclusions regarding entrainment potential at NMPS based on data from Vernon and Cabot Station, (absent empirical data from NMPS), the Vernon radio telemetry and Cabot Station hydroacoustic data would need to be evaluated taking project operations into consideration.	The results show a significant relationship between flow and entrainment at Cabot Station. The Station operates most frequently in the evening hours which is coincidentally the same time of the day in which juvenile shad tend to migrate. In addition to information on timing of juvenile shad migration at Cabot and Vernon, researchers in the Connecticut River also determined the diel timing of the juvenile shad migration. Layzer (1977) reported the greatest activity for juvenile shad migration in the Connecticut River occurs between 1200 and 2200 h. and O'Leary and Kynard (1986) reported peak migration activity between 1800 to 2200 h. Neither of these studies were influenced by generation at hydroelectric facilities. **Layzer. J.B. 1977. Emigration of Radio-tagged juvenile American shad in the Connecticut River with Particular Reference to the Northfield Mountain Pumped Storage (NMPS) Hydroelectric Project 1976-1977. Prepared for Northeast Utilities Service Company. Berlin, CT.** **O'Leary, J.A. and B. Kynard. 1986. Behavior, Length, and Sex Ratio of Seaward-Migrating Juvenile American Shad and Blueback Herring in the Connecticut River. Transactions of American Fisheries Society 115:529-536.**
USFWS-8	*4.1.4 Verification Sampling* The consulting group sampled juvenile shad in the Cabot bypass to determine the appropriate size of targets to use in the hydroacoustic analysis. They also used these data to estimate the number of shad entrained versus bypassed. Results showed that 43 percent of shad used the bypass and 57 percent were entrained into the project turbines. These results differ from those of previous downstream effectiveness studies of the Cabot Station bypass. Based on evaluations performed in 1992 and 1993, passage effectiveness was 87 to 94 percent (Section 1.1, page 1-2). The report should include a discussion of any changes that may have happened at the project facilities or operations between 1993 and 2015 that may help explain the difference in bypass effectiveness (e.g., has unit hydraulic capacity increased? Are the turbines operating at different times or for longer periods than they used to?). Table 4.1.4-2 provides summary data on the concurrent sample dates. It would be helpful to add a column specifying which units were operating and at what output (not just how many). Additionally, we request that hourly data be provided for a subset of sample nights capturing a range of passage distributions and operational conditions.	The hydraulic capacity of the Cabot Units has remained the same between 1993 and 2015. However, generation is variable from year to year and depends on inflow to the Project. As stated in the report, one potential explanation for the elevated entrainment rate at Unit 6 is due to its close proximity to the canal wall where emigrating shad are likely to entrain along the wall. These shad would be first subjected to the flow field of unit 6 upon reach the intake area. Attachment D (Study 3.3.3) Amended Table 4.1.4-2 No hourly catch data are available for the downstream fish bypass sampling. Only the start and end time of the collection events were recorded.
USFWS-9	*4.2 Radio Telemetry* *4.2.1 Control Experiment* Forty percent of control fish lost or shed their tags and 80 percent of control fish died in the first 2 days. Control fish were observed to list and/or swim abnormally. Because the mock tags differed from actual tags, it is difficult to know how representative those tag loss and mortality rates are for nano-tagged study fish. Figures 3.2.2-2 and 3.2.2-4 show the nano tags and mock tags, respectively. Figure 3.2.2-3 shows nano-tagged fish swimming in a tank. None appear to be listing or swimming abnormally. This suggests that the mock tag may have been more difficult for fish to adjust to (i.e., weight not distributed in a manner that would allow the fish to maintain equilibrium).	Listing and abnormal swimming behavior did not immediately manifest in control fish. The first signs occurred approximately one hour after tagging presumably after fatigue set in. The photograph of the tagged shad depicted in Figure 3.2.2-3 was taken immediately after tagging. These fish were released approximately 15 minutes after tagging. The majority of the weight of a nano-tag or any radio tag is in the battery and while the weight distribution in the bb weights were not exactly the same as the nano-tags it was a close approximation. Should the study be repeated, dummy tags would be used.

Commenter	Comment	Responses
USFWS-10	*4.2.2 Routes of Passage* 1. Given the high mortality rates of control fish and limited data collected, FL has indicated that it intends to redo the radio telemetry portion of the study for NMPS and TF. However, the report makes no mention of this and instead evaluates the available data collected in 2015 as if the study was sufficient as completed. 2. The second to last paragraph of this section is very confusing in the way detections are discussed. It looks like 77 of the 129 tagged fish released 1.2 miles upstream of NMPS intake were detected at Shearer Farms. Of those 77 fish, 32 were detected at the Gill Banks station, leaving 45 fish that were not detected. Twenty-one of that 45 were detected at the NMPS intake. Three tagged fish were detected in the upper reservoir. FL states that these numbers suggest an entrainment rate of 3 percent at NMPS. The Service does not believe it is appropriate to base an entrainment estimate on numbers of tagged fish detected in the upper reservoir. Given the pressure and hydraulic changes a fish is exposed to during the pumping process, it is highly likely that the radio tags, which were affixed externally to the fish via a barbed No. 16 dry fly hook inserted into the musculature at the base of the dorsal fin, would become dislodged in transit through the intake. Based on in-river detections only, it appears that entrainment into NMPS was in the range of 27 percent (21 detected at the NMPS intake out of 77 detected at Shearer Farms) to 58 percent (77 detected at Shearer Farms minus the 32 detected at Gill Banks). If we assume that the 24 fish last detected at Shearer Farms (i.e., those that were not subsequently detected at the NMPS intake or Gill Banks) either died or shed their tags, omitting them from the pool of fish available to potentially become entrained at NMPS reduces the total number of test fish from 77 down to 53, resulting in an entrainment estimate of 40 percent (21 out of 53). 3. Thirty-two fish detected at Gill Banks plus the 54 fish released upstream of the TF dam were available to enter the TF canal. Sixteen tagged fish were detected. Twelve of those 16 fish were never detected after entering the TF canal. Only 18 out of 86 tagged fish (21 percent) were detected in the upper canal (n=16) or at the dam (n=2). Of the 16 fish that entered the canal, only four were detected on multiple occasions. This section contains no information on these four individuals with respect to where they were detected and how/if they passed the project. We do note that the disposition of those fish is described in Section 4.2.3: three of the four fish were detected in the tailrace (though none were detected at the bypass or Cabot forebay receivers) and the fourth fish was detected in the forebay but not at any downstream receiver. Regardless, the overall number of fish available for evaluation through the canal is insufficient to draw any conclusions as to preferred passage route or associate passage to any given set of operational conditions. 4. FL should provide more information on the 18 fish detected in the immediate vicinity of the dam/gatehouse: how many of those 18 were released from which location; what was the mean travel time between each receiver; what were the operational conditions at those times, etc. 5. At a meeting held on September 20, 2015, FL indicated that, due to the problems encountered during the 2015 fieldwork, it intended to repeat the study, either in 2016 or 2017 (subsequently, FL decided not to repeat the study in 2016 due to low river flow conditions and is proposing doing the study in 2017). The Service supports this proposal, but before repeating the study, we recommend that FL attempt to determine why so many tagged fish were not detected within the study area by: (1) performing a validation study to assess tag retention as fish are pumped up the mountain into the upper reservoir (this would not be needed if FL agreed to the assumption that fish last detected at the lower reservoir intake should be considered entrained); (2) redoing the control experiment using dummy nano tags, not mock tags, to see if retention and survival differ from the original experiment; and (3) performing validation experiments to determine the detectability of nano tags under typical operational conditions at all potential passage routes.	2. The data collected supports an entrainment rate of 3.9% at NMPS. 3. The fate of all fish released upstream of NMPS is summarized in Attachment E (Study 3.3.3) 4. Information on the 18 fish detected in the immediate vicinity of the dam/gatehouse, including release locations and mean travel time between receivers is provided in Attachment F (Study 3.3.3). Operational conditions during the study period have been provided in tabular form. 5. Should the study be repeated, the following will be considered for inclusion in the study scope (1) performing a validation study to assess tag retention as fish are pumped up the mountain into the upper reservoir; (2) redoing the control experiment using dummy nano tags, not mock tags, to see if retention and survival differ from the original experiment; and (3) performing validation experiments to determine the detectability of nano tags under typical operational conditions at all potential passage routes.
USFWS-11	*4.2.3 Rate of Movement* Tagged shad have a mean downstream movement rate within the TF impoundment of 0.31 river miles per hour (RM/h). The rate of movement through the bypass reach based on a single tagged fish was 1.45 RM/h, and the rate of movement through the canal based on four tagged fish was 0.03 RM/h. Table 4.2.3-1 summarizes the movement data. The largest data set (for movement through the impoundment) shows a wide range of movement rates. To understand these data, more detail on these individuals is needed (i.e., movement rate between receivers in relation to the operational conditions at/over that time interval).	The rate of movement was calculated as specified in the RSP and presented in the report and therefore no further analysis is warranted. FL has provided the operations data, the raw telemetry data and individual fish tagging and release information which can be used for further analysis at the discretion of the USFWS.

Commenter	Comment	Responses
USFWS-12	*4.2.4 Timing of Passage* 1. FL states that movement through the project occurred during evening hours, with the three tagged fish detected in the Cabot tailrace passing through Cabot Station between 2117 and 2137 on October 12, 2015. For the two tagged fish that passed at the spillway (both through Bascule 1), one passed on October 12 at 2134 and the other passed the following evening at 2322. In addition to the canal and spillway fish, we recommend providing a table that shows the time fish were detected at the in-river receivers, as this will aid in determining whether there are differences in the timing of migratory movements at the dam/canal relative to more riverine locations (e.g., Shearer Farm, Gill Bank, etc.). The canal passage timing described in the narrative does not comport to information depicted in Figure 4.2.2-2. The figure indicates that two of the three fish detected in the Cabot tailrace passed on October 14 and the third passed on October 15, while the narrative states that all fish passed on October 12. FL should address this discrepancy. 2. Further, FL states that 12 of the 16 fish that entered the canal were first detected on October 12 between 2117 and 2202. According to Figure 4.2.2-2 and Table 4.2.2-2, 10 of the 16 fish were first detected on October 12. One fish was detected around 0500 on October 13, two more fish were first detected on October 14 (one around 2100 and one at 0000 hours) and the remaining three fish were detected on October 16 (two at around 0500 to 0600 hours and the other near 0000 hours). 3. In order to give context to the passage timing data, FL should provide a table showing the release location, date and time for each tagged fish, as well as subsequent detection locations, dates and times for those same fish. Operational conditions should be provided for the time when detections occurred. For example, the first release date of any test lot was on October 12. According to Table 4.2.2-2, the October 12 release occurred at 1920 hours. Flows through the canal gatehouse increased from about 2,000 cfs at 1800 hours to over 12,000 cfs around 2000 to 2100 hours, with Bascule Gate 1 flows running from 1,500 cfs to 5,000 cfs during that same timeframe. Of the 10 fish detected on October 12, seven were not detected again, while the remaining three were detected in the tailrace. If only 20 fish were released at the upstream of TF dam on October 12, and 10 of those were detected in the canal that suggests that the data set, while not extensive, may provide more useful information than FL has suggested.	1. The timing of passage was evaluated as described in the RSP and reported in the study report. The operations data, provided herein, in combination with the raw radio telemetry data set, which was sent to stakeholders upon request, is available for further analysis at the discretion of the USFWS. The three fish in question here were all first detected in the canal on 10/12/2015; however the only other subsequent detections were at the Cabot Tailrace several days later. Therefore actual passage times, and routes of passage within the canal are unknown. 2. We agree that 10, not 12, of the 16 fish that entered the canal were first detected on October 12. 3. Information on fish that passed through to the canal are provided in more detail as stated in Comment USFWS-10, see Attachment F (Study 3.3.3).
USFWS-13	*4.2.5 CanalDrawdown* Seventeen nano-tagged fish were released at two locations (upstream and downstream of Station 1) in the canal the night of October 4, 2015. Canal dewatering commenced later in the evening, continuing until the station went offline at 0600 hours on October 5. The station remained offline until October 11. Mobile tracking of tagged fish was initiated at 1310 hours on October 5. Seven fish were detected in the canal: five in the same areas they were released (two at the upper canal release site and three at the lower release site), one fish at the Station 1 forebay, and the remaining fish at the Cabot forebay. It is unclear from the report whether the canal test fish were released within larger groups of fish or alone. Releasing only a small number (8 or 9 fish) of tagged fish by themselves could have increased their risk of predation. The report should clarify the release protocols. The final disposition could not be determined for any of the 17 test fish; none were detected downstream of Cabot Station or Station 1. It appears that only a single mobile tracking event took place. Subsequent tracking efforts could have provided additional information regarding movement of fish remaining in the canal during the drawdown. Further, an effort to recapture these fish could have been made to verify whether they were alive or dead, which also would aid in assessing the impact of the drawdowns. Additional information relative to the drawdown should be provided, such as how many units were generating, at what level they were generating, and for how long after fish releases did generation continue. FL should clarify whether the drawdown is accomplished only with the turbines or if other mechanisms (e.g., gates) are used. If the radio telemetry portion of this study is to be repeated, we recommend also repeating the canal drawdown evaluation, taking into consideration the comments provided herein.	In the case of the canal drawdown release group no additional shad were released with the tagged group due to the lack of available shad at the time. Additional information relative to operations during the drawdown is provided in Attachment C (Study 3.3.3) including how many units were generating, at what level they were generating, and for how long after fish releases did generation continue. In addition to Cabot Station the canal drawdown is accomplished through a drainage tunnel called Keith Tunnel. The concrete-lined Keith Tunnel is located in the upper quarter of the canal and serves as the primary means of dewatering the upper portion of the canal. The Keith Tunnel typically remains open for the duration of the canal outage period. Should the study be repeated, a repeat of the radio telemetry portion of this study would include the canal drawdown evaluation if shad are available.
USFWS-14	*5.0 DISCUSSION*	Range testing was conducted at every monitoring site but not under every operational condition which is outside the scope

Commenter	Comment	Responses
	FL reasonably argues that the ability to definitively determine route selection and travel times based on the telemetry results is limited due to a small data set that FL attributes to tag loss and mortality based on results of the control experiment. However, the Service remains unconvinced that tag loss, mortality due to tagging stress, or the distance between the release site to the first receiver location are the only factors contributing to the low numbers of juveniles detected. While telemetry array testing and calibration was conducted (Appendix A), the narrative suggests that power levels were recorded at all receiver locations, but does not specify under what operational (i.e., flow) conditions those tests were conducted, leaving open the question as to how effective the receivers were at detecting tags on moving individuals through each receiver area at varying velocities. Also, there appeared to be a much higher detection rate for fish released upstream of TFD on October 12 (10 of 20 fish detected in upper canal). FL should review the data to see if there is an explanation for the apparent differential in detection, as it may inform ways to improve the detection rates in any subsequent studies that may be undertaken.	of traditional radio telemetry monitoring calibration efforts. Additional information relative to operations during the drawdown is provided in Attachment C (Study 3.3.3). Should the study be repeated, FL will review the data to evaluate if there is a differential in detection rate between release dates and locations.
USFWS-15	*5.4 Downstream Passage Timing, Route Selection, and Rate of Movement* The consulting group states that peak entrainment at Cabot Station occurred between 1300 and 2300 hours, presumably related to an increase in diel movement by juvenile shad. Reference is made to TransCanada's radio telemetry study (which showed that most tagged shad passed the project during that same time period) to support this contention, as well as the split beam hydroacoustic data at Cabot Station. However, relying only on data from forebay receivers is problematic for reasons outlined in our comments under Section 4.1.3. To reiterate, as the consulting group's own data show, there is a close relationship between flow rate through Cabot Station and entrainment (Figure 4.1.1-1), making it difficult to discern whether the higher entrainment is due to natural diel migratory behavior or due to migrants' tendency to "follow the flow." For example, are they becoming entrained because that is when they are moving or are they moving and subsequently becoming entrained due to increased flow during periods of generation (which happen to coincide with a certain diel period)? FL should provide the full data set of radio-tagged fish so that we are able to analyze the in-river detections and compare those to detection times in forebay/intake areas.	See Comment USFWS-7 (Study 3.3.3) for discussion on diel migration timing. The full radio telemetry data set was provided to stakeholders upon their request prior to filing the report.
USFWS-16	*5.5 Rate of Entrainment at NMPS* The hydroacoustic data was deemed unreliable by FL due to excessive milling behavior of targets. Additionally, the radio telemetry data set was limited because a large number of tagged fish went undetected. These study deficiencies prevent making an entrainment estimate. Given the problems encountered and the resultant inability to achieve study goals and objectives, the Service's position is that both the radio telemetry and NMPS hydroacoustic portions of the study should be repeated in 2017.	In 2016, FL conducted a feasibility evaluation to determine if hydroacoustic equipment could be deployed further within the NMPS intake at a point where velocities would obligate entrainment of juvenile shad and reduce milling such that an estimate of entrainment could be achieved. Multiple options for deployment were considered but none were feasible due to safety constraints. Repeating the study would likely result in the same limitations encountered in 2015 and therefore FL does not intend to conduct another hydroacoustic evaluation in 2017.

Commenter	Comment	Responses
USFWS-17	*5.6 Survival Rates for Juvenile Shad Entrained into Station 1 and Cabot Station* This section of the report folds in results of the balloon tag study, which is included in Appendix B. We recommend that the results of the hydroacoustic and radio telemetry studies be presented first, followed by the balloon tag study results. Also, there should be a section of the report that attempts to utilize results from all of the various studies to calculate a total thru-project survival for juvenile shad at both NMPS and TFD. As noted in our comments under Section 5.5, the radio telemetry data set was limited due to the large number of tagged fish that were never detected. Other than the first release of tagged fish at the TFD location on October 12 (when 10 of 20 fish were detected in the upper canal), detection rates were extremely low (2 of20 fish of the TFD October 13 release and 2 of23 fish of the TFD October 15 release). Given that the data do not allow for definitively determining passage route selection, the Service's position is that the radio telemetry portion of the study should be repeated in 2017. No problems were identified by the consulting group for the hydroacoustics portion of the study at the Cabot Station intake. However, in this section the group states that the hydroacoustic data may have overestimated turbine entrainment because the echo characteristics used in the analysis were based on fish collected at the bypass sampler, which is located at the surface and therefore would be expected to collect surface-oriented species like American shad *(Alosa sapidissima).* The group refers to data collected during the 2014 canal drawdown where non-surface-oriented species such as tessellated darter *(Etheostoma olmstedi)* and spottail shiner *(Notropis hudsonius)* were among the most abundance species observed, along with American shad. The Service notes that in Study Report 3.3.7: Fish Entrainment and Turbine Passage Mortality Study Report, FL's consultant (Kleinschmidt) states that tessellated darters "do not undergo obligatory migration that would bring it in contact with the Cabot or Station No. 1 intake areas" (page 4-18) and that "Impacts are predicted to be low. Relatively few fish would be expected to encounter the intakes ... "(page 4-19). Similarly, for spottail shiner, Kleinschmidt states "Shiner species are ... residents of large rivers. Preferred substrate consists of sand or gravel; thus, it is unlikely that they would be abundant in the immediate vicinity of the project intakes." Kleinschmidt goes on to state that the likelihood of entrainment "is low as these species are not attracted to habitat characteristic(s) [sic] of the intake areas. Shiners may occupy weeded fringes in the lower portion of the ... Canal but are unlikely to encounter the intake in substantial numbers" (page 4-23). One reasonable explanation for the abundance of shiners and darters in the immediate vicinity of the intake in the apparent absence of suitable habitat is that those fish moved downstream during the canal drawdown (i.e., would otherwise not be in that area). Therefore, we do not believe a case has been made that Cabot Station entrainment has been overestimated.	FL believes that the report is effective as written and is not proposing to reorganize the results. An attempt to utilize results from all of the various studies to calculate a total thru-project survival for juvenile shad at both NMPS and TFD is not feasible with available data and is outside the scope as described in the RSP. While the risk of entrainment of cyprinid species is generally low at Cabot Station, some level of entrainment is likely to occur. The rate of entrainment of resident species may be influenced by the drawdown as the USFWS suggests but to what degree is unknown. It is important to consider that many cyprinids and juvenile centrarchids and percids are of similar size as juvenile shad and cannot be differentiated in the split-beam data set and were therefore included in the entrainment estimate. Data collected during the drawdown study demonstrates that these fishes are present in the canal. To what extent the evaluation overestimated shad entrainment is not known but some level of overestimation is likely as all targets that approximated the size of a juvenile shad were included in the estimate, some of those fish were undoubtedly not shad and therefore it is reasonable to conclude that some level of overestimation did occur.
USFWS-18	***Appendix B - Direct Injury and Relative Survival of Juvenile American Shad*** *4.0METHODS* *4.4.2 Sample Size Calculations* This section describes how Normandeau Associates determined the appropriate sample size for each test location and treatment, describing that the calculations were based on past studies and were designed to assure that sufficient fish releases were made to calculate 1-hour and 48-hour mortality. Table 4-1 includes calculations of sample size based on various combinations of control survival rates of 90 percent to 100 percent, recapture rates of 90 percent to 100 percent and expected survival rates of 85 percent to 95 percent. Based on these calculations, 120 shad were released through Cabot station Unit 2; 90 through Station No. 1, Unit 2/3; and 90 through Station No.1, Unit 1. Sixty to 62 fish were released for each flow scenario through Bascule gate 1 and Bascule gate 4. These sample sizes were inadequate to permit a statistically significant calculation of 48-hour survival as described in section 4.2.7, but this result should have been anticipated by Normandeau Associates' own prior studies as discussed in section 4.2.7 below.	Some mortality was expected during the 48-h holding period but were not prepared for the high mortalities of both treatment (between 18 and 89%) and control (close to 35%) fish during the delayed holding period. A substantial number of additional fish would have been required to bring the precision of the 48-h survival estimates to the proposed level of plus or minus 10%, 90% of the time. For instance, with a control survival of 80% and turbine survival of 80% close to 300 treatment and 300 control fish would have to be released to attain the proposed precision on the survival estimate. Since only 64% of the control fish were alive at 48 h and the percentage of the alive treatment fish was even lower in most instances, hundreds more fish would have had to be released to attain the proposed precision.
USFWS-19	*4.2.6 Assessment of Juvenile Shad Injuries* This section states that "Shad without visible injuries that were not actively swimming or (were) swimming erratically at recapture were classified as loss of equilibrium," and then states that this condition "often disappears within 10 to 15 minutes after recapture if shad are not injured." The classification of fish with loss of equilibrium (LOE) is then further defined in Table 4-4, where it states that if a fish classified as LOE dies within one hour, it is considered a "major malady," but if it survives past one hour it is considered a "minor malady." This entire analysis is severely flawed. First, if a fish has LOE after passage through any route, it is highly vulnerable to predation and unable either to swim to suitable habitat or join a school of fish for protection. Regaining equilibrium in 10 to 15 minutes in a tank as discussed in the narrative would be of little consequence if the fish has already been predated in natural habitat. Even more problematic is classification of a captured	See responses to MDFW-4 and MDFW-5 under Study No. 3.3.7.

Commenter	Comment	Responses
	fish that regains equilibrium or dies sometime after one hour to be a "minor malady." A fish with LOE for one hour in the natural environment would even more certainly perish. In all, these classifications severely downplay the impacts of passage through turbines or other routes.	
USFWS-20	*4.2. 7 Survival and Malady-Free Estimation* As noted above, Normandeau Associates calculated the fish release sample size based on past studies and calculation in Table 4-1. In this section, Normandeau Associates describes that the basis for using high survival, high recovery rates and high control mortality in its calculations for this study were the results from previous studies of chinook salmon and other salmonids, However, it is then cited that studies of juvenile shad at the Holtwood Project (Susquehanna River) had high control mortality using 105-135 mm fish, and as a result a "valid 48 hour long term survival could not be obtained" for that study. The report then concludes that because, in this study, shad had high mortality rates in both control and test fish, "only a one-hour survival estimate is considered reliable." The problem with this conclusion is that, based on its own studies done at Holtwood, Normandeau Associates should have anticipated that mortality of juvenile shad controls in this study would be higher than in salmonid studies, and similar to what was experienced at Holtwood, especially given that the fish used in this study were even smaller (90-122 mm) than the larger fish used at Holtwood. Therefore, more realistic inputs to the sample size calculations summarized in Table 4-1 should have been used, which would have resulted in a substantially larger sample size per treatment.	Similar high mortalities of the both treatment (24%) and control (30%) juvenile shad during the 48-h delayed assessment period was also observed for the shad passage tests at TransCanada's Vernon Station during the fall of 2015. These fish were of similar origin as the fish tested for FL and they were subjected to the same handling procedures. It is unknown whether the small size (average total length approximately 97 mm) of these Connecticut River shad or some other factors made them more sensitive to capture and tagging effects. Unless the factors responsible for the high mortalities during holding were determined and corrected a large number of fish would still be required to obtain the set precision for the survival estimates (plus or minus 10%, 90% of the time). There was some precedent for low mortality of juvenile shad during the delayed holding period at the Cabot Station which was also considered in developing the sample size protocol. Juvenile shad and herring were passed through the log sluice chute in the fall of 1994 (RMC 1995). These fish were obtained from the Cabot sluice fish sampling facility and tagged and handled similar to the present study. These fish were also quite small, with a mean length near 92 mm. During the 48-h delayed assessment, only 4 of the 139 (3%) treatment and 4 of the 139 (3%) control fish died. RMC. 1995. *Log sluice passage of juvenile Clupeids at Cabot Hydroelectric Station Connecticut River, Massachusetts.* Report prepared for Northeast Utilities Service Company, Hartford, CT
USFWS-21	*5.0 RESULTS* *5.1.1 Cabot Station Unit 2* This section should include the recapture rate of control fish.	Recapture rate was 94.4% for control fish (67/71) and all were alive.
USFWS-22	*5.1.2 Station No. 1* Recapture rate for the control fish was 94.4 percent, yet the recapture rates for the test fish were much lower (75.6 percent for Unit 1 and 72.2 percent for Units 2/3). As both groups of fish were discharged into the same environment, the report should explain the potential reasons for this discrepancy. The conclusionary statement that assigning dislodged tags as dead should be considered conservative, since tags could be dislodged in turbulent in-turbine or tailwater conditions that are not lethal, is conjecture and is not supported by any data. The statement that turbulent conditions would not be lethal is unsupported by any data. Turbulent conditions sufficient to dislodge a tag can just as readily be considered sufficient to result in severe injury or mortality. Similar statements appear throughout the results section and should be deleted.	Control fish and treatment fish do not experience the same conditions; typically control fish are released into a more placid environment because the primary purpose of the controls is to parse out the effects of handling, tagging, recapture, and holding. We respectfully disagree based on our many studies on juvenile salmonids. Because of their small size and sensitivity to handling, we have established a protocol of only attaching one HI-Z tag to juvenile clupeids in the thicker portion of their body just anterior of the dorsal fin. This differs from the protocol established for juvenile salmonids and most other species where an additional tag is attached near the adipose fin or posterior of the dorsal fin. We have found that there is no suitable location to attach a second tag to most of the clupeids designated for a study. The results of our studies on juvenile salmonids and other species have shown that fish recaptured with one of the tags dislodged are not always injured or dead. Thus, we believe some of the juvenile shad where only a tag was recaptured passed alive and uninjured; however, we cannot provide a percentage.
USFWS-23	*5.1. 3 Bascule Gates* Treatment groups released over the Bascule gates had even lower recapture rates than at Station No. I: 56.7 percent at the 2,500 cfs setting to 79 percent at the 5,000 cfs setting. However, all control fish released downstream of both Bascule gates were recaptured. Again, Normandeau Associates should provide an explanation for the differential in recapture rates within and among assessment areas. Just over 29 percent of shad passed through the Bascule gates were assigned a dead status based on the recapture of just tags or reception of only stationary radio signals. Normandeau Associates suggests that this assignment is likely conservative, as a portion of these fish may have been alive but lost their tags due to turbulent conditions in the spillway discharge, as we questioned above. In addition, given the high rate of recapture for controls (none of which lost tags, although presumably they were exposed to the same turbulent conditions), the Service does not believe that assigning those treatment fish as dead is conservative. Normandeau Associates references Figures 2-2 and 2-3; we believe the figures referred to are 3-2 and 3-3.	The control juvenile shad were released downstream of the discharge from the Bascule Gates beyond the highly turbulent area. The main reasons for releasing control fish is to separate out the effects of handling, tagging, recapture and holding form the effects of passage through a specific test route. The high turbulent area in the discharge from the Bascule Gates is part of the passage route effects and the control fish were not subjected to it. Regarding the assignment of dead to fish where only its tag was recaptured see response to USFWS-22 above (Study No. 3.3.3). Assignment of figure numbers appears to be correct.
USFWS-24	*5.2 Recapture Times* This section reviews the amount of time from release to recapture. In general, the recapture period after release was short, between 3.5 and 6.3 minutes on average for the turbine-passed fish. As such, there was limited time after release during which fish would be subject to other causes of trauma outside of the immediate turbine discharge and turbulence of the Bascule gate spill areas. As these areas are an integral part of the safety of each route, most, if not all of the trauma a recaptured fish suffered was most likely induced by passage through the turbine or discharge over a gate.	The effect of passing through the turbulent areas in the tailrace and downstream of the Bascule Gates are accounted for since the treatment fish are recaptured downstream of these areas. The primary intent for the malady metric was to quantify injuries and the severity of these injuries (see response to MDFW-4 and 5 under Study No. 3.3.7); however additional analysis was performed which classified all fish with only loss of equilibrium at recapture as having a malady that was passage and/or technique induced. See Attachment G (Study 3.3.3) for alternative analysis and corresponding tables. The new MF estimates followed the same trends as reported previously.

<table>
<tr><th>Commenter</th><th>Comment</th><th>Responses</th></tr>
<tr><td></td><td>In Table 5-4, the maladies suffered by fish are provided by passage route/treatment. There are large numbers of held fish classified as having died "without passage-related maladies." Table 5-4 calculates the proportion of fish that died without passage-related maladies based on the total number of fish examined. The proper calculation would be the proportion of fish that died without "passage-related maladies" relative to the total number of examined fish that exhibited no "passage-related maladies." These entries in Table 5-4 should be corrected. Analyzing the data this way shows a range of mortality from 14.7 percent offish passed over Bascule Gate #1 at 1,500 cfs to 90.9 percent offish passed over Bascule Gate #4 at 1,500 cfs (see table below).

<table>
<tr><th>Passage Route</th><th>% of Non-Passage-Related Maladies that Died</th></tr>
<tr><td>Cabot Unit 2</td><td>21.9</td></tr>
<tr><td>Station 1 Unit2/3</td><td>16.3</td></tr>
<tr><td>Station 1 Unit 1</td><td>51.0</td></tr>
<tr><td>Bascule 1 - 1,500 cfs</td><td>14.7</td></tr>
<tr><td>Bascule 1 - 2,500 cfs</td><td>85.7</td></tr>
<tr><td>Bascule 1 - 5,000 cfs</td><td>78.1</td></tr>
<tr><td>Bascule 4 - 1,500 cfs</td><td>90.9</td></tr>
<tr><td>Bascule 4 - 2,500 cfs</td><td>81.8</td></tr>
<tr><td>Bascule 4 - 5,000 cfs</td><td>78.2</td></tr>
</table>
These data and the data on the 1-hour and 48-hour survival appear to be very closely correlated, with the routes showing the highest 1-hour and 48-hour mortality corresponding to the routes that also had the highest "non-passage-related maladies" as characterized by Normandeau Associates. If these fish, in fact, were suffering from non-passage related effects, there is no identified explanation for why these data are correlated. The most plausible explanation for the correlation is that the "non-passage-related maladies" are in fact passage-related. As such, the overall conclusions on survival by route should consider those fish characterized as having nonpassage- related mortalities that died while being held as passage-related mortalities.</td><td>Cabot Station Unit 2 still had the highest MF rate at 91.6% (previous rate was 92.7%). The MF rates for Station No 1 were 67.6% (Units 2/3) and 61.4% (Unit 1).

As noted previously the highest MF rate for Bascule Gate passed fish was for fish passed through Gate 1 at 1,500 cfs; revised value was 77% and previous value was 82%. The revised MF rates for all the remaining Bascule Gate tests ranged between 31.7% and 47.3%. The previous values for these gates ranged from 55.9% to 68%.</td></tr>
<tr><td>USFWS-25</td><td>Appendix B
• What is a non-passage malady? How do you know it is non-passage-related?
• Explain the distinction between "without maladies (passage-related)" and "with non-passage maladies." It may be more clear to retitle them as "non-passage maladies" and "without maladies."
• How can the control fish have passage-related maladies? Are those injuries incurred during passage through the conveyance pipe to the tailrace?</td><td>Because of the sensitivity of juvenile clupeids to handling, we are not convinced that the fish displaying loss of equilibrium after turbine and bascule gate passage resulted solely from the passage route environment; however, as explained above, additional analysis was run including loss of equilibrium as a passage or technique related malady. For the control fish, loss of equilibrium should be due to sampling technique. A total of 20 of the 142 (14%) examined controls had only loss of equilibrium at recapture.

Control fish would not have injuries due to passage through the turbine or Bascule Gate. Observed injuries to control fish could result from passage through the release system, fish recapture, and/or a predator.</td></tr>
<tr><td>USFWS-26</td><td>Appendix C
Additional explanation is needed to better understand how probable cause was determined. For instance, Fish 004 from Test Lot IA was classified as having a passage malady, yet no obvious injuries were observed, leading to a Probable Cause classification of Undetermined. If the cause was undetermined, why was it considered a passage malady? Likewise, for Fish 006 from Test Lot 2A, the Probable Cause was determined to be Shear, yet it was deemed to not be a passage malady.

Are fish whose probable cause of injury is classified as undetermined in the table the same fish considered to have non-passage maladies in Appendix B? If the cause is undetermined, it could potentially be passage-related.</td><td>See Attachment H (Study 3.3.3) for revised Appendix C.</td></tr>
<tr><td>NMFS-1</td><td>Section 4.1 Run Timing, Duration and Magnitude

4.1.1 Cabot Station

The report states that 1,660,166 shad size targets were estimated to be entrained at Cabot Station. We recommend the report provide context on this number in terms of how many juvenile shad in total might have passed downstream past the project.</td><td>A juvenile shad population estimate within the study area was not a component of the RSP and no empirical data are available by which to make such an estimate.</td></tr>
<tr><td>NMFS-2</td><td>4.1.2. Turners Falls Power Canal
The report states that high levels of milling behavior made it difficult to estimate run timing, duration and magnitude of juvenile shad outmigration. We view milling behavior as evidence that the project is not providing safe, timely and effective passage for juvenile shad.</td><td>Milling behavior is common among schooling alosines in any environment in which water velocity does not necessitate downstream movement and is not directly associated with obstacles and should not necessarily be construed as evident of passage success. In terms of this study the term milling is used to describe the movement of fishes in multiple directions</td></tr>
</table>

<table>
<tr><th>Commenter</th><th>Comment</th><th>Responses</th></tr>
<tr><td></td><td></td><td>as observed in the split-beam data set.</td></tr>
<tr><td>NMFS-3</td><td>4.1.3 Northfield Mountain

The report states that the large numbers of fish exhibiting milling behavior in front of the Northfield Mountain intake prevented a valid entrainment estimate from being calculated. These results indicate that safe, timely and effective passage are not occurring for downstream migrating juvenile shad that encounter the Northfield Mountain tailrace.

With 27.3% of fish undetected and their fate unknown, we recommend the report includes this uncertainty into the estimation of entrainment such that a low and high range is reported.</td><td>An entrainment estimate that includes uncertainty is not likely to be achievable due to the few numbers of recaptures and the limitations of mark recapture theory. In mark recapture theory there is no way to differentiate between mortality at the last recapture event (i.e. the upper reservoir) and the fact that a fish wasn't recaptured or selected a different route. It is always reported as a joint probability and therefore ambiguous.</td></tr>
<tr><td>NMFS-4</td><td>4.2.2. Routes of Passage

This section states that 129 shad were released 1.5 miles above the Northfield Mountain intake/tailrace and 54 were released 1.25 miles above the Turners Falls dam. It then suggests that fish were lumped and the reader is not provided with a breakdown of the fate of each fish relative to where it started. Table D-1 summarizes our understanding of these fish based on the text in the report. We request that this be clarified, and that the release point for each of these fish is stated for the each of the six fates in Table D-1.

Table D-1. Summary of the fate of the 183 study fish released in the Turners Falls Impoundment
<table>
<tr><th>Fate</th><th>Number</th></tr>
<tr><td>Never detected at any fish telemetry station</td><td>70</td></tr>
<tr><td>Remained in the Turners Falls Impoundment & never detected downstream of the Turners Falls dam or gatehouse</td><td>71</td></tr>
<tr><td>Passed over the Turners Falls Dam</td><td>2</td></tr>
<tr><td>Passed through the Power Canal</td><td>16</td></tr>
<tr><td>Last detected at the NMPS intake/tailrace reciever</td><td>21</td></tr>
<tr><td>NMPS Upper Reservoir</td><td>3</td></tr>
<tr><td>Total</td><td>183</td></tr>
</table>
We remain unclear on the fate of the 129 fish released above Northfield Mountain. Based on our understanding of the reported results, Table D-2 suggests 28 unaccounted for fish. The text states that 32 emigrated past the Northfield Mountain intake/tailrace and continued approximately 0.66 miles downstream of the NMPS intake/tailrace for a 41.6% (32/77) passage rate through this reach. Our understanding of the 32 fish that entered the next reach, 72.7% (32*72.7 = 23.3) were either detected in the Northfield Mountain intake/tailrace, the upper reservoir or downstream of the Northfield Mountain intake/tailrace. We assume this is the fate of 23 unaccounted for fish, leaving 9 fish undetected. However, 9/32 = 28.1% (not 27.3%) which leaves these results under question. We request a clear accounting of each of the 129 fish released above the Northfield Mountain intake/tailrace be reported.

Table D-2. Summary of the fate of 129 fish released 1.5 miles above Northfield Mountain
<table>
<tr><th>Fate</th><th>Number</th></tr>
<tr><td>Detected at Shearer Farms</td><td>77</td></tr>
<tr><td>Last detected at the NMPS intake/tailrace receiver</td><td>21</td></tr>
<tr><td>NMPS Upper Reservoir</td><td>3</td></tr>
<tr><td>Unknown/not explained</td><td>28</td></tr>
<tr><td>Total</td><td>129</td></tr>
</table></td><td>The fate of all juvenile shad is broken down between release groups in Attachment E (Study No. 3.3.3).

The fate of the 129 fish released upstream of NMPS has been addressed in the response to USFWS-10 (Study No. 3.3.3)</td></tr>
<tr><td>NMFS-5</td><td>4.2.3 Rate of movement

The report states a mean downstream movement rate of 0.31RM/h based on 113 juvenile shad. This number should be broken down between the two release groups.</td><td>The rate of movement for the fish released upstream of NMPS was 0.27 RM/hr. The rate of movement for the fish released upstream of TFD was 0.43 RM/hr.</td></tr>
</table>

Commenter	Comment	Responses
NMFS-6	*Section 5.1 Proportion of Juvenile Shad Passing Downstream through the Power Canal versus over the Dam under varied Operational Conditions, including a Range of Spill Conditions* As was stated in Section 4.2.2, 218 juvenile shad were tagged and released in the Turners Falls headpond, yet the analysis in the canal is based on a total of 16 fish. In addition, these fish likely experienced some form of stress from transporting, handling, holding and tagging that occurred. As the number of fish dramatically diminished, schooling behavior also decreases. Therefore, we view these results with a great deal of uncertainty.	The fate of all juvenile shad is broken down between release groups in Attachment E (Study No. 3.3.3). The sample size of shad that entered the canal was lower than anticipated and stress from handling is always a concern during tagging studies. However, all tagged shad released in the impoundment were released with a minimum of 50 untagged shad to help promote natural schooling behavior. These additional fish in concert with other fish in the system helped to reduce irregular behavior that may be attributed to the lack of schooling.
NMFS-7	*Section 5.2 Rate of Downstream Movement within the Impoundment, over the Dam and through the Bypass Reach, or through the Power Canal* As is reported, very few fish were available for this analysis. We recommend the report state the amount of error associated with the various rates of movement.	Error associated with the rate calculation will be provided in an addendum and filed with FERC on 4/30/2017.
NMFS-8	*Section 5.4 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.* This section presents movement rates based on 4 out of 218 fish that were tracked downstream of Station 1. The ability to interpret the data and provide meaningful conclusions is limited. This section also discussed the results of 15 discrete verification sampling events whereby the data suggested that 43% of sampled fish exited the canal via the bypass and 57% subject to entrainment at Cabot Station. The report does not clearly state the survival estimate as a percentage for juveniles via the downstream bypass next to the Cabot Station intake structure.	No survival data were collected at the fish bypass by which to estimate survival.
NMFS-9	*Section 5.5 Rate of Entrainment at the Northfield Mountain Project* The report suggests a 3.9% entrainment rate based on three entrained fish detected in the upper reservoir. The report does not make it clear what the Northfield Mountain operating conditions were during the study. It is important to understand how long pumping occurred, how much pumping occurred, and what the volume of pumped water was relative to flows in the Turners Falls impoundment. Assigning a 3.9% entrainment rate with no mention of project operations does not provide context for the impact. Entrainments rates may vary significantly based on project operations. We recommend project operations for the duration of the study be included in the report.	Project operations is provided in tabular form for the duration of the study period, August 1 through November 15, 2015 in Attachment I (Study No. 3.3.3).
MADFW-1	*3.2.2 Tagging* The report states that barbed No. 16 dry fly hooks were used to affix nano tags to test fish and mock tags to control fish. While the weight and approximate size of the mock tag were similar to the nano tag, Figures 3.2.2-2 and 3.2.2-4 clearly show differences in how the tag weight is distributed. Additionally, the control group was not introduced to a salted environment to minimize stress. The study should have used dummy nano tags rather than the tin mock tags on the control fish as well as subjecting both groups to the same tank environment to eliminate potential sources of variability in survival between groups. This approach should be used in the repeat of the study.	See response in comment USFWS-3 (Study No. 3.3.3).
MADFW-2	*4 Results* *4.1.1 Cabot Hydroacoustics* • Results from Cabot Station show that entrainment increased as volume of water through Cabot Station increased; however, entrainment through Unit 6 was higher than Unit 1, even though Unit 1 was operated more frequently. Unit 2 also had lower than expected entrainment, given the frequency of operation. Unit 1 is run preferentially to promote attraction to the bypass, but these results show that this may not be working.	See Response in comment USFWS-8 (Study No. 3.3.3).
MADFW-3	*4.1.2 TF Power Canal* The hydroacoustic equipment in the power canal encountered fish engaging in milling behavior rather than moving in a downstream direction. This behavior reduced the ability of the hydroacoustic equipment to enumerate individual targets and lead to overestimation as fish could move in and out of the beam multiple times. This situation did not allow for an estimate of the run timing, duration and magnitude or entrainment of juvenile shad. While milling may occur at lower velocities, milling would not be expected at the higher velocities that would occur during typical peaking operations. This section of the report should clarify whether there was an association between flow and target detectability. If milling did not occur under higher generation flows, could those specific data be evaluated to assess run timing, duration and magnitude if not entrainment?	See response in comment USFWS-6 (Study No. 3.3.3).
MADFW-4	*4.1.4 Verification Sampling* Based on concurrent observations at the bypass sampler and Cabot Station intake, it was estimated that an average of 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 1990s, which estimated much higher bypass efficiency. The report should include a discussion of any changes	See response to USFWS-8 (Study No. 3.3.3).

Commenter	Comment	Responses
	to project facilities or operations that may help explain the difference in bypass effectiveness (e.g., has unit hydraulic capacity increased? Are the turbines operating at different times or for longer periods than they used to?).	
MADFW-5	*4.2 Radio Telemetry* *4.2.1 Controls* 40% of control fish lost their tags and 80% of control fish died in the first 48 hrs. Control fish were observed to list and/or swim abnormally. Because the mock tags differed from actual tags, it is difficult to know how representative the tag loss and mortality rates are relative to nano-tagged study fish. If this study is rerun the mock tags should be designed to be more like the actual tags used.	Should the study be repeated, dummy tags would be used.
MADFW-6	*4.2.2 Routes of Passage* At the Oct. 31 study report meeting FL related that it is evaluating whether it can meet the study objectives without re-doing the radio telemetry portion of the study for NMPS and TF. Given the high mortality rates of control fish and limited data collected, the Division would support a decision to re-do this portion of the study. However, the report makes no mention of this and instead evaluates the available data collected in 2015 as if the study was sufficient as completed. FL reports the rate of entrainment to the NMPS project as 3.9%. As 3 of the 77 radio tagged juvenile shad that emigrated through the reach of the Connecticut River containing the NMPS Project intake/tailrace were detected in the upper reservoir. The Division does not believe it is appropriate to base an entrainment estimate on numbers of tagged fish detected in the upper reservoir. Given the pressure and hydraulic changes a fish is exposed to during the pumping process, it is highly likely that the radio tags, which were affixed externally to the fish via a barbed No. 16 dry fly hook inserted into the musculature at the base of the dorsal fin, would become dislodged in transit through the intake. With this in mind, another 21 fish which entered the reach from upstream were never detected again, if we assume they were entrained, but not detected due to tag loss, the rate is then 24 of 77 or 31%. Likewise, the number of tagged fish entering the canal (16) is insufficient to draw any conclusions as to preferred passage route or associate passage to any given set of operational conditions. As already stated, at the October 31, 2016 study meeting, FL indicated that, due to the problems encountered during the 2015 fieldwork, it intended to repeat the study, either in 2016 or 2017 (subsequently, FL decided not to repeat the study in 2016 due to low river flow conditions) FL now states that they are is evaluating whether it can meet the study objectives without re-doing the radio telemetry portion of the study for NMPS and TF. The Division supports re-doing this portion of the study. But before repeating the study, we recommend that FL attempt to determine why so many tagged fish were not detected within the study area by: (1) performing a validation study to assess tag retention as fish are pumped up the mountain into the upper reservoir (this would not be needed if FL agreed to the assumption that fish last detected at the lower reservoir intake should be considered entrained); (2) redoing the control experiment using dummy nano tags, not mock tags, to see if retention and survival differ from the original experiment; and (3) performing validation experiments to determine the detectability of nano tags under typical operational conditions at all potential passage routes.	See response to USFWS-10 (Study No. 3.3.3).
MADFW-7	*4.2.5 Canal Drawdown* If the radio telemetry portion of this study is repeated (which the Division suggests), we recommend also repeating the canal drawdown evaluation as no useful data were produced- the final disposition could not be determined for any of the 17 test fish; none were detected downstream of Cabot Station or Station 1. Seven fish were detected in the canal: five in the same areas they were released (two at the upper canal release site and three at the lower release site), one fish at the Station 1 forebay, and the remaining fish at the Cabot forebay. It appears that only a single mobile tracking event took place. Subsequent tracking efforts could have provided additional information regarding movement of fish remaining in the canal during the drawdown.	Should the study be repeated it would include the canal drawdown evaluation. Also see responses to USFWS-4 and USFWS-13 (Study No. 3.3.3).
MADFW-8	*5 Discussion* FL argues that the ability to determine route selection and travel times based on the telemetry results is limited due to a small data set that FL attributes to tag loss and mortality based on results of the control experiment. The Division agrees, but based on the questions about the validity of the controls (mock tags not being identical to real tags) we would argue to repeat the radio tag portion of the study while concentration on suggestions outlined above (comments on 4.2.2).	Should the study be repeated, FL will consider the Divisions recommendations as described in comment MDFW-6.
MADFW-9	*5.4 Downstream Passage Timing, Route Selection, and Rate of Movement* FL states that entrainment at Cabot Station is highest between 1300 and 2300 hours. They assume that this is related to shad behavior with an increase in movement at night. However other study data show a close relationship between generation (flow) at Cabot Station and entrainment (Figure 4.1.1-1). Is higher entrainment due to natural daily migratory behavior or due to migrants' tendency to "follow the flow"?	See response to USFWS-15 (Study No. 3.3.3).

Commenter	Comment	Responses
MADFW-10	*5.5 Rate of Entrainment at NMPS* The Division believes that both the radio telemetry and NMPS hydroacoustic portions of the study should be repeated in 2017. The hydroacoustic data was unusable due to the excessive milling behavior of fish at the intake. Additionally, the radio telemetry data set was limited because a large number of tagged fish went undetected. These study deficiencies prevent any meaningful entrainment estimate.	See response to USFWS-16 (Study No. 3.3.3).
MADFW-11	*5.6 Survival Rates for Juvenile Shad Entrained into Station 1 and Cabot Station* There should be a section of the report that attempts to combine results from all of the studies to calculate a total through-project survival for juvenile shad migrating past NMPS and TFD. The very limited data set from radio tagged fish (discussed above) does not allow for determination of passage routes, therefore the Division believes that the radio telemetry portion of the study should be repeated in 2017	Such an analysis was not envisioned in the RSP and is outside the scope of this study.
CRWC-1	*4.1 Run Timing, Duration, and Magnitude (Hydroacoustics)* For the Northfield Mountain and Power Canal locations that had significant milling, a review of the data to evaluate the amount of milling may provide a general picture of the timing of shad movement. Section 4.1.3 in the report fails to note that the study was conducted during a season in which only three of the possible four turbine pumps/generators were in operation.	See response to USFWS-6 (Study No. 3.3.3)
CRWC-2	*4.2.2 Routes of Passage* The report says 129 fish were released above Shearer. Of the 129, 77 were detected at Shearer and 24 detected in the Northfield forebay and 3 in the upper reservoir. This does not provide sufficient information as to whether fish different fish were detected down river from Shearer. A table with individual fish ID's at each location would be very helpful to better understand movement. The description of the fate and routes of fish released above the Turners Falls dam is inadequate. A calculation of a 3.9% entrainment requires that the 77 fish detected at Shearer all pass Northfield. Based on the fish loss from upstream station to downstream station, it seems overly optimistic to assume that no fish were lost between Shearer and the project. As such any calculation of entrainment would be bias. Three fish were entrained and 21 last detected at the intake of the Northfield station. It is likely that some of the 21 fish were entrained, and that they lost their tag during the pumping cycle (highly likely as tags were lost in the control tank) or that they were not detected in the upper reservoir. If all 21 were entrained and 77 did pass, the entrainment rate would be 31.2% (24/77). And if only the fish last detected during pumping were entrained, the entrainment rate would be 22.1%. Again, this assumes that all 77 Shearer fish passed the project. While this is somewhat speculative, the potentially high entrainment rate reinforces the need to repeat the study.	The fate of the 129 fish released above NMPS has been addressed in response to USFWS-10 (Study No. 3.3.3).
Karl Meyer	Study 3.3.3 Evaluate Downstream Passage of Juvenile American Shad This study is set to be redone in 2017 due to poor initial results and lack of flow in summer/fall 2016. In 2016 Station 1 operated CONTINUOUSLY from mid-July through mid-October. Hence, due to lack of significant flow to run Cabot Station, all down-running juvenile shad were subject to entrainment at this site. This is a situation that must be included in the modeling and implementation of next year's study: i.e.: create a scenario where Cabot is down, and Station 1 running full.	Should the study be repeated, FL will consider including such a scenario.

Study No. 3.3.7 Fish Entrainment and Turbine Mortality

Commenter	Comment	Responses
MDFW-1	*Adult Shad Entrainment* The report concludes that because there were no detections in the upper reservoir- therefore there was no entrainment. This all depends on being able to detect entrained fish. Were the droppers fixed to the bottom, or floating on the surface? Surface droppers would be likely to miss fish. Please elaborate on the location of the droppers and on how detection was tested. However, the study revealed that shad were detected at the NMPS intake/tailrace under all experienced operational and diel conditions. During upstream migration many adult shad that entered the Turners Falls Canal were observed milling in the Cabot Station forebay for up to 48 hours before continuing upstream, suggesting these shad are vulnerable to entrainment or impingement at Cabot Station during their upstream migration.	See response to Comment MDFW-6 under Study No. 3.3.2.
MDFW-2	*Adult Shad Turbine Mortality* Mortality is reported as a "daily mortality rate". This is not comparable to the other turbine survival data reported for resident fish species, which is given as % survival. FL should include tabular data on fish available to pass a given route, routes taken, and subsequent fates (i.e., survival) of those fish in numbers, percent and relative percent.	See response to comment MDFW-23 under Study Report 3.3.2.
MDFW-3	*Appendix A, 4.2.5 Classification of Recaptured Juvenile Shad* How can a shad that does not surface and is not recaptured be deemed "alive" by radio telemetry? Especially when "the shad appeared to have moved into underwater structures that prevented the HI-Z tags from buoying it to the surface". Surly dead shad get pinned under debris in the turbulent environment of a tailrace.	This is the standard classification established for 25 years to best interpret the status of non-recaptured fish. The characteristics of the received radio telemetry signal are used to assign a likely status of these non-recovered fish along with where the signal is originating from. When the signal for a juvenile fish is moving against strong currents, we have found that these fish are likely preyed upon. We have been able to verify this in the past when the predator has been buoyed to the surface by the ingested tagged juvenile fish. If the radio signal is moving downstream at a similar rate as the current or meandering in an eddy area, our past experience has indicated that these fish are likely alive and the HI-Z tag either became detached or deflated. This likely classification is also based on past experience where we have been able to see the fish in clear water environments. Unless there are unique circumstances, we typically assign a juvenile fish a dead status if the signal becomes stationary just downstream of the turbine or spillway discharge; especially if only the HI-Z tag is recaptured. There are some tailraces which have large riprap along the shore areas and some of the turbine or spill discharge is directed toward these areas. Based on numerous studies, we have observed a few of the juvenile fish being discharged into these areas and becoming entrapped in underwater crevices in these rocks. By physically moving boulders, we have been able to retrieve some of these fish and rarely are these fish dead unless the area becomes dewatered due to wave action and/or tailrace fluctuations. Based on our 25 years of observations, the live actively swimming fish, not the stressed and injured fish, are the ones that seek shelter in the riprap areas if discharged in the proximity of these areas. Our observations on adult fish with stronger swimming abilities differ some from that of the juveniles which is explained further under the response to MDFW-7 (Study No. 3.3.7) below.
MDFW-4	*Appendix A, 4.2.6 Classification of Juvenile Injuries* The classification of shad without visible injuries that exhibited loss of equilibrium (not actively swimming or swimming erratically) which survives for more than an hour as "minor malady" is very problematic. Any juvenile shad that experienced such a dramatic reduction of mobility in a natural environment for one hour (or much less) would almost certainly be eaten by something.	We agree that fish that are disoriented after turbine or spillway passage would be more susceptible to predation if predators are in the area. The major and minor malady classification was primarily established to serve as a metric to classify the severity of injuries and not whether a fish would survive or perish. Additionally, juvenile clupeids are extremely sensitive to handling and some of the loss of equilibrium was due to the compounding effects of tagging and recapture that naturally passed fish would not experience. The incidences of loss of equilibrium alone without accompanying injuries have been infrequent in the more than 100,000 HI-Z tagged juvenile salmonids passed through turbines and spillways.
MDFW-5	*Appendix A, Table 4-4* How can a treatment fish with no visible injuries that dies after 1 hr be deemed "non-passage related"? The control group will give the rate of "non-passage related" mortality- any fish that goes through a unit and then dies should be "passage related". "Any minor injury that leads to death within 1 hour is classified as a major injury. If it lives or dies after 1 hour it remains a minor injury" A minor injury is a major injury? An injury that leads to death (after an hour) is "minor"?	The issue of fish dying with no visible injuries had to be addressed when the HI-Z tag studies initially began. There were many discussions and ultimately it was decided to classify fish that died after 1 hour as a non-passage related malady if no injuries were observed when computing the malady-free rate. These fish are still considered as passage-related mortalities when calculating the survival rate. See response above about major vs minor classification (MDFW-4, Study No. 3.3.7).
MDFW-6	*Appendix A, Table 5-4* There are large numbers of held fish classified as having died "without passage-related maladies." The proportion of fish that died without passage-related maladies is based on the total number of fish examined. The proper calculation would be the proportion of fish that died without "passage-related maladies" relative to the total number of examined fish that exhibited no "passage-related maladies." Table 5-4 should be corrected (example in letter). These data and the data on the 1-hour and 48-hour survival appear to be very closely correlated, with the routes showing the highest 1-hour and 48-hour mortality corresponding to the routes that also had the highest "non-passage-related maladies" as characterized by Normandeau	One of the main reasons for developing a malady classification was to come up with a metric that would account for visible injuries (both internal and external), scale loss (>20% per side) and loss of equilibrium, and also provide a way to classify the seriousness of an injury. The intent was not to use the malady metric as a proxy for mortality; although major maladies often result in death.

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	Associates. If these fish, in fact, were suffering from non-passage related effects, there is no identified explanation for why these data are correlated. The most plausible explanation for the correlation is that the "non-passage-related maladies" are in fact passage-related. As such, the overall conclusions on survival by route should consider those fish characterized as having non-passage-related mortalities that died while being held as passage-related mortalities.	
MDFW-7	*Appendix B, 4.2.4 Classification of Recaptured Adult Eels* How can an eel that does not surface and is not recaptured be deemed "alive" by radio telemetry? Especially when "the eel appeared to have moved into underwater structures that prevented the HI-Z tags from buoying it to the surface". Surly dead eels get pinned under debris in the turbulent environment of a tailrace. Number of control eels used. The methods state that control fish would be released downstream of the treatment sites. The total number of control fish necessary to estimate survival was determined to be 25. Based on information provided in Table 4-3, a total of 20 control eels were used for the Bascule gate testing, five controls were used at Cabot Station, and no controls were used for Station No. 1. FL should explain why the controls were apportioned the way they were and how it was possible to estimate survival at Station No. 1 Unit 1 and Units 2/3 without accounting for control mortality.	The alive classification for adult eels that move into underwater structures and crevices is based on our numerous HI-Z studies on adult eels. Early on we found that the tagged eels dove deep soon after turbine passage, and if available, sought underwater hiding areas especially during bright sunny days. In the first large study conducted on the St Lawrence River, we found that our chances of recapturing the turbine passed eels increased at night. Since that first study, we have been able to decrease the chances of the eels finding an underwater entrapment area by increasing the number of attached HI-Z tags and decreasing the inflation time of the tags. Assigning an alive status to many of the entrapped eels is based on field verification where eels that have been stationary for up to several hours suddenly pop to the surface with fully inflated HI-Z tags. We have never captured a severely injured eel or dead eel that had a stationary signal in a tailrace after turbine passage; in fact injured and dead eels typically surface much sooner than healthy specimens. The 25 eels released as controls were assigned to all the treatment releases. This procedure has been used in past studies where the number of specimens available for a study is limited; which was the present case. Additionally this allocation of control fish to different test conditions has proven to be sufficient if control recapture rate and survival rates are near or 100%. Also there is no need to adjust for potentially different predation rates at the different test sites when testing large adult fish. The only issue we have had in the past with predation on adult fish was sea lions taking adult salmon.
MDFW-8	*(from Study No. 3.3.3) 5.6 Survival Rates for Juvenile Shad Entrained into Station 1 and Cabot Station* There should be a section of the report that attempts to combine results from all of the studies to calculate a total through-project survival for juvenile shad migrating past NMPS and TFD. The very limited data set from radio tagged fish (discussed above) does not allow for determination of passage routes, therefore the Division believes that the radio telemetry portion of the study should be repeated in 2017.	See response to MDFW-11 under Study No. 3.3.3.
USFWS-1	*2.1.1, Station No. 1* Computational Fluid Dynamics (CFD) modeling of the Station No. 1 intake demonstrated that 91 percent of the rack face had approach velocities of less than 2.0 feet per second (fps). We request that FL include in this report the relevant data (either in tabular or graphical format) from the CFD report (Study 3.3.8).	Figures 8.2.1-4, 8.2.2-4, and 8.2.3-4 from the report for Study No. 3.3.8 depict velocity vectors about 1 foot upstream of the Station No. 1 trashracks at two different station flows (1,433 and 2,210 cfs) and various canal flow scenarios. All reports are available to all stakeholders; therefore, FL does not feel it is necessary to include CFD results in the report for Study No. 3.3.7.
USFWS-2	*2.1.2, Cabot Station* CFD modeling of the Cabot Station intake demonstrated that only 32 percent of the rack face had approach velocities of less than 2.0 fps, with the highest velocities located in front of Unit 6. We request that FL include in this report the relevant data (either in tabular or graphical format) from the CFD report (Study 3.3.8).	Figures 8.2.3-3 and 8.3.3-3 from the report for Study No. 3.3.8 depict velocity vectors about 1 foot upstream of the Cabot Station trashracks at two different station flows (7,500 and 13,728 cfs). All reports are available to all stakeholders, therefore, FL does not feel it is necessary to include CFD results in the report for Study No. 3.3.7.
USFWS-3	*2.3, Fish Species in Study Area* We agree that risk of impingement would be low for transformers. However, the average size of transformers of 150 mm to 174 mm (6 to 7 inches) along with their body morphology (i.e., length) may present some risk of entrainment injury or mortality. According to the size-based predicted survival of entrained fishes provided in TransCanada's (TC) Study Report 23 (Table 6.1-3), 4-inch fish have a predicted survival through the Vernon Project's vertical Francis turbines 9 and 10 ranging from 92.2 percent to 96.1 percent and 8-inch fish survival ranges from 84.4 percent to 92.2 percent. As noted below, the Cabot and Station No. 1 turbines have specifications that likely result in lower predicted survival (i.e., faster turbine runner speed, higher head).	Information contained in TC Study Report 23 has not been verified by FL. Assuming data presented by TC are accurate, transformers that approach the Cabot Station intakes and enter the area of influence may be subjected to entrainment.
USFWS-4	*3.1.1, Potential Entrainment and Impingement Risk* We also note that mean intake velocity alone does not fully predict entrainment or impingement, as velocities at trashracks can have "hot spots" with higher intake velocities. If mean velocity is close to the sustained swim speed of target fish species, an assessment of actual velocities in the field under maximum generation is likely needed.	As a majority of the species/length classes was identified as unable to escape the velocities at Northfield and Cabot Station, this additional assessment would only be applicable to Station No. 1. Depending on where the fish interacted with the intake, several additional species could be susceptible to impingement and/or entrainment at Station No. 1 during times of maximum generation.
USFWS-5	*3.1.2, Turbine Passage Mortality* Table 4.1-4 summarizes the Francis turbine dataset used in Franke et al. (1997) and Tables 4.1-5 and 4.1-6 further refine the dataset based on similarity to Cabot Station unit specifications and Station No. 1 unit specifications, respectively. While we understand that it would be nearly impossible to find another site with exactly the same turbine characteristics as Cabot or Station No. 1, FL included stations that have certain parameters quite dissimilar from the subject turbines. For example, stations with twice the runner speed (Caldron Falls, WI) and one-third the	A summary table is attached as Attachment A (Study 3.3.7).

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	head (Minetto, NY) of the Cabot units were included. We request that a table be included that provides summary results of the turbine testing at stations FL included in the analysis (by species and size class). Both the range and mean survival by project, fish species and size class should be provided.	
USFWS-6	*4.1, Resident Fish* In Table 4.1-1, each trait (by species) is rated as having an increased risk to entrainment ("+") or a lower likelihood of entrainment ("-"). However, for the trait Reproductive Strategy, only the first six species have a rating. Similarly, white perch (*Morone americana*) do not have a Demography rating and no rating is given for Habitat within Channel for bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*), and from rock bass (*Ambloplites rupestris*) to tessellated darter (*Etheostoma olmstedi*). Only the first 11 species received a rating for the trait Migration and Movement. The Table should be corrected to address these omissions.	A revised Table 4.1-1 is attached as Attachment B (Study 3.3.7).
USFWS-7	*4.1, Resident Fish* Table 4.1-2 rates the entrainment susceptibility based on each species' (or group of species) sustained swim speed relative to the calculated approach velocities at the three intakes. A "+" denotes the ability of that fish to escape entrainment, while a "-" indicates it is unable to escape entrainment. For many of the entries (n=29), it appears that a fish with a sustained swim speed lower than the intake velocity was given a "+" rating. We assume that most of these errors were made by comparing the fish's burst speed to the mean intake velocity rather than its sustained swim speed. The Table should be corrected accordingly.	A revised Table 4.1-2 is attached as Attachment C (Study 3.3.7).
USFWS-8	*4.1, Resident Fish* Tables 4.1-7 and 4.1-8 provide the estimated percent survival of each fish species at Cabot Station and Station No. 1 based on those hydropower projects in the Franke et al. (1997) database with turbine specifications most similar to the two FL stations at the Turners Falls Project. Nine different receiver stations were used in the analysis for Cabot Station (Table 4.1-5) and 11 different stations were used in the analysis for Station No. 1 (Table 4.1-6). Most of these stations tested species multiple times, therefore there were a range of survival results which should be fully presented in Table 4.1-7 (rather than the single survival value used). For example, just using results from the E.J. West, New York Station, immediate survival values for largemouth bass (*Micropterus salmoides*) ranged from 0.80 to 0.96 and 48-hour survival values ranged from 0.43 to 0.89. We also recommend that FL provide the underlying data from Franke et al. (1997) for each of the stations identified in Tables 4.1-5 and 4.1-6 as an appendix to the report.	A summary table is attached as Attachment D (Study No. 3.3.7).
USFWS-19	*4.2.1, Adult American Shad Entrainment* Risk of entrainment of adult American shad was assessed using radio telemetry as part of Study 3.3.2 (Evaluate Upstream and Downstream Passage of Adult American Shad). According to FL, there was no confirmed entrainment of adult shad into the NMPS or Station No. 1 during the 2015 monitoring period. Adult shad were confirmed to be entrained through the Cabot Station powerhouse. In the report, FL states "Of the 86 fish that utilized the power canal during emigration, 24 were confirmed to have transitioned from Cabot Forebay to the Cabot Tailrace." Using the numbers FL provides results in a calculated entrainment rate of 27.9 percent (24 out of 86). However, Study Report 3.3.2 states that 28 fish transitioned from the forebay to the tailrace. Further, while 86 adult shad entered the canal, only 67 were documented exiting via either the Cabot bypass or intake. We believe that 67 should be used as the denominator in the calculation, as this is the number of fish documented as passing through the canal. Using that value results in an entrainment rate through Cabot Station of 41.8 percent (24/67).	We disagree with the logic of discounting the 19 fish that never were detected as leaving the canal in order to reduce the denominator. Does that mean we can apply this line of logic and remove the number of fish that never passed upstream from the denominator to quantify upstream passage rates for either ladder? In total 86 fish were present in the canal and available to pass, if 19 did not pass their fate is still known and we assume they remained in the canal. In total, 28 (as stated in Study Report 3.3.2) out of the 86 fish that were available to pass downstream were entrained, or 32.6% were entrained.
USFWS-10	*4.2.1, Adult American Shad Turbine Mortality* In our comments on Study Report 3.3.2, we are requesting that FL include tabular data on fish available to pass a given route, routes taken, and subsequent fates (i.e., survival) of those fish in numbers, percent and relative percent. That information should be presented in this report also, as it will allow for direct comparison with the survival estimates provided for resident species.	Clarification is needed to address this comment. It is unclear how tracking and survival data for adult American Shad, a migratory species for which FL was not required to collect any empirical turbine mortality data on, allow for direct comparison with resident fish survival estimates.
USFWS-11	*4.2.1, Adult American Shad Turbine Mortality* We request that FL use the Franke et al. (1997) turbine blade strike equation to calculate survival, as TC did in its Study Report 23. As noted in our July 14, 2016 comments on TC' s Study Report 23, a deficiency of the EPRI entrainment and survival database is that no sites assessed survival of adult American shad, nor were any similar-sized fish evaluated (i.e., fish within the size interval 15.1 inches to 20 inches). That deficiency notwithstanding, calculating a mean survival for fish greater than 12 inches would at least provide some point of comparison to the radio-telemetry results. Additionally, if the telemetry data are insufficient to determine passage-related mortality with any confidence, the Franke et al. (1997) blade strike equation may be the only means of estimating mortality.	Blade strike analysis was not required by RSP.
USFWS-12	*4.2.2, Juvenile American Shad (reiterated comments on Study No. 3.3.3 from 12/13/16 letter)* • Although the radio-telemetry data provide some information relative to passage route and residency time within the canal, we have concerns about the effectiveness of the receivers in detecting the shad tags (i.e., three shad were detected in the Cabot tailrace that never were detected in the forebay). Given these concerns, we do not believe the data are sufficient to draw conclusions on entrainment potential at Station No. 1.	See response to USFWS-10 under Study 3.3.3.

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	• The hydroacoustic data for Cabot Station revealed substantial entrainment, with rate of entrainment increasing as generation increased. In addition, the paired sampling at the Cabot bypass and intake revealed that only 43 percent of juvenile shad used the bypass, while 57 percent were entrained. These results suggest a much lower bypass effectiveness than previously conducted studies, where 87 percent (in 1992) and 94 percent (in 1993) of study fish used the bypass. • For a number of reasons described in our December 13, 2016 letter commenting on Study Report 3.3.3, we do not agree with FL's estimated entrainment at NMPS of 3.9 percent. Rather, we believe the data set (limited though it is) suggests an entrainment rate of between 27 to 58 percent. We do note that in Study Report 3.3.7, FL states that 21 fish were detected at the NMPS intake, whereas in this report the stated number of fish detected at the intake is 24 fish. FL should address this inconsistency.	
USFWS-13	*4.2.2, Juvenile Shad Turbine Mortality (reiterated comments on Study No. 3.3.3 from 12/13/16 letter)* 1. FL's consultant (Normandeau Associates) provides calculations used to determine the appropriate number of test and control fish to use in the study. The calculations were based on equations derived using results from previous balloon tag studies that relied on salmonids, even though Normandeau Associates knew that survival of juvenile shad likely would be substantially lower. This assumption resulted in an insufficient number of test fish and the inability to estimate survival beyond 1 hour. 2. In assessing juvenile shad injuries, a shad without visible injuries, not actively swimming or swimming erratically at recapture was classified as "loss of equilibrium" (LOE). If an LOE fish died within an hour, it was considered a "major malady," if it survived past 1 hour, it was considered a "minor malady," but if it regained equilibrium within 10 to 15 minutes, it was considered "malady free." Our position is that a fish exhibiting LOE (particularly small fish such as juvenile shad) for any length of time in the natural environment likely are at an increased risk of predation and therefore should not be assessed as malady-free or minor malady. We request that FL provide the number of eels exhibiting short-term (i.e., less than 15 minutes) loss of equilibrium if that information is available. 3. Recapture rates differed between test and control fish at both Station No. 1 and the Bascule gates. Potential reasons for this differential should be provided by FL. 4. We have a number of questions regarding the injury assessment component of the study; in general, more detailed explanation is required for how maladies were assigned.	1. Sample size is addressed in response to USFWS-24 below (Study No. 3.3.7). 2. Issues regarding of loss of equilibrium are addresses in the response to MDFW-4 above (Study No. 3.3.7); instances of eels with only loss of equilibrium is addressed in the response to USFWS-16 below (Study No. 3.3.7). 3. One of the main causes for higher recapture rates for control than treatment fish was likely due to control fish being released in a substantially less turbulent environment than the treatment fish. See response to USFWS-29 (Study No. 3.3.7) for further explanation. 4. See responses to MDFW-4 and MDFW-5 above (Study No. 3.3.7) for clarification on injury classification.
USFWS-14	*4.2.2, Juvenile Shad Turbine Mortality* Similar to our comments under the Adult Shad Turbine Mortality section above, we request that FL use the Franke et al. (1997) turbine blade strike equation to calculate survival for juvenile shad, as TC did in its Study Report 23. Although empirical turbine mortality data were collected for juvenile shad as part of Study 3.3.7, comparing site-specific data to calculated estimates is useful in assessing the validity of the blade strike equation, as well as a check on the utility of using an outdated and incomplete data set (i.e., EPRI) for desktop entrainment and impingement analyses.	Blade strike analysis was not required by the RSP.
USFWS-15	*4.2.3, Adult American Eel Entrainment* Once Study Report 3.3.5 has been issued, FL should provide an addendum to Study Report 3.3.7, incorporating relevant information from that study.	FL will incorporate relevant information related to American eel entrainment in the report being prepared for Study No. 3.3.5.
USFWS-16	*4.2.3, Adult American Eel Turbine Morality* 1. Normandeau Associates provides calculations used to determine the appropriate number of test and control fish to use in the study. The sample size calculation assumes 100 percent control survival, a recapture rate of 95 percent, and an expected passage survival and malady-free rate of greater than 85 percent. Based on those assumptions, Normandeau determined that 30 to 50 treatment eels would be needed per scenario and 25 combined control eels. While Normandeau Associates cites several turbine direct survival studies on adult eels to ground-truth those assumptions, those tests were done on Kaplan and bulb turbines (Table 5-6). Just going by the turbine blade strike equation would suggest the assumption of greater than 85 percent survival would not be met. Fortunately, the assumptions appeared to have been met at the sites and therefore, sample sizes were sufficient to derive both immediate (1-hour) and delayed (48-hour) survival estimates. 2. In assessing eel injuries, an eel is assigned as "loss of equilibrium" if it does not disappear within 10 to 15 minutes after recapture. Our position is that a loss of equilibrium, even if only for 10 to 15 minutes, likely increases an eel's risk of predation (although less so than for a juvenile shad) or failure to be able to seek out safe and adequate habitat and therefore an eel that regains equilibrium should not necessarily be assessed as malady-free. We request that FL provide the number of eels exhibiting short-term (i.e., less than 15 minutes) loss of equilibrium if that information is available.	1. We did base our eel sample size on adult eels passed through Kaplan /propeller units because we had not previously passed eels through Francis turbines. Although we had not previously tested eels at Francis units we have passed juvenile fish of several species and adult shad through Francis units and expected survival estimates to be greater than or equal to 85%. We were somewhat surprised when our tests at Francis units for both FL and TransCanada revealed better passage survival at most of the Francis units than the Kaplan/propeller units. We have recommended that reasons for this be further investigated. 2. Only one of the 300 eels tested displayed loss of equilibrium only at capture. This fish had passed through Station No. 1, Units 2/3. We suspect that there are few piscivores in the Connecticut River that would prey on large emigrating adult eels; there may be a slight chance of eagle predation if a stunned eel was on the surface.
USFWS-17	*4.2.3, Adult American Eel Turbine Morality* There is a minor discrepancy between data provided in Table 5-1 and 5-5: 27 eels were recaptured alive at Station No. 1 Unit 1, but only 26 were examined for maladies. Also, there appears to be an error in Table 5-1: the combined Bascule Gate 4 number recaptured alive is 86 fish, yet that is the same number given for the number alive after 48 hours, even though 2 fish died in holding. These discrepancies should be corrected.	See Attachment E (Study No. 3.3.7) for revised Table 5-1.

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USFWS-18	*4.2.3, Adult American Eel Turbine Morality* In the report, Normandeau Associates states that control fish would be released downstream of the treatment sites. The total number of control fish necessary to estimate survival was determined to be 25. Based on information provided in Table 4-3, a total of 20 control eels were used for the Bascule gate testing, five controls were used at Cabot Station, and no controls were used for Station No. 1. FL should explain why the controls were apportioned the way they were and how it was possible to estimate survival at Station No. 1 Unit 1 and Units 2/3 without accounting for control mortality.	See response to MDFW-7 above (Study No. 3.3.7)
USFWS-19	*4.2.3, Adult American Eel Turbine Morality* Also, Tables 5-1 and 5-5 present the control data as combined for all release sites. While this may be acceptable, given that all controls were recaptured and all apparently were malady-free, in order to avoid confusion, we recommend adding in a separate subsection for controls under the Results section. Currently, the control results are only discussed under the Cabot Station subsection, which suggests that all controls were released at that test site.	See Attachment F (Study No. 3.3.7) for a discussion of control fish recapture rates and time.
USFWS-20	*4.2.3, Adult American Eel Turbine Morality* Control fish are not discussed in the Recapture Time section. We request that recapture time for controls, by release site, be provided in order to compare recapture times between test and control fish.	See Attachment F (Study No. 3.3.7) for a discussion of control fish recapture rates and time.
USFWS-21	*4.3, Station Impacts* Tables 4.3.2-1 and 4.3.2-2 provide entrainment risk scores for resident species at Station No. 1 and Cabot Station, respectively. While FL's RSP stated that the species evaluated would be selected based on results of the Fish Assemblage Study (3.3.11), we believe that data collected as part of Study 3.3.18 (Impacts of the Turners Falls Canal Drawdown) also should be considered in the analysis. For example, the most abundant species encountered during Study 3.3 .18 in Zone 1 (the zone closest to the Cabot intake) were spottail shiner (Notropis hudsonius) and tessellated darter, yet both of these species were assigned a rank of "1" for Habitat & Biology and a Likelihood of Entrainment either of "l" (tessellated darter) or "2" (spottail shiner). The next most abundant species was smallmouth bass (Micropterus dolomieu), which also received scores of "l" for both Habitat & Biology and Likelihood of Entrainment. FL should explain why the rankings do not reflect empirical data.	The RSP specified that "*River resident species composition and length frequency distribution will be derived from the site-specific fish abundance survey data* ***collected in the Turners Falls Impoundment as part of Study No. 3.3.11***." Study No. 3.3.18 was not identified as a source of data. As the USFWS notes in comments pertaining to Study No. 3.3.18, "*One reasonable explanation for the abundance of shiners and darters in the immediate vicinity of the intake in the apparent absence of suitable habitat is that those fish moved downstream during the canal drawdown (i.e., would otherwise not be in that area)*." This reinforces the idea that the presence of these species in the canal is a temporary artifact of the drawdown process, and not representative of chronic year round habitat use for these species. Therefore, FL believes use of data from Study No. 3.3.18 would potentially bias the analysis.
USFWS-22	*4.3, Station Impacts* Table 4.3.3-1 provides entrainment risk scores for resident species at NMPS. For nearly every species, FL ranks the Habitat and Biology as "1", meaning it is unlikely to be present in the vicinity of the NMPS intake, even though some species were collected at the sampling station located immediately upstream of the intake as part of the Fish Assemblage Study (Study 3 .3 .11). Although the number of fish collected for some species was lower than for others, given that the sampling was restricted to a relatively low sampling effort single boat electrofishing pass, we believe a rank of "2" is appropriate for all species that were collected from Station 73.9. Likewise, the Likelihood ranking for all species collected at Station 73.9 should be "2." Of the 10 species collected from Station 73.9, seven have swim speeds over 1 fps less than NMPS' intake velocity and should be ranked as a "3." Adult smallmouth bass should be ranked "O" and young-of-year should be ranked "3." Table 4.1-2 does not provide swim speeds for juvenile bass, but it is reasonable to rank them a "2." We recommend that FL adjust the rankings, which should have the effect of increasing the overall risk scores for those species collected in closest proximity to the NMPS intake.	Many of the species such as Smallmouth Bass make extremely limited localized movements because they are cover-oriented. For example, McBride (1985) showed that most tagged Smallmouth Bass in the Mohawk River move extremely short distances over several seasons. Station 73.9 is located approximately a half mile from the NMPS intake and features habitat that would tend to attract the subject species whereas the NMPS intake, located a distance away, does not. FL does not agree that use of data from station 73.9 is representative of the NMPS intake.
USFWS-23	*4.3, Station Impacts* We request that FL provide an explanation for: (1) its decision to use an unfiltered dataset; (2) why it chose not to use the blade strike equation; and (3) why it analyzed the data relative to species of fish rather than fish size.	(1) It is unclear what is meant by an "unfiltered" data set. (2) Use of the blade strike equation was not explicitly required in the RSP. (3) The narrative in Section 4.3 discusses qualitative effects on YOY, juvenile and adult lifestages of species. It may be inferred that this embraces a range of sizes of fish from small to large within each applicable species group.
USFWS-24	*Study No. 3.3.3, Appendix B - Direct Injury and Relative Survival of Juvenile American Shad* *4.4.2 Sample Size Calculations* This section describes how Normandeau Associates determined the appropriate sample size for each test location and treatment, describing that the calculations were based on past studies and were designed to assure that sufficient fish releases were made to calculate 1-hour and 48-hour mortality. Table 4-1 includes calculations of sample size based on various combinations of control survival rates of 90 percent to 100 percent, recapture rates of 90 percent to 100 percent and expected survival rates of 85 percent to 95 percent. Based on these calculations, 120 shad were released through Cabot Station Unit 2; 90 through Station No. 1, Unit 2/3; and 90 through Station No. 1, Unit 1. Sixty to 62 fish were released for each flow scenario through Bascule gate 1 and Bascule gate 4. These sample sizes were inadequate to permit a statistically significant calculation of 48-hour survival as described in section 4.2.7, but this result should have been anticipated by Normandeau	See response to USFWS-18 under Study No. 3.3.3

Commenter	Comment	Responses
	Associates' own prior studies as discussed in section 4.2.7 below.	
USFWS-25	*Study No. 3.3.3, Appendix B - Direct Injury and Relative Survival of Juvenile American Shad* *4.2.6 Assessment of Juvenile Shad Injuries* This section states that "Shad without visible injuries that were not actively swimming or (were) swimming erratically at recapture were classified as loss of equilibrium," and then states that this condition "often disappears within 10 to 15 minutes after recapture if shad are not injured." The classification of fish with loss of equilibrium (LOE) is then further defined in Table 4-4, where it states that if a fish classified as LOE dies within one hour, it is considered a "major malady," but if it survives past one hour it is considered a "minor malady." This entire analysis is severely flawed. First, if a fish has LOE after passage through any route, it is highly vulnerable to predation and unable either to swim to suitable habitat or join a school of fish for protection. Regaining equilibrium in 10 to 15 minutes in a tank as discussed in the narrative would be of little consequence if the fish has already been predated in natural habitat. Even more problematic is classification of a captured fish that regains equilibrium or dies sometime after one hour to be a "minor malady." A fish with LOE for one hour in the natural environment would even more certainly perish. In all, these classifications severely downplay the impacts of passage through turbines or other routes.	See response to MDFW-4 and MDFW-5 above (Study No. 3.3.7).
USFWS-26	*Study No. 3.3.3, Appendix B - Direct Injury and Relative Survival of Juvenile American Shad* *4.2.7 Survival and Malady-Free Estimation* As noted above, Normandeau Associates calculated the fish release sample size based on past studies and calculation in Table 4-1. In this section, Normandeau Associates describes that the basis for using high survival, high recovery rates and high control mortality in its calculations for this study were the results from previous studies of chinook salmon and other salmonids, However, it is then cited that studies of juvenile shad at the Holtwood Project (Susquehanna River) had high control mortality using 105-135 mm fish, and as a result a "valid 48 hour longterm survival could not be obtained" for that study. The report then concludes that because, in this study, shad had high mortality rates in both control and test fish, "only a one-hour survival estimate is considered reliable." The problem with this conclusion is that, based on its own studies done at Holtwood, Normandeau Associates should have anticipated that mortality of juvenile shad controls in this study would be higher than in salmonid studies, and similar to what was experienced at Holtwood, especially given that the fish used in this study were even smaller (90-122 mm) than the larger fish used at Holtwood. Therefore, more realistic inputs to the sample size calculations summarized in Table 4-1 should have been used, which would have resulted in a substantially larger sample size per treatment.	See response to USFWS-20 under Study No. 3.3.3
USFWS-27	*Study No. 3.3.3, Appendix B - Direct Injury and Relative Survival of Juvenile American Shad* *5.1.1 Cabot Station Unit 2* This section should include the recapture rate of control fish.	See response to USFWS-21 under Study No. 3.3.3
USFWS-28	*Study No. 3.3.3, Appendix B - Direct Injury and Relative Survival of Juvenile American Shad* *5.1.2 Station No. 1* Recapture rate for the control fish was 94.4 percent, yet the recapture rates for the test fish were much lower (75.6 percent for Unit 1 and 72.2 percent for Units 2/3). As both groups of fish were discharged into the same environment, the report should explain the potential reasons for this discrepancy. The conclusionary statement that assigning dislodged tags as dead should be considered conservative, since tags could be dislodged in turbulent in-turbine or tailwater conditions that are not lethal, is conjecture and is not supported by any data. The statement that turbulent conditions would not be lethal is unsupported by any data. Turbulent conditions sufficient to dislodge a tag can just as readily be considered sufficient to result in severe injury or mortality. Similar statements appear throughout the results section and should be deleted.	See response to USFWS-22 under Study No. 3.3.3
USFWS-29	*Study No. 3.3.3, Appendix B - Direct Injury and Relative Survival of Juvenile American Shad* *5.1.3 Bascule Gates* Treatment groups released over the Bascule gates had even lower recapture rates than at Station No. 1: 56.7 percent at the 2,500 cfs setting to 79 percent at the 5,000 cfs setting. However, all control fish released downstream of both Bascule gates were recaptured. Again, Normandeau Associates should provide an explanation for the differential in recapture rates within and among assessment areas. Just over 29 percent of shad passed through the Bascule gates were assigned a dead status based on the recapture of just tags or reception of only stationary radio signals. Normandeau Associates suggests that this assignment is likely conservative, as a portion of these fish may have been alive but lost their tags due to turbulent conditions in the spillway discharge, as we questioned above. In addition, given the high rate of recapture for controls (none of which lost tags, although presumably they were exposed to the same turbulent conditions), the Service does not believe that assigning those treatment fish as dead is conservative. Normandeau Associates references Figures 2-2 and 2-3; we believe the figures referred to are 3-2 and 3-3.	See response to USFWS-23 under Study No. 3.3.3

<table>
<tr><th>Commenter</th><th>Comment</th><th>Responses</th></tr>
<tr><td>USFWS-30</td><td>Study No. 3.3.3, Appendix B - Direct Injury and Relative Survival of Juvenile American Shad
5.2 Recapture Times
This section reviews the amount of time from release to recapture. In general, the recapture period after release was short, between 3.5 and 6.3 minutes on average for the turbine-passed fish. As such, there was limited time after release during which fish would be subject to other causes of trauma outside of the immediate turbine discharge and turbulence of the Bascule gate spill areas. As these areas are an integral part of the safety of each route, most, if not all of the trauma a recaptured fish suffered was most likely induced by passage through the turbine or discharge over a gate.

In Table 5-4, the maladies suffered by fish are provided by passage route/treatment. There are large numbers of held fish classified as having died "without passage-related maladies." Table 5-4 calculates the proportion of fish that died without passage-related maladies based on the total number of fish examined. The proper calculation would be the proportion of fish that died without "passage-related maladies" relative to the total number of examined fish that exhibited no "passage-related maladies." These entries in Table 5-4 should be corrected. Analyzing the data this way shows a range of mortality from 14.7 percent of fish passed over Bascule Gate #1 at 1,500 cfs to 90.9 percent of fish passed over Bascule Gate #4 at 1,500 cfs (see table below).

<table><tr><th>Passage Route</th><th>% of Non-Passage-Related Maladies that Died</th></tr><tr><td>Cabot Unit 2</td><td>21.9</td></tr><tr><td>Station 1 Unit2/3</td><td>16.3</td></tr><tr><td>Station 1 Unit 1</td><td>51.0</td></tr><tr><td>Bascule 1 - 1,500 cfs</td><td>14.7</td></tr><tr><td>Bascule 1 - 2,500 cfs</td><td>85.7</td></tr><tr><td>Bascule 1 - 5,000 cfs</td><td>78.1</td></tr><tr><td>Bascule 4 - 1,500 cfs</td><td>90.9</td></tr><tr><td>Bascule 4 - 2,500 cfs</td><td>81.8</td></tr><tr><td>Bascule 4 - 5,000 cfs</td><td>78.2</td></tr></table>
These data and the data on the 1-hour and 48-hour survival appear to be very closely correlated, with the routes showing the highest 1-hour and 48-hour mortality corresponding to the routes that also had the highest "non-passage-related maladies" as characterized by Normandeau Associates. If these fish, in fact, were suffering from non-passage related effects, there is no identified explanation for why these data are correlated. The most plausible explanation for the correlation is that the "non-passage-related maladies" are in fact passage-related. As such, the overall conclusions on survival by route should consider those fish characterized as having non-passage-related mortalities that died while being held as passage-related mortalities.</td><td>See response to USFWS-24 under Study No. 3.3.3.</td></tr>
<tr><td>USFWS-31</td><td>Study No. 3.3.3, Appendix B - Direct Injury and Relative Survival of Juvenile American Shad
Appendix B
• What is a non-passage malady? How do you know it is non-passage-related?
• Explain the distinction between "without maladies (passage-related)" and "with non-passage maladies." It may be more clear to retitle them as "non-passage maladies" and "without maladies."
• How can the control fish have passage-related maladies? Are those injuries incurred during passage through the conveyance pipe to the tailrace?</td><td>See response to USFWS-25 under Study No. 3.3.3</td></tr>
<tr><td>USFWS-32</td><td>Study No. 3.3.3, Appendix B - Direct Injury and Relative Survival of Juvenile American Shad
Appendix C
Additional explanation is needed to better understand how probable cause was determined. For instance, Fish 004 from Test Lot IA was classified as having a passage malady, yet no obvious injuries were observed, leading to a Probable Cause classification of Undetermined. If the cause was undetermined, why was it considered a passage malady? Likewise, for Fish 006 from Test Lot 2A, the Probable Cause was determined to be Shear, yet it was deemed to not be a passage malady.

Are fish whose probable cause of injury is classified as undetermined in the table the same fish considered to have non-passage maladies in Appendix B? If the cause is undetermined, it could potentially be passage-related.</td><td>See response to USFWS-26 under Study No. 3.3.3</td></tr>
<tr><td>CRWC-1</td><td>The adult shad telemetry study (Study Report 3.3.2) notes that six fish detected were detected at the Station No. 1 forebay with 7 successful escapes (pg. 4-72). The Kleinschmidt Associates (contractor to FirstLight) database has 7 fish including 2 released in the impoundment</td><td>The database is accurate and suggests an error in the report text. The error will be corrected in the addendum to Study No. 3.3.2.</td></tr>
</table>

Commenter	Comment	Responses
	including one which did not escape. Clarification is needed.	
CRWC-2	The estimate of 3.9% entrainment at the Northfield project of juvenile shad represents the absolute minimum, as not all 77 fish detected at Shearer likely passed the Northfield project and more than 3 fish were likely entrained.	The entrainment rate was based on empirical data collected with radio-telemetry techniques.
NMFS-1	*2.1.1, Station No. 1* The report should highlight that Station 1 does not have a downstream bypass.	FL does not think it is necessary to highlight features that do not exist at Station No. 1.
NMFS-2	*2.1.2, Cabot Station* The report should note that the current rack spacing for both the upper 11 feet that has 0.9 inch spacing or below 11 feet where the racks have 5 inch spacing. This spacing is wide enough to allow juvenile shad and silver eel entrainment.	Section 2.1.2 of the report states the rack spacing of both the upper and lower portions of the Cabot intake.
NMFS-3	*2.2.1, Powerhouse Tailrace* Under a four unit pumping scenario, velocities across the channel were 3-4 ft/s. These velocities are high enough to entrain juvenile shad.	We agree that the velocities in the intake/tailrace channel are high enough to entrain juvenile fish, but only those fish that enter the area of influence.
NMFS-4	*2.3, Fish Species in Study Area* The report states "the lifecycle of Sea Lamprey is such that impacts due to entrainment and/or impingement at the Northfield Mountain and Turners Falls Projects are likely negligible." We disagree with this statement. Laboratory research on Pacific lamprey found that impingement can occur at approach velocities as low as 1.5 ft/s.(Moser et al., 2015)	Moser et al. (2015) discusses impingement of lamprey on 3.175 mm bar screens. The trashrack spacing at Northfield Mountain (152.4 mm), Station No. 1 (66.7 mm), the upper portion of Cabot (23.9 mm) and lower portion of Cabot intake (90.5), far exceed the width of the spacing referenced by Moser et al. (2015) and likely allow for entrainment, rather than impingement of individuals that enter the area of influence for each intake. Moser et al. (2015) also states that impingement may be less of a problem where bypass screen gaps are greater than 10 mm, which describes all of the intakes at Northfield Mountain and Turners Falls Projects.
NMFS-5	*3.1.1 Potential Entrainment and Impingement Risk* The report mentions the critical swim speed Ucrit. We recommend that the licensee determine the median time a fish spent milling in front of the forebay. This time should be used to determine Ucrit.	Ucrit is a measure of the ability of the a fish to maintain a rate of speed for a certain amount whereas milling describes random, low energy movement patterns in no one particular direction. It is unclear how median milling time is related to or can be used to determine Ucrit.
NMFS-6	*3.1.1 Potential Entrainment and Impingement Risk* The report states that the potential for entrainment was assessed through comparison of swim speed capabilities and mean intake velocities at full generation. However, mean intake velocity does not take into account velocity hot spots due to debris accumulation. The report continues to assume that smaller fish with body widths less than the trashrack bar spacing would not be susceptible to entrainment. We recommend this assumption be modified such that total length and body width are taken into account.	Depending on fish size and swimming capabilities, impingement and entrainment risk likely increases at hotspot velocity areas for those fish that enter the area of influence. USFWS incorrectly commented that the report assumes that smaller fish with body widths less than the trashrack bar spacing would not be susceptible to entrainment. The report actually assumes that smaller fish with body widths less than the trashrack bar spacing would in fact be susceptible to entrainment but not impingement. For nearly all species, if the body width does not permit entrainment, then surely body length would also preclude the potential for entrainment.
NMFS-7	*4.1, Resident Fish* The entry for American shad in Table 4.1-3 is for juveniles only; no data are presented for entrainment of adults.	As indicated in the methods, Table 4.1-3 was based on fish species and sizes observed during the 2015 Fish Assemblage Assessment (Study No. 3.3.11). As no adult shad was observed, the species was omitted from Table 4.1-3.
NMFS-8	*4.2.1 Adult American Shad* The results indicate that five confirmed dead fish were found that passed via the Cabot Powerhouse resulting in 20.8% mortality. If the assumption is made that unaccounted for adult shad perished in the turbines, then the mortality rate could be as high as 62.5%. The report states that 50% of the shad detected at the intake left the area and continued upstream migration within 37.6 hours. This suggests that at least half the population experiences a day and a half of delay at the Project.	There is no basis for assuming that fish undetected exiting the canal perished in the turbines.
NMFS-9	*4.2.2 Juvenile American Shad* The reported 1 hour survival rates for downstream migrating juvenile shad for the smaller Francis units at Station No. 1 were 67.8% and 76.6%. Such results indicate that the project is not providing safe, timely and effective passage. Based on the 16 tagged fish that entered the canal and knowing that shad typically exhibit school behavior, we cannot draw any meaningful conclusions from the one fish that entered the Station 1 forebay.	Control mortality of juvenile shad was rather high; therefore, mortality due to turbine passage or the collection, tagging, and holding process cannot be differentiated.
NMFS-10	*4.3.1 Cabot Station* The first sentence in this section references a footnote that explains low, intermediate and high entrainment sensitivity. These qualitative risk assessments require further clarification. Entrainment mortality and injury can result from shear/turbulence, cavitation, pressure change or blade strike (Pracheil et al. 2016). Binned summed scores (e.g. 0-5, 6-10) do not provide a clear explanation entrainment risk given various ways passage via a turbine can injure a fish.	As discussed in the referenced footnote, each of five entrainment loss risk sensitivity categories were scored on a scale from 0 to 3 based on the results from Section 4.1. Entrainment mortality is but one of the five categories considered when charactering the relative risk of entrainment loss to populations of any given species. Table 4-3.1.1 summarizes scoring for all categories. The variable of turbine mortality was ranked as "Survival" (the inverse of "mortality"), and was assigned a tiered score based on the literature analysis in section 4.1 which accounts for the various origins of potential entrainment mortality, based on empirical study results gleaned for independent studies performed on an array of similar turbines. These species specific turbine survival rates varied; The footnote to table 4.3.1-1 details that survival estimates of 90-100% were given a risk index of 0, 80-89% received a score of 1, 70-79% received as score of 2 and survival rates of less

Commenter	Comment	Responses
		than 70% were scored as a 3. Thus fish with higher risk of an individual experiencing turbine mortality were assigned a higher index score than those demonstrating a lower risk.

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

Commenter	Comment	Responses
USFWS-1	Field Methods The early spawning survey targeted a period when water temperature ranged from approximately 7-14°C...a second survey was scheduled to coincide with water temperatures ranging from approximately 18-22°C." However, sampling only occurred May 4-6, 2015 and June 11 and 13, 2015. Thus, the consulting group sampled over 20 miles of river in only two days in the early-mid spring and again during two days in the late spring. Based on this limited sampling, sampling timing, and review of the provided results, the sampling regime likely failed to identify and evaluate all spawning areas throughout the reach.	The USFWS is incorrect. Sampling was conducted May 4-6 and June 11-13. This represents three days of sampling per event rather than two as stated. As noted in the report, discussed at the USR meeting, and also documented in study 3.3.14, a significant linear distance of the upper TFI littoral zone is dominated by fine substrate with little cover or structure to support spawning. Although the TFI is 20 miles long, much of the shoreline is barren of spawning habitat, and thus the isolated locations where spawning structure existed were limited. The survey boat traversed all littoral zone areas at approximately walking speed (*i.e.* 3-4 MPH) which allowed the survey crew to investigate the littoral zone for evidence of fish spawning, and detect areas with suitable spawning habitat. The survey boat stopped to survey each area where spawning habitat or evidence of spawning was found. Therefore a 3-day survey was adequate to visit all such sites on each occasion. The RSP states that "*.. the field survey effort will be scheduled to* ***maximize potential observations*** *of different species spawning activities*." Therefore the goal was to identify as many spawning sites as possible. There was no requirement to "identify and evaluate **all** spawning areas".
USFWS-2	Field Methods Additionally, in the final study report, the littoral zone is defined as "a general guideline to be the area extending from the edge of the water line at the shore at the time of the survey, out to a depth of approximately six feet to the extent that observable characteristics of the littoral zone varies with water clarity, water level, time of day, and the prevailing weather conditions." However, in the RSP and USR, *this* criterion was not included or defined. This definition of the littoral zone is problematic, as it discounts reoccurring drawdowns. The impoundment is known to fluctuate up to 9 feet as a result of project operations. At a minimum, the littoral zone should be defined as the regular high water mark out to the maximum drawdown depth of 9 feet. Further, the USR states that "to the extent practical, the physical surveys sought to document potential spawning habitat across the full range of licensed water surface elevations of 176.0 to 185.0 ft msl." In the final study report, it is unclear how this was accomplished at each site, especially considering the minimal sampling effort involved.	According to the RSP, "*the stakeholders agreed to focus the study on the zone of reservoir fluctuation (i.e., 176 to 185 ft msl) and shallower areas (less than 1 foot deep) at low pond elevation,* ***if practical in the field***". Field data on spawning bed elevations were gathered at ambient water elevations available under dynamic conditions. The water surface elevations during the survey periods (as measured at Turners Falls Dam) ranged between 180.9 to 182.3 ft, which is close to the long term median of 181.3 ft. As noted on field sheets, ambient turbidity permitted observations at depths of up to 6 ft. This facilitated viewing spawning to a depth within the littoral zone down to approximately 175 ft. Nest elevations observed in this study were detected as low as 177.5 ft. Habitat suitability of potential spawning sites located above the water levels present during the time of the surveys were also evaluated, such as emergent riparian weed beds at sites 003, 010 and 017.
USFWS-3	Results This section references Appendix A, which includes data sheets from the early and late spring spawning surveys. However, the provided sheets only list sites 001 to 006, not sites 008 to 017. The Service requests that the appendix be updated to include all data sheets. Moreover, within this section and throughout the text, sampling dates should be changed to accurately reflect the dates surveying was performed (i.e., May 4-6, June 11 and 13). As currently written, the text implies that sampling was also performed on June 12, which does not appear to be correct based on the provided data sheets.	Sampling was conducted at sites 008 to 017 on May 5-6. These data sheets were inadvertently omitted from the study report. Omitted data sheets area attached in Attachment A (Study 3.3.13). Early spring surveys were conducted from May 4-6, 2015, and late spring surveys were conducted from June 11-13, 2015. An initial attempt to commence the late spring survey on June 1 was aborted and delayed to mid-June due to the onset of heavy rain and unsafe high flows. Surveys were conducted on June 12, 2015 of the middle section of the TFI; however, no spawning sites were found in the areas surveyed that day.
USFWS-4	Discussion The Service notes that, based on the modeling of historic Turners Fall Impoundment (TFI) water surface elevations, sites surveyed along the length of the River are impacted and dewatered as a result of peaking and NMPS pumping operations. Even brief dewatering can cause egg and larvae mortality. While the steady and unsteady state graphs provided in Figures 4.3.2-1 to 17 and 4.3.4-1 to 15 graphically depict project-influenced dewatering, the report write-up does not explicitly draw these conclusions and instead focuses only on specific sites that were adequately submerged.	The report section 5.3 discusses a number of sites that are submerged to varying degrees of time during a typical spring cycle. This provides a risk index showing that sites that have a lower submergence probability are more at risk to dewatering than sites that are calculated to be submerged a majority of the time and thus such impacts are in fact identified. For example, the report states that "*Site 1 and Site 10 are submerged about 50% or less of the time during April and May….Site 10… is submerged about 60% of the time … therefore is not consistently usable*."
USFWS-5	Discussion: Potential Impacts of Project Operations on Nest Abandonment, Spawning Fish Displacement and Egg Dewatering Within the text identifying the impacts of project operations on late spring spawning, there is a section that states "should TFI elevation rise following nest construction, the increased depth did not appear to prohibit spawning and nesting success was not affected." Based on the past and present tense used in this sentence, it is unclear if this was actually observed, and it seems unlikely that it could have been based on the limited duration of sampling along 20 miles of river. A rapid rise in water elevation has the potential to severely impact the spawning activities of a variety of fish species, resulting in eggs or fry being washed away. If there was a direct observation of "no impact to spawning and nesting success" as the TFI increased, these details should be provided in the final study report. Otherwise, this conclusion is just conjecture and should be removed from the report.	The referenced "no impact" conclusion was drawn from an application of depth criteria curves from cited habitat suitability literature to depths that would result from an increase in impoundment depth. The criteria show that in the cited examples the increase in depth does not exceed the depth tolerance for the nesting species being discussed. The concern about eggs or fry "being washed away" would result from increases in velocity, rather than depth. The study used actual water level elevation data and TFI hydraulic model output to describe changes in water depth in relation to spawning sites.

Commenter	Comment	Responses
MADFW-1	Study Area It is stated that "the areas typically wetted when the TFI is at the upper range of its WSEL (185.0 ft) were also observed to evaluate potential spawning habitat". Data sheets provided show that surveys took place at WSELs between 180 and 183.5. Why were no surveys conducted at the low pond level (176) to see if any spawning areas were dewatered?	See USFWS-2. Lower pond elevations did not occur at during the survey season. According to the RSP, "*the stakeholders agreed to focus the study on the zone of reservoir fluctuation (i.e., 176 to 185 ft msl) and shallower areas (less than 1 foot deep) at low pond elevation, **if practical in the field***". As noted on field sheets, ambient turbidity permitted observations at depths of up to 6 ft. This facilitated viewing spawning to a depth within the littoral zone down to approximately 175 ft.
MADFW-2	Field Methods It is unclear how much detailed observation and study could be completed as the consultants surveyed over 20 miles of river in only three days on each of two sampling events (early season and late season). One would assume that objective 3) "evaluate potential impacts of impoundment fluctuations on nest abandonment, spawning fish displacement, and egg dewatering" would require systematic sampling of known nesting and spawning areas at a variety of impoundment elevations (as was done in the Sea Lamprey spawning study).	The potential and actual spawning locations were mapped in the field and elevations of each site were collected. The elevations of the spawning locations were then compared to actual and modeled water surface elevations at each location to determine potential impacts.
MADFW-3	Potential Impacts of Project Operations on Nest Abandonment, Spawning Fish Displacement and Egg Dewatering This is the important part. With a maximum allowed reservoir fluctuation of 9 feet there must be large sections of littoral habitat that are potentially dewatered daily. Any eggs exposed to air are lost, but what about the loss of *potential* spawning habitat? Maybe fish do avoid nesting in the regularly dewatered area- but the loss of this area for spawning is a project related effect. Data are reported as % of time that potential spawning areas are submerged adequately. This is insufficient data unless the timing can be correlated with spawning. Unless the time the areas are adequately submerged is the time the fish are spawning it is not important. These must be some way to represent this in a table or graph.	The study collected empirical observations of spawning under ambient field conditions as well as potential spawning areas within the zone of allowable reservoir fluctuation. For example, the study identified areas of emergent riparian vegetation that were all or partially above the ambient water line during the survey that could potentially support northern pike or yellow perch spawning. These were duly documented and discussed. The percentage of time a site is submerged (or conversely, dewatered) provides a relative risk index showing that some sites that have an inherently lower submergence probability than other sites that were shown to be submerged a majority of the time based on the reservoir elevation model.
CRWC-1	The RSP to this study listed one of the specific objectives as, "delineate, qualitatively describe…, and map shallow water habitat types." The report shows a map with dots for nesting spots identified, but no delineation of habitat types.	Section 5.2 of this report qualitatively describes the shallow water habitat types and the referenced map identifies actual spawning locations and potentially suitable spawning habitat for the littoral zone fish species that were the subject of this study. Shallow water habitat types were mapped and profiled in detail in the report for Study No. 3.3.14 (*Aquatic Habitat Mapping of Turners Falls Impoundment*).
CRWC-2	The RSP had many maps showing the study area for this study (Figures 3.3.14-1, Pages 1 through 23[we think the numbering should have been 3.3.15-1]). It appears that the entire study area could not have been covered in the two field days devoted to this effort in May and then June.	See response to USFWS-1.
CRWC-3	Task 2 of the RSP indicates that FirstLight was supposed to observe tributaries identified in Study 3.3.17 as accessible during spawning seasons. The report says they looked at "major" tributaries and list a few by example, but it is unclear if Study 3.3.17 was consulted in any way.	Tributaries were viewed; those with observed evidence of spawning were documented.
CRWC-4	The second paragraph of Section 3.1 in the Study Report said the littoral zone was considered to be the area extending from the edge of the water line at the shore of the time of survey to 6 ft in depth. Relying on 6 ft of water during the field visit is a little odd, since water level fluctuated by 2 ft or so during a field day. Also, the RSP maps show some potential littoral areas in the middle of the river. Did the field crew confirm that those areas were not good candidates?	See response to USFWS-2. "Off shore" littoral areas were assessed. Specifically sites 002, 004 and 101 appeared to either have evidence of spawning or have potentially suitable spawning substrates.
CRWC-5	The raw data sheets in Appendix A only contain sites 001-006 for the early spring surveys. Sites 8-17 were not included.	Sampling was conducted at sites 008 to 017 on May 5-6. These data sheets were inadvertently omitted from the study report. Omitted data sheets area attached in Attachment A (Study 3.3.13).

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

Commenter	Comment	Responses
USFWS- 1	1.1 Background The report states that "according to the United States Fish and Wildlife Service historic fish count data, the number of sea lamprey passing upstream of the Holyoke Dam and Turners Falls Dam has remained stable in recent years." This statement is misleading and it is unclear what "recent" means. Viewing Figure 1.1-1, to which the text references, it is evident that there have been considerable fluctuations in the population since recording began in 1975, with a sharp decline from over 100,000 lamprey in 1998 to 20,000 in 2000. Additionally, between 2000 and 2012, there was considerable variability in lamprey counts ranging from 15,000 to 75,000. In the past 3 years (2013-2015), lamprey counts were just over 20,000. Thus, the language in this section should be changed to reflect the considerable variability in sea lamprey counts and the relatively low number of sea lamprey in the past 3 years, compared to historical levels.	This paragraph was rewritten: The historic count data of sea lamprey passing upstream of the Holyoke Dam began in 1975 and is displayed in figure 1.1-1. Overall, the mean annual count is 33,598 with a maximum annual count of 101,758 in 1998 and a minimum annual count of 14,089 in 2012. In the last three years (2013, 2014 and 2015) the number of sea lamprey passing Holyoke Dam has been very consistent with 22,092; 22,136 and 22,245 counted, respectively. However, in years prior to 2013 there has been a considerable amount of year to year variability with a wide range of fluctuations. From 1998 to 1999, the amount of lamprey counted at Holyoke dropped from 101,758 to 21,000. In 2002, the number of lamprey was 73,491 and dropped to 17,636 by 2006.
USFWS-2	*2.1.5 Hatfield S Curve below Route 116 Bridge-below Cabot Station* The beginning of this paragraph states that "there were no lamprey redds located at these locations during the initial spawning survey" and then later it is stated that "there were four lamprey redds monitored at this location." Is the latter portion referring specifically to the gravel bar on the eastern bank of the River? As written, this entire section is difficult to follow. The last sentence reads "Redds were monitored below the Route 116 Bridge because they were the only redds located in the mainstem of the river below Turners Falls Dam during the spawning survey." The Service requests that this section is rewritten to accurately and clearly reflect lamprey spawning site information.	The initial survey for lamprey redds was conducted from Vernon Dam to the Route 116 Bridge in Sunderland and focused on historically known Lamprey spawning locations. In the initial search, the study team did not locate any redds between Cabot Station and the Sunderland Bridge. To further pinpoint spawning locations, the study team mobile tracked radio tagged Lamprey. Using mobile tracking, the study team was still unable to locate any redds between Cabot Station and the Route 116 Bridge. The study team continued to search further downstream of the Route 116 Bridge and mobile tracked a lamprey to the Hatfield S Curve location. Upon further inspection, there were four redds located on the eastern bank of the River of the Hatfield S Curve area. These redds were used as the only monitoring site below Cabot Station even though the location was a slight variance from the study plan.
USFWS-3	3.4 Mapping 3.4.1 Suitable Habitat Habitat Suitability Index (HSI) values ranging from 0 to 1 were defined for depth, velocity, and substrate. Each HSI value indicates how close the habitat is to the species' optimal conditions, with higher values representing the most suitable areas. The referenced HSI curves were developed based on information available at the time of study plan development. However, the results of this study indicate that lamprey utilized habitat with coarser substrate and greater depths than those in the referenced HSI curves. This is primarily due to the fact that the information used to develop those curves was from studies on smaller streams than the habitat evaluated in this study. The referenced curves indicated a suitability index of 0.5 for cobble and 1.0 for gravel, suggesting that gravel is a more suitable spawning substrate than cobble. However, cobble was the dominant substrate at spawning sites monitored in this study. Likewise, spawning was most prevalent at depths that far exceeded the HSI curve-identified preferred depths of 0.79 to 1.12 feet and a maximum depth having any habitat value of just 2.3 feet. In this study, spawning was identified at depths from 0.6 feet to 8.8 feet, with the mean depths at the five identified sites ranging from 1.91 to 4.59 feet. Based on these study results, we believe that FL should consult with the Service and other parties to modify the HSI curves for use in this study as well as Study No. 3.3.1 *Instream Flow Studies in Bypass Channel and below Cabot Station*. The existing curves are likely underrepresenting how much suitable sea lamprey habitat exists and where, and potentially affect the evaluation of the impacts of project operations. Once new curves are agreed to, the analysis of lamprey habitat will need to be repeated using the revised curves.	We agree that the referenced HSI values used to develop suitable habitat mapping were not consistent with our findings during the 2015 study period. Lamprey spawning habitats assessed during this study consisted mostly of cobble dominated substrates and depths outside of the range used to map suitability. However, it is outside of the scope of this study to revise or quantitatively modify the HSI curves. Observational data collected in this study can be used to interpret IFIM results for Sea Lamprey.
USFWS-4	*3.4.1.1 Turners Falls Impoundment* The discussion in this section refers to running the TFI model under one operation/flow condition, with the TFI at only one elevation level: the median impoundment level for May and June based on historical data from 2000 to 2015. Since the pond fluctuates, the median level does not represent the actual conditions under which lamprey select spawning habitat. This is addressed in our comments on Section 4 Results below.	Mapping suitable habitat using data from the Hydraulic model was not in the approved study plan. The objective was to "identify areas within the Project area where suitable spawning habitat may exist for adult Sea Lamprey." We decided to develop one map of suitable habitat in the TFI which required the use of HSC and the Hydraulic model data in conjunction.
USFWS-5	3.5 Effects of Project Operations To accurately assess the effects of project operations on sea lamprey spawning activity, FL should provide operational data from Vernon, TF, and NMPS projects as well as inflow data on the Ashuelot and Millers rivers during the study period. Twenty-nine redds were GPS-located and revisited weekly for monitoring, however we are concerned that redds were not checked more frequently, as there may have been times between collections when the nests were dewatered. Providing operational and inflow data and relating it to observed redds will allow stakeholders to more accurately ascertain project effects.	Operational data from Vernon, TF, and NMPS projects as well as inflow data on the Ashuelot and Millers rivers during the study period exists in graphical form in section 4.5 of the report. Operations Data is attached: Attachment A(Study 3.3.15)

Commenter	Comment	Responses
USFWS-6	4.0 RESULTS 4.5 Site Specific Habitat Measurements The figures for site-specific habitat measurements, on pages 43-47, identify the need for additional data. For example, Figure 4.5.1 shows Vernon Dam discharge from June 10 through June 17 as well as depth and velocity on various sampling dates. Discharge throughout this time period is highly variable, however sampling coincides with increased discharge and there are no sampling dates that coincide with low flows. Specifically, it is worrisome that no sampling occurred around the time of July 5, when discharge was most variable and velocity decreased to below 1 foot/second. Sampling should have coincided with low discharge periods when nest stranding is most likely. Additionally, Figure 4.5-3 shows the Millers River discharge but fails to include TFI backwatering and NMPS-related fluctuations. In addition to these concerns, June 2015 was an unusually wet month and overall the data in this study is not representative of historic in-river conditions. At the October 31, 2016 study report meeting, FL indicated that they may be able to utilize the hydraulic model to address the concerns we state above and determine if nests were inundated or exposed under the full range of operating conditions. This additional analysis should be performed to assess the full range of potential project impacts based on the range of flow and elevation conditions that can occur during the lamprey spawning period, not just conditions that occurred during the 2015 sampling. Revised results should be included in a revised final study report.	The comment should read, "…discharge from June 10 to July 17" Sampling was done at random, multiple times per week as per the Study plan. In other words, we did not plan our sampling around high/low/med discharge days. To our knowledge there is no hydraulic model data or bathymetry data for the tributary sites, therefore it is not possible for us to examine the exposure/inundation of these redds in relation to operations in the same manner as we did for the Stebbins Island sites.
NMFS-1	**General Comment:** This study found Sea Lamprey spawning redds in the following locations: the Ashuelot River, near Stebbins Island, near the Millers River confluence with the Mainstem Connecticut River, Fall River, and the Hatfield S curve. The stated goal of this study was to determine whether Project operations adversely affected spawning activity. Based on the initial findings of identified redd locations, the Fall River site should have been the spawning location receiving the most frequent visits. However, Project operations routinely affect the amount of water that is spilled, hence the hydraulics at the Fall River site are affected by project operations.	The RSP did not state that one site should receive more visits than any other site. The hydraulics at the Fall River are affected by project operations; however, based on the criteria in the study plan: - **No effect(**no observable difference to habitat/redd structure or lamprey activity) - **Moderate effect**(observable difference to habitat/red structure and/or behavior noticed but normal spawning occurs) - **Large effect**(observable structural differences to habitat/redds and observable decreased spawning activity) - **Severe effect**(noticeable habitat/redd degradation, dewatering, scour, and no successful spawning) It was concluded that the Fall River site experienced no effect from project operations even with the potential for backwatering. The reason for this conclusion is based off the criteria above, there were never any observable differences to the habitat or redd structure and lamprey activity in the Fall River was very apparent. On top of that, it was one of the two sites where we captured an ammocoete suggesting that it was indeed a successful spawning site. Backwatering and increased depths did not seem to impact the behavior or spawning Lamprey in any way throughout this study.

Commenter	Comment	Responses
NMFS-2	**Specific Comments** **Section 4.5 Site Specific Habitat Measurements** *Millers River Redds* The report states: "The WSEL in the lower reaches of the Millers River is influenced by inflows to its watershed, by the level of the TFI, Northfield Mountain operations (pump and generation scenarios), and Connecticut River flows. The redds that were located in the Millers River and any variations in depth and velocity were only due to discharge at the Birch Hill Dam rather than Project operations." Based on this statement, the data collected at these redds are not contributing towards the stated study goals which is to determine project effects on spawning activity. We recommend the report include a map of the Turners Falls impoundment, the spatial extent of project backwater effects in the Millers River due to fluctuating water surface elevations and a detailed location of the observed redds in the Millers River. *Fall River Redds* The report states: The extent of the Fall River confluence and the amount of backwater experienced is influenced by spillage at the TFD. The FirstLight relicensing Study No. 3.3.17 determined that Connecticut River backwatering effects can extend approximately 250-300 ft upstream into the Fall River. In the 2015 monitoring period, the capped redd in the Fall River was located approximately 195 ft upstream of the confluence, which is within the range susceptible to backwatering depending on mainstem conditions. Figure 4.5-4 clearly shows that as discharge at the dam increases, the depth increases at the Fall River redds and the water velocity decreases due to backwatering. Based on this information, this redd should have received the most field visits. Because Turners Falls is a peaking operation project, dam releases can change dramatically which in turn affects the hydraulics at the Fall River redd site. While figure 4.5-4 provides valuable information, the report needs to more fully explain when and how much depths and velocities are being affected by dam releases. Based on already collected existing data, we recommend the report include 1)the percent of time the redd experienced a backwater condition due to dam releases and (2) information on how rapidly dam releases either created a backwater effect or how rapidly decreased dam releases affected depths and velocities at the redds.	The statement highlighted in green fails to include the sentences that follow in the report, thus it is out of context. The following sentences read.. "Since there were no large fluctuations in depth or velocity, nor any observed differences to redd structure or lamprey activity throughout the study, the influences listed above are considered negligible on the Millers River Lamprey spawning habitat." According to Study 3.3.17, the influence of TFI backwater in the Miller's River extends roughly 1,000+ft from the confluence, "to a high gradient riffle in the Millers River." Our redds were located approximately 1,000 ft upstream of the confluence at this exact riffle location, therefore most hydraulic influence was due to the Birch Hill Dam as observed in Figure 4.5-3. The report already includes a map of the TFI and detailed locations of the observed redds in the Millers River. To our knowledge there is no hydraulic model data or bathymetry data for the tributary sites, therefore it is not possible for us to map the spatial extent of project backwater effects in the Miller's River or Fall River. See Study 3.3.17 for spatial extent of backwatering based off observations. See response to **NMFS-1** above
MADFW-1	5.3 Suitable Habitat The results of this study show that Sea Lamprey spawn in a wider variety of substrate and flow than the HSI curves used would suggest. Given these results- it may be prudent to adjust the HSI curves before FL uses the results of the Instream Flow Study to calculate Sea Lamprey spawning habitat below the TF dam.	See response to **USFWS-** 4 above
MADFW-2	5.4 Effect of project operations on Spawning Habitat The report describes using the impoundment hydraulic model to input flows known to have occurred during the lamprey nesting season in 2015- no dewatering was expected to occur. The report should also analyze the potential for dewatering based on all possible permitted operational flows. They could also model "typical operations".	See response to **USFWS-6** comment located above
CRWC-1	The FERC Study Plan Determination dated February 21, 2014, stated on page B-71,…"we recommend FirstLight not limit its detailed monitoring to only 25 redds, but utilize all survey data, including the location and depth of suitable habitat and redds, for comparison with results of the hydraulic model in study 3.2.2. FirstLight should then determine if spawning areas/redds are subject to dewatering and describe the degree of project-related water level fluctuation at each spawning site." The hydraulic model was used only to confirm that during the period from June 19 to July 10 that the observed redds were not dewatered. This is a single year of data when flows during this period were generally high. Redd locations observed during the study and all suitable habitat should be evaluated using a low flow year.	See response to **USFWS-6** comment located above
CRWC-2	Because FirstLight did not adequately use the hydraulic data, we do not concur with the conclusion that there is no project effect at all spawning sites in the study. For comparison, Table 5.3-3 in TransCanada's Study 16 showed that some of the sea lamprey nests near Stebbins Island were exposed 5% of the time. There was nothing like that in the FirstLight observations.	We disagree that the hydraulic data was used inadequately. The data was used to determine if any lamprey nests around Stebbins Island were exposed during the study period. TransCanada's study showed that some of the sea lamprey nests near Stebbins Island were exposed "during post-spawning season low-water surveys." We also want to note that we did not survey the same nest locations as TransCanada, there are several possible nesting areas around Stebbins Island. If needed, we can assess dewatering of nests around Stebbins Island for pre and post-spawning season, this will have to be addressed in an addendum.
CRWC-3	Depth and velocities from field notes when sea lamprey were observed on redds should be used to revise the Habitat Suitability (HSI) Curves. Revised HSI curves should then be used to revise habitat mapping.	See **USFWS-** 4 above

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

Commenter	Comment	Responses
USFWS-1	Shear Stress and Relative Shear Stress GSE states that the Delphi panelists concurred with GSE's proposal to not develop specific HSI values for SS and RSS, given that using simple metrics like velocity, bathymetry and substrate would fail to account for factors such as substrate cohesion, vegetation, embedded organic material, biofilms and macroinvertebrates that help stabilize substrates and limit the effects of shear at the streambed. As noted in our comments on appendices B, C and D, we can find no documentation that the panelists agreed with GSE's rationale for excluding those parameters from curve development. In addition, at the October 31, 2016 study report meeting, GSE disclosed that one of the Delphi panelists had provided input on the SS and RSS technical memo sent out by GSE to the Delphi panel for its consideration. As such, one of the panelists was asked to deliberate on a document that he had helped develop. This presents the appearance of bias. Either none or all of the Delphi panel should have had input on the technical memo.	All of the email correspondence with panelists is included here as Attachment A (Study 3.3.16). See responses from panelists B. Wicklow (4/27/2016), C. Loftin (5/11/2016), and D. Strayer (6/1/2016). Developing suitability criteria mussels is a novel approach and is biologically difficult challenge FL tried to accomplish with an open and collaborative process, using both expert opinion (from all panelists) and continual feedback from NHESP on the Delphi questionnaire, responses from participants, and the memos related to the most challenging parameters. All experts were asked to provide as much information as they could on each parameter; some provided more than others, and part of FL's effort was to summarize everything about shear stress and mussel biology for everyone to review...and that became part of the FERC record. This was not conflict of interest or deception; it was one of panelists serving their role as an expert panelist trying to develop habitat suitability criteria. If another panelist had drafted the exact same memo, or a similar memo on some other key parameter, or simply shared an existing thesis or manuscript relevant to our challenge, all panelists and FL would have welcomed it because it would help increase our understanding and further our goals. In either case, other panelists, NHESP, and any one of the stakeholders would have access to the information. Indeed, as MADFW has suggested, all Delphi panelists had the opportunity to review and comment on the technical memo. Notwithstanding the issues identified in the screening level analysis for shear stress and substrate, if there is a specific reason why this caused bias, we fail to see it.
USFWS-2	GSE posits that it is high flows that are most likely to influence SS and RSS, which GSE says are well outside of the operating range of the Turners Falls Project. Based on coarse-scale data for Reach 5, GSE calculated a high RSS value of greater than 5 for a relatively low 1.5 year flood flow and used this to suggest that RSS may not be meaningful because, although Reach 5 had high RSS values for typical high flows (suggestive of unsuitable habitat), that reach also has beds of yellow lampmussels that are not in apparent decline. At the October 31, 2016 study report meeting, Massachusetts Natural Heritage and Endangered Species Program (NHESP) staff pointed out that by focusing only on natural high flow, GSE did not provide an opportunity for the Delphi panel to evaluate RSS results for flows within the project's operational range. Therefore, it was premature for a decision to be made on whether SS and RSS should be omitted from curve development. The Service agrees, and recommends that GSE conduct a similar coarse-level analysis of RSS at flows within the project's operational capacity (e.g., RSS at both minimum and maximum generation).	FL will perform additional screening level analysis of shear stress parameters at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1).
USFWS-3	Appendix A We note that on February 2, 2016, Dr. Peter Hazelton of the NHESP sent an electronic message to GSE providing several suggestions based on his review of the Round 1 Delphi materials. One of the suggestions was to not use a composite HSI for all three species and both life stages; rather, habitat modeling should be conducted separately for each species and life stage. However, upon review of Study Report 3.3.1, it appears that composite HSI curves were used: one for yellow lampmussel juvenile, Eastern pondmussel juvenile and adults, and tidewater mucket juveniles, and the other for yellow lampmussel and tidewater mucket adults. While some of the final curves were identical (e.g., benthic velocity and depth for adult yellow lampmussel and adult tidewater mucket), others were not (e.g., particle size differed among juvenile yellow lampmussel, juvenile Eastern pondmussel and adult Eastern pondmussel). GSE should provide an explanation for not adopting NHESP's recommendation to develop separate HSI curves.	As presented in Tables 3-1 and 3-2 of the report, the binary HSI scores were presented separately for both adult and juvenile lifestages of the three Massachusetts state-listed mussel species. The HSI for several species and lifestages were composited for the analysis in the IFIM Report because the only difference in the criteria was substrate for yellow lampmussel juvenile, Eastern pondmussel juvenile and adults, and tidewater mucket juveniles. In the IFIM report, it assumed that all substrate in Reach 5 was suitable for all species and lifestages, so composite HSI were used. Now that more detailed substrate data has been obtained by FL in Reach 5, FL will apply the HSI for all species and lifestages separately when performing additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1).
USFWS-4	Appendices B, C and D: Delphi Panel Materials, Rounds 1 through 3 Appendix B provides the scoring sheet for the five selected parameters that would be used to develop HSI curves: velocity, depth, particle size, percent cover, SS and RSS. Appendix C includes summary scores for those parameters, based on feedback from the panelists, as well as a supplemental table where some of the scores (e.g., substrate, cover and particle size for yellow lampmussel ; depth and cover for eastern pondmussel; and velocity, depth and cover for tidewater mucket), were overridden by the moderator. This decision seems to run counter to the Delphi process. While the moderator solicited input from the panelists on these deviations, it does not appear that any of the comments provided directly address the deviations. GSE should clarify whether there was consensus among the	According to the methods used to develop the HSI criteria (Crance 1987), the medians of estimates provided by the experts for each variable and life stage were used as coordinates for the preliminary SI curves. Because the end goal was to develop binary suitability, the score was to be either 1.0 or 0.0. Areas of disagreement were identified and highlighted. For Round 2, FL asked that panelists review the individual scores, proposed binary scores, and the moderator's notes on the proposed HSI curves and panelists were asked to provide specific recommendations and rationale for any further adjustments. The rationale for departure was clearly explained in the scoring sheets and the panelists agreed on the final HSI values. All of the email correspondence with panelists is included here as Attachment A (Study 3.3.16).

Commenter	Comment	Responses
	panelists regarding the deviations and provide documentation supporting that consensus.	
USFWS-5	GSE's reasoning for modifying the scores for depth was that shallow water is unsuitable due to risks of desiccation, predation, etc. However, one of the panelists noted that both the eastern pondmussel and tidewater mucket have been found in very shallow water (centimeters deep). While there may be risks to residing in shallow water, there also may be benefits (e.g., increasing the chance of host fish interaction). In addition, underestimating suitability at the shallower depths would yield results that underestimate project-related operational impacts of water level fluctuations. The Service recommends that the depth HSI curves for all three species be adjusted to comport with the composite suitability score calculated based on the panelists' input.	For the final binary HSI values, the conclusion of the Delphi Panel is that depths greater than 10 cm (0.33 feet) are considered suitable and depths less than 10 cm are considered unsuitable for all species. This comment is contrary to suggestion of MADFW (see comment MADFW-10).
USFWS-6	Round 2 results show that the panelists appeared to have fairly consistent scoring with respect to the SS and RSS parameters and the comments they provided suggest they think these parameters are important to freshwater mussels. Further, the additional comments panelists provided in Round 3 in response to GSE's February 11, 2016 memo indicate they do not support the conclusions of the memo. We recommend that GSE either provide documentation showing that there was consensus among the panelists regarding the decision to not develop curves for SS and RSS or, if consensus was not reached, use the scores provided by the panelists to develop SS and RSS curves.	All of the email correspondence with panelists is included here as Attachment A (Study 3.3.16). See responses from panelists B. Wicklow (4/27/2016), C. Loftin (5/11/2016), and D. Strayer (6/1/2016). FL will perform additional screening level analysis of shear stress parameters at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1).
USFWS-7	Lastly, we recommend reformatting the panelist comments to more clearly identify which comments were provided by which panelist during each round.	According to the methods used to develop the HSI criteria (Crance 1987), the primary characteristic of Delphi is anonymity. All of the email correspondence with panelists is included here as Attachment A (Study 3.3.16), but the scoring was presented to preserve anonymity.
MADFW-1	Shear Stress and Relative Shear Stress FL stated that the Delphi panelists concurred with FL's proposal not to develop specific HSI values for SS and RSS, given that using simple metrics like velocity, bathymetry and substrate would fail to account for factors such as substrate cohesion, vegetation, embedded organic material, biofilms and macroinvertebrates that help stabilize substrates and limit the effects of shear at the streambed. The Division does not agree with FL's assessment of the Delphi panel's conclusions. As stated by USFWS in their comments, the development of SS and RSS suitability criteria were inappropriately dismissed by FL. Delphi panelist recommendations stated that SS and RSS may be among **the most** important habitat parameters for mussels and that it should be feasible to develop SS and RSS thresholds from existing case studies or existing, field-collected data. The importance of shear velocities and SS as factors in shaping freshwater mussel communities has been well supported in the literature (Hardison & Layzer 2001, Allen & Vaughn 2010, Daraio et al. 2010a & b, French & Ackerman 2014, Morales et al. 2006). Further, SS was identified by FL as an important parameter associated with mussel abundance and distribution in the Conowingo Project (FERC Draft EIS 2014, FERC/DEIS-0255D). The Division concurs with the Delphi Panel that modeling SS is an essential component to evaluating potential Project effects on state-listed mussels and has recommended SS thresholds for use in habitat suitability modeling (see *Developing Shear Stress Thresholds* section, below). Any proposed deviations from the suggested methods outlined below should be provided for stakeholder review and comment. We also recommend that the Division's suggested methods, any deviations proposed by FL, and any stakeholder comments on FL proposed deviations should then be provided to the Delphi Panel for review and comment.	FL will perform additional screening level analysis of shear stress parameters at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1). For clarification, FL had no involvement in the relicensing studies performed at the Conowingo Project.
MADFW-2	*High Flows:* FL posits that it is high flows that are most likely to influence SS and RSS, which it says are well outside of the operational range of the Project. Based on coarse-scale data for Reach 5, FL calculated RSS at greater than 5 for a 1.5 year flood event and used this to suggest that RSS in this context may not be meaningful because, although Reach 5 had high RSS values for typical high flows (suggestive of unsuitable habitat), it also has beds of Yellow Lampmussels that are not in apparent decline. At the October 31, 2016 study report meeting the Division stated that, by focusing only on natural spring high flows, FL did not provide an opportunity for the Delphi panel to evaluate SS for flows within the Project's operational range and that it was premature for a decision to be made on whether SS and RSS should be omitted from HSI curve development. We also recommended that FL conduct a similar coarse-level analysis of SS/RSS at flows within the Project's operational capacity (e.g., at both minimum and maximum generation).	FL will perform additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1).
MADFW-3	FL correctly cites Allen & Vaughn (2010) that "high flows" often outperform other parameters in predicting the presence and abundance of freshwater mussels. However, FL apparently misinterpreted the high flows modeled by Allen & Vaughn to mean flows greater than the 80th percentile (20% exceedance) and interprets these 80th percentile "high flows" (approximately 20,800 cfs or	The annual flow duration curve shows the 27th exceedance percentile equals 16,900 cfs.

Commenter	Comment	Responses
	greater) to justify their claim that the effects of flow on mussel habitat are outside the operational capacity of Station 1 and Cabot Station, which "*corresponds to approximately the 71 percentile or the 29 exceedence percentile*." Allen & Vaughn clearly state that the "*low and high flow levels corresponded to exceedances of 95.15 ± 0.99 and 27.02 ± 2.06, respectively.*" In other words, the high flows used in the Allen & Vaughn models represent the 73rd percentile or 27% exceedance values, which suggests that the Project's operational capacity is likely within the range of flows with the potential to affect mussel distribution and abundance.	
MADFW-4	Comparison of only flood stage or annual high flows are inadequate to understand Project effects on mussels within the Project area because it does not consider mussel phenology, the importance of sustained recruitment of juveniles in creating and maintaining healthy mussel populations, and Project alteration of flows during the critical summer months (see *Juvenile Mussels* section, below). Flood stage flows may indeed affect mussel distribution, but occur at irregular intervals and, as noted by FL, are well outside of the Project's operational capacity. In addition, mussels are adapted to seasonally fluctuating flows in unregulated rivers (FL memorandum to Delphi Panel). However, mean April flows (36,600 CFS, per p. 44 of Meeting Minutes from 10/31-11/1/2016) are not characteristic of flows during critical lifestage periods like the summer months, when juveniles are detaching from host-fish and seeking to settle and establish in suitable habitat. Therefore, it is critical that SS be modeled for summer months in order to understand the affect of Project operations during the key spawning and juvenile settling periods.	FL will perform additional screening level analysis of shear stress parameters at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1).
MADFW-5	The method FL used to calculate SS is unclear. In the memorandum given to the Delphi panel following Round 1, FL proposes that RSS is commonly greater than 5 but provides no explanation of how critical SS was measured. Were these critical SS values based on median bed particle sizes? Or did FL use data from previously established research (e.g., high flow SS thresholds described in Allen & Vaughn 2010, or previously used by FL in the Conowingo Project)? In their comments following Round 3 (PDF Page 54 of Study Report 3.3.16), Delphi panelists shared similar concerns that SS calculations were not being clearly articulated. We request that FL provide all equations and values used to calculate SS.	Shear stress and relative shear stress definitions were provided to panelists in Round 1 instructions. Calculations can be provided in any updated study report. For clarification, FL had no involvement in the relicensing studies performed at the Conowingo Project.
MADFW-6	*Juvenile Mussels:* To understand the effect of Project operations on state-listed mussels, it is critical to understand the nexus of natural, seasonal periodicity of flows and juvenile settlement. Once established, adult mussels are able to withstand higher flows due to their larger mass, ability to anchor/burrow into substrates, and overall contribution to bedload stability. However, the most sensitive lifestage to benthic velocities and SS is likely to be the early juvenile stage, especially during the settlement period (Daraio et al. 2010a & b, French & Ackerman 2015, Morales et al. 2006 & 2013, FL – comments from Delphi Panel). All three state listed mussels found within the Project area are considered long-term brooders (Haag 2012), and after spawning in late summer, adult females hold larvae through the winter and the following spring and summer. It is possible for these species to infect a host fish throughout most of that period. However, we know that attachment on fish hosts occurs during the summer months in New England (May – September; Kneeland & Rhymer 2008) for Yellow Lampmussel and Tidewater Mucket. Similarly, the time during which early juveniles are excising from host fish, being distributed by river currents, and settling into appropriate substrates is also likely during the summer months. In both cases, larvae and juveniles would typically be in the water column during lower, relatively consistent summer flows in an unregulated river. However, Project operations are creating consistently and abnormally high flows during the summer months. By creating elevated benthic velocities and SS levels, Project operations may affect the ability of juveniles to settle and establish within suitable habitat. Peaking summertime flows above a critical threshold may be causing recruitment failure within Reaches 1-4, where relic, adult Yellow Lampmussel shells have been found at multiple locations over the last 40 years (NHESP data, including but not limited to relic shell observations at First and Second Islands in 2007). This may also be the case in portions of Reach 5, where adult state-listed mussels have not been found north of river mile 99.269 (Twelve Year Summary Rare Mussel Survey Report 2003-2014, Holyoke Project FERC No. 2004). Indeed, the presence of adult state- listed mussels in the lower portions of Reach 5 does not necessarily indicate that these populations are self-sustaining because, if juveniles cannot establish at rates sufficient to offset adult mortality, these populations may not be able to persist in the long-term.	FL will perform additional screening level analysis at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1).
MADFW-7	*Developing Shear Stress Thresholds:* The Delphi panelists suggested that it should be feasible to develop SS thresholds from existing case studies or existing, field-collected data. The Division similarly recommends developing empirically derived SS thresholds from the literature sources, consistent with the following criteria:	FL will perform additional screening level analysis of shear stress parameters at transects in Reach 5, as discussed with USFWS and NHESP during a conference call on January 4, 2017; the meeting minutes and approach outlined by FL are included as Attachment A (Study 3.3.1).

Commenter	Comment	Responses
	Criteria 1: Juveniles of all three species, Criteria 2: Adult Eastern Pondmussel and Tidewater Mucket, Criteria 3: Adult Yellow Lampmussel Empirical SS thresholds for juvenile settlement have already been determined for juvenile Eastern Pondmussel and Eastern Lampmussel, which is closely related to Yellow Lampmussel. French and Ackerman (2014) found that there was a significant increase in SS tolerance in juvenile mussels that used either their foot or other mechanisms to adhere to substrate. They also found that juvenile mussels had a much higher Shields parameter (θ) and critical SS (τ_{crit}) than sediment of a similar size. In that study, the highest measured critical SS (θ = 1.5, τ_{crit} = 0.72 Pa) was lower than the previously determined 20 dynes/cm^2 (2.0 Pa) low-flow threshold identified by Allen & Vaughn (2010). The latter values were used by FL in modeling habitat suitability for mussels in the Conowingo Project. Therefore, for adult mussels the Division recommends a SS threshold (τ_A) of 150 dynes/cm^2. For juvenile mussels the Division recommends a critical SS threshold (τ_J) of 10 dynes/cm^2. These are at or near thresholds established by Allen & Vaughn (2010), and used by FL in evaluation of mussel abundance and SS associated with the Conowingo Project. Given that empirical evidence exists for juvenile critical thresholds below 10 dynes/cm^2, the Division feels that these thresholds are conservative estimates and take into consideration the fact that bed SS is often overestimated where detailed information is not available on bed roughness and substrate classes (Schwendel et al. 2010). Juvenile SS thresholds should be modeled during the period of June-October to most closely mirror the key spawning and juvenile settling periods; adult SS thresholds should be modeled for all months of the year. The Division recommends that FERC require FL to model SS for each transect cell in the data generated from HEC-RAS models, and calculate SS from field data where available. Modeled benthic velocities may be used to estimate SS as these velocities will be lower than the depth averaged velocity, and are likely a more accurate representation of shear velocity at the sediment interface (Schwendel et al. 2010). Bed SS should be calculated for each cell using the formula previously provided by FL in the Study Report. If τ_{BED} exceeds τ_A or τ_J, then the SS is unsuitable for adult or juvenile mussels, respectively, at that flow.	For clarification, FL had no involvement in the relicensing studies performed at the Conowingo Project.
MADFW-8	Appearance of Bias: At the October 31, 2016 study report meeting FL disclosed that one of the Delphi panelists had provided input on the SS and RSS technical memo sent by FL to the Delphi panel for its consideration and thus commented on by one of the authors of the technical memo. The Division agrees with USFWS comments that this presents the appearance of bias and that either none or all of the Delphi panelists should have had input on the technical memo.	Developing suitability criteria mussels is a novel approach and is biologically difficult challenge FL tried to accomplish with an open and collaborative process, using both expert opinion (from all panelists) and continual feedback from NHESP on the Delphi questionnaire, responses from participants, and the memos related to the most challenging parameters. All experts were asked to provide as much information as they could on each parameter; some provided more than others, and part of FL's effort was to summarize everything about shear stress and mussel biology for everyone to review...and that became part of the FERC record. This was not conflict of interest or deception; it was one of panelists serving their role as an expert panelist trying to develop habitat suitability criteria. If another panelist had drafted the exact same memo, or a similar memo on some other key parameter, or simply shared an existing thesis or manuscript relevant to our challenge, all panelists and FL would have welcomed it because it would help increase our understanding and further our goals. In either case, other panelists, NHESP, and any one of the stakeholders would have access to the information. Indeed, as MADFW has suggested, all Delphi panelists had the opportunity to review and comment on the technical memo. Notwithstanding the issues identified in the screening level analysis for shear stress and substrate, if there is a specific reason why this caused bias, we fail to see it.
MADFW-9	Appendix B, C and D: Delphi Panel Materials, Rounds 1 through 3 Appendix B provides the scoring sheet for the five selected parameters that would be used to develop HSI curves: velocity, depth, particle size, percent cover, SS and RSS. Appendix C includes summary scores for those parameters, based on feedback from the panelists, as well as a supplemental table where some of the scores (e.g., substrate, cover and particle size for Yellow Lampmussel; depth and cover for Eastern Pondmussel; and velocity, depth and cover for Tidewater Mucket) were overridden by the moderator. The Division agrees with USFWS comments that this decision runs counter to the Delphi process, that FL should clarify whether there was consensus among the panelists regarding proposed FL deviations, and provide documentation supporting that consensus. We similarly recommend that depth HSI curves for all three species be adjusted to comport with the composite suitability score calculated based on the panelists input.	See response to USFWS-4.
MADFW-10	The Division notes several deviances from the Delphi derived HSI scores that need further clarification. *Depth, All Species and Lifestages:* The Division agrees that depths less than 10 cm may predispose mussels to greater levels of predation and desiccation, and feels that this is an adequate limitation to be placed on depth.	This is consistent with the Delphi-driven HSI. This comment seems to contradict MADFW-9.

Commenter	Comment	Responses
MADFW-11	The Division notes several deviances from the Delphi derived HSI scores that need further clarification. *Suitable Substrate Classes, Yellow Lampmussel:* FL has overridden the Delphi mean scores to suggest that mud/clay are suitable substrates for Yellow Lampmussel, and supports this claim from observations throughout the species range. However, though FL has provided a list of studies and datasets that are available, they have not provided any data or data summary regarding habitat use for this species. If such data exists, then it should be possible for FL to calculate Category II or Category III HSI curves and not binary curves from expert opinion. If FL asserts that a class of substrate is suitable for mussels beyond what has been decided during the Delphi process, then FL should provide a thorough summary of the data used in that decision.	FL didn't override the scores, rather further clarified substrate classes from Round 2 to Round 3. Based on panelist comments, mud/clay was broken into separate classes as clay and mud/silt. As reflected in the final HSI criteria, clay was judged as unsuitable and mud/silt was judged as suitable.
MADFW-12	The Division notes several deviances from the Delphi derived HSI scores that need further clarification. *Percent Cover, All Species and Lifestages:* FL has asserted that there is "*no evidence to suggest that dense cover is unsuitable*" for any of the species. Although this may be true, it was the lack of data to construct data-driven Category II or III HSI curves that drove the use of a Delphi approach. The change of cover categories from unsuitable to suitable was also not consistent across species or lifestages, and no data or citations were provided to support what appears to be arbitrary changes in suitability. If such data exists, then why was the Delphi process required for Percent Cover? In lieu of data or citations to support FL's position, the Division requests that FL to utilize percent cover as it was a Delphi-driven parameter, even if this parameter is not used for modeling habitat suitability.	When developing the Round 1 questionnaire, cover type and percent were included as potential factor that would be important to mussels and solicited panelists input. The scores for percent cover were relatively uniform for the three target species. The Delphi-driven HSI criteria for cover were presented in the report.
CRWC-1	CRWC did not review this study report in detail, but we would like to point out that having the consultant who was hired to prepare the mussel report (Ethan Nedeau of Biodrawversity) also sit on the Delphi panel compromises the objectivity of the results.	See responses to USFWS-1 and MADFW-8.

Study No. 3.5.1 Baseline Inventory of Wetland, Riparian, and Littoral Habitat in the Turners Falls Impoundment, and Assessment of Operational Impacts on Special-Status Species (ADDENDUM)

Commenter	Comment	Responses
MADFW-1	USFWS-3 Puritan Tiger Beetle As previously requested in our comments (dated April 30, 2016) on Study Report 3.5.1, the Division requests that Figures 2.1-5 through 2.1-8, inclusive, be revised to include monthly mean and median WSELs (including standard deviations) for May – August. Although the Division acknowledges that river flows exceed the operational capacity of the Project during portions of the year, we also request that this data be provided for January – April and September – December in order to help assess potential Project effects on larval life stages.	In its addendum, FL modified the plots to exclude September as requested by MADFW. In reviewing MADFW's April 30, 2016 comment letter, FL did not see where MADFW requested Figures 2.1-5 through 2.1-8 be updated to also include the monthly mean WSEL or standard deviation (see page 16 of 26, item 2 under Puritan Tiger Beetle). In addition, MADFW is now requesting the same information for the January –April and September-December time frame, which was not requested in its April 30, 2016 letter. FL has already addressed MADFW initial comments to eliminate the month of September from the analysis, which was done as part of this addendum and proposes no further analysis.
MADFW-2	USFWS-3 Cobblestone Tiger Beetle FL surveyed six elevation transects at known Cobblestone Tiger Beetle (CTB) habitat in Montague and developed a digital terrain model of potential CTB habitat based on elevation/bathymetric data. FL used the calibrated hydraulic model to simulate WSELs at each location under actual conditions between January 1, 2008 and September 20, 2015. In the Addendum FL assessed the extent of available CTB habitat for corresponding WSELs, as well as the percent of time elevations are inundated (based on either 0.0 or 24.0 hours between May and August). In the MRSP, FL committed to using data provided by the hydraulic model to estimate the change in water surface elevation over a range of flows, and that the hydraulic model will illustrate the relationship between water surface elevation and flow at transects where tiger beetles are found. Therefore, we request that FL provide a figure showing how predicted water surface elevations at the Montague site vary over the full range of flows within the operational capacity of the project; all associated raw numerical data should be provided in editable spreadsheet format. This figure should be similar to Figure 2.1-1 of the Addendum, which shows how water surface elevations vary at Rainbow Beach over the full range of flows.	Shown in Attachment A (Study No 3.5.1) is the Montague USGS Gage Rating Curve. This is not based on modeled data; the data was taken directly from the USGS.
MADFW-3	USFWS-3 Cobblestone Tiger Beetle Tables 2.2-1 and 2.2-2 of the Addendum show the percent of time that potential habitat is inundated for a period of 24 hours and the percent of time potential habitat is inundated for 0.0 hours. The tables also show how available habitat varies across WSELs. We request that FL provide corresponding figures showing the percent of time that potential habitat is inundated for less than 24 hours but more than 0.0 hours, per the following categories: 1-5, 6-9, 10-14, and 15+. All associated raw numerical data should be provided in editable spreadsheet format.	FL will provide corresponding figures showing the percent of time that potential habitat is inundated for less than 24 hours but more than 0.0 hours, per the following categories: 1-5, 6-9, 10-14, and 15+. Data used to develop the requested figures will be provided in editable spreadsheet format on 4/3/2017.
MADFW-4	USFWS-3 Cobblestone Tiger Beetle In the MRSP, FL committed to providing an analysis of both flood depth as well as duration across a range of potential project flows. Therefore, we request that FL provide the mean (±1 standard error), median number of hours per day, and number of times per day (±1 standard error) each elevation was inundated for each calendar day averaged *across* the eight year period for each transect. All associated raw numerical data should be provided in editable spreadsheet format.	FL will provide the mean (±1 standard error), median number of hours per day, and number of times per day (±1 standard error) each elevation was inundated for each calendar day averaged across the eight year period for each transect. All associated raw numerical data will be provided in editable spreadsheet format and filed with FERC on 4/3/2017.
MADFW-5	MADFW-4 Puritan Tiger Beetle FL developed a digital terrain model of potential PTB habitat at Rainbow Beach and the North Bank based on elevation data from transects surveyed in 2015. FL used the calibrated hydraulic model to simulate WSELs at each location under actual conditions between January 1, 2008 and September 20, 2015.In the Addendum, FL assessed the extent of available PTB habitat for corresponding WSELs at each site, as well as the percent of time elevations are inundated (based on either 0.0 or 24.0 hours between May and August). Tables 2.3-1 and 2.3-4 of the Addendum show the percent of time that potential habitat at Rainbow Beach and the North Bank is inundated for a period of 24 hours and the percent of time potential habitat is inundated for 0.0 hours. The tables also show how available habitat varies across WSELs. We request that FL provide a corresponding figure showing the percent of time that potential habitat is inundated for less than 24 hours but more than 0.0 hours, per the following categories: 1-5, 6-9, 10-14, and 15+. All associated raw numerical data should be provided in editable spreadsheet format.	See response for MADFW-3.
MADFW-6	As stated in the MRSP, FL committed to providing an analysis of both flood depth as well as duration across a range of potential project flows. Therefore, we request that FL provide the mean (±1 standard error), median number of hours per day, and number of times per day (±1 standard error) each elevation was inundated for each calendar day averaged *across* the eight year period for each transect (separately for Rainbow Beach and the North Bank). Averages should be calculated for all months to facilitate assessment of potential effects on both adult (May – August) as well as larval (year round) life stages. All associated raw numerical data should be provided in editable spreadsheet format.	See response for MADFW-4.
MADFW-7	General Comments re: State-listed Plants Task 3, Objective 1 of the MRSP required FL to provide maps be generated to show all known, historic and potentially suitable habitats; potentially suitable habitat was defined as an area which appears to provide suitable habitat characteristics but which is currently unoccupied by state-listed plants. In Study Report 3.5.1, FL provided maps of occupied habitat and confirmed (Page 3-3) that "*following the initial field reconnaissance,*	Attachment B (Study No 3.5.1) includes an ArcGIS polygon shapefile of mapped unoccupied habitat.

Commenter	Comment	Responses
	maps were generated to show all known, current, and potentially suitable habitat." However, maps of potentially suitable habitat were not provided in Study Report 3.5.1. In the Addendum, the maps of potential habitat (Figures 3.0-1 through 3.0-3) appear to depict areas that were previously provided to FL by the Division to help identify areas warranting field assessment. These areas do not represent an on-the-ground delineation of potentially suitable habitat as required by (and defined within) the MRSP and the Division's *Habitat Assessment and Survey Guidelines*. Therefore, the Division reiterates its request that FL provide maps (and ArcGIS shapefiles) of potentially suitable habitat for state-listed plants based on its field assessments. If FL did not field-delineate the extent of potentially suitable habitat as required by the MRSP, then field assessments should be conducted in 2017.	
MADFW-8	In response to comments on Study Report 3.5.1, FERC's June 29, 2016 determination recommended that "*the information requested by Massachusetts DFW be included in the addendum or FL should indicate why the information cannot be provided*" in reference to comments requesting FL to (a) articulate habitat suitability preferences for each species in terms of substrate and flow parameters; and (b) that Objective 3 (e.g., how quality, quantity and location of habitat changes over a range of elevations and flow parameters) be used to refine habitat suitability preferences, including assessment and spatial mapping of plant health and vigor (measured in terms of plant height and density) at occupied sites as they vary across spatial/elevation gradients (MRSP, p. 11). In the Addendum (Page 3-66), FL briefly described habitat preferences used to identify plant survey locations. However, FL did not define habitat suitability preferences for each species based on an assessment of inundation frequencies, durations, timing or magnitude. Additionally, FL stated that, due to field season time constraints, specific measurements (including height) of individual plants were not collected despite the fact that field work occurred during the 2015 field season for this study. Additionally, and as detailed in Comment #3 below, it does not appear that FL incorporated information on rare plants observed in Reach 3 of the Bypass Reach, a critical source of information on habitat suitability preferences. Therefore, FL has not sufficiently addressed Objectives 2 and 3 of the MRSP and has not provided an explanation (either in Study Report 3.5.1 or the Addendum) for why they deviated from FERC's determination. Therefore, the Division requests that FERC direct FL to define habitat suitability preferences for each species based on an assessment of inundation duration, frequency and timing at the soil interface (e.g., root inundation) for public review and comment, One aspect of a plant's tolerance to inundation is root inundation, best represented by the elevation recorded by FL for each plant (i.e., soil/plant interface). For example, some species may be unable to inhabit lower elevations due to longer and/or more frequent inundation of substrates (e.g., root structures) during the growing season (resulting from peaking operations). However, another critical aspect of a plant's tolerance is the timing and height of inundation relative to the plant's reproductive parts (measured as height above the soil/plant interface). Not only can inundation damage or remove flowering parts or wash away pollen, it can render the reproductive part unavailable when pollinators are present. The analysis by FL needs to factor in the physical height of reproductive parts and phenology of reproduction on each day of the reproductive window, per the table below.	More detail regarding habitat preferences for each species will be provided and include information developed as a result of responses within this matrix resulting from MADFW comments. This information will be filed with FERC on 4/3/2017. With regard to the physical height of reproductive parts, the MRSP does not call for the inclusion of the height of reproductive structures as part of the analysis, and therefore it was not included in the analysis as it is outside the scope of the MRSP.
MADFW-9	Therefore, and to help facilitate the assessment above, for each transect we request that FL: Calculate and provide a table showing the number of hours per day each elevation was inundated, as well as the number of times each elevation is inundated, on each calendar day (May 15 and October 31) for each year of the eight year period of record (2008-2015; 170 days*8 years*n elevations). Data should include the full range of elevations and flows provided in Figures 2.4-1 and 2.4-2 (for Transect 1), 2.4-3 and 2.4-4 (for Transect 2), etc.	In the October 2016 addendum FL provided summary figures showing durations of inundation for each Transect (for both 0 and 24 hours). The raw data needed to complete the hourly analysis for each individual elevation at each transect, for the range of flows were included in the data which was attached to the October Addendum as Attachment C (Study 3.5.1). FL will provide updated spreadsheets with the requested data which will include May 15 through October 31 on 4/3/2017.
MADFW-10	For the analysis conducted in 1), FL should calculate and provide a table showing the daily mean (±1 standard error), median number of hours per day, and number of times per day (±1 standard error) each elevation was inundated, for each calendar day (May 15 – October 31) averaged *across* the eight year period for each transect.	FL will calculate and provide a table showing the daily mean (±1 standard error), median number of hours per day, and number of times per day (±1 standard error) each elevation was inundated, for each calendar day (May 15 – October 31) averaged across the eight year period for each transect. This information will be filed with FERC on 4/3/2017.

Commenter	Comment	Responses
MADFW-11	For Reach 3 of the Bypass Reach (the 2-D study area), the MRSP stated that "*FirstLight will use the 2-D hydraulic model information and transect information from the IFIM study to evaluate hydraulic conditions (water surface elevation) across any range of flows (this will eliminate the need for specific transect placement in the 2-D study area). This hydraulic information will be used with measured elevation data collected at occupied sensitive plant sites to evaluate how Project operations may impact habitat suitability for the plants within the bypass reach.*" Additionally, in subsequent consultations with the Division, FL confirmed that fine-scale data collection associated with 2-D modeling of the Bypass Reach, combined with modeling of flow parameters in occupied habitat for each species, would provide extensive information regarding habitat suitability preferences for each species observed there. As we noted in our comments on Study Report 3.5.1, the Bypass Reach might also provide information on habitat suitability preferences for species not observed during FL surveys (but known to occur historically) through data collected in potentially suitable but unoccupied habitats. However, to date FL has not provided any assessment associated with state-listed plants in the 2-D study area and has not provided an explanation (either in Study Report 3.5.1 or the Addendum) for why this information has not been provided. Strangely, the Addendum acknowledged that Transect T-3 (located within Reach 2 and representing the only source of data provided to date on rare plants within the Bypass Reach) was not actually visited in the field, so substrate and plant locations along this transect were not collected. Therefore, the Division requests that FERC direct FL to incorporate data from state-listed plant observations in the 2-D study area in its assessment of habitat suitability preferences (see Comment #2 above), including a description of how this information was used. Additionally, the Division requests that FL provide the following information: Table(s) showing predicted water surface elevations over the full range of flows within the operational capacity of the project for the 2-D study area; all associated raw numerical data should be provided in editable spreadsheet format.	Attachment C (Study No 3.5.1) includes ArcGIS shapefiles of all RTE species mapping within the by-pass reach as a polygon shapefile. Unlike the Turners Falls Impoundment and downstream of Cabot in Reach 4 and 5, modeled historical time series data of flow and elevation from the 1-D HEC-RAS model is not feasible to develop in the 2-D study area. A 2-D model (River2D) was used in Reach 3 due to the hydraulic complexity of the reach which includes side channels, islands, and inflow from the bypass reach, Cabot Station, and the Deerfield River. While over 100 steady state model runs were completed to analyze a wide range of flows, each steady state model took several days to stabilize even on a 12 Core Workstation with 128 GB of RAM. Therefore a similar hourly time's series data for Reach 3 is not feasible. However, to adequately cover the locations of the rare plans within the 2-D study area, FirstLight will provide stage vs discharge curves at 10 locations for a combination of bypass flows and Cabot generation. While inflow from the Deerfield River can affect the lower part of this area, only the minimum flow of 200 cfs from the lowermost hydroelectric project on the Deerfield River will be used in these analyses to emphasize impacts from flows that are within the control of FirstLight. Figures and tables of these stage vs flow relationships at 10 locations, will be supplied in a filing on 4/3/2017. These figures and tables will also show the minimum and maximum elevations of the rare plant locations that are found in the 10 representative locations. The elevations and flow data used to create these figures and tables will be supplied in Excel format.
MADFW-12	Elevation data for individual plants observed within the 2-D study area. In instances where minimum and maximum elevations were taken to describe a larger population (e.g., individual plant elevations were not taken), we request that FL provide the minimum and maximum elevations (measured at the soil interface to capture root inundation) for each spatially distinct population of each species. In these instances, please also provide any available data regarding how density and plant vigor varied across each population (see Comment #2, above).	Utilizing elevation data developed as part of Study (Study 3.3.1) FL will provide the minimum and maximum elevations for each spatially distinct population of each species within the 2-D study area. As described in the MRSP The boundaries of populations were GPS located and displayed as polygon around the population. Within the 2-D study area, the number of rare plants encountered made data collection at each plant observation infeasible. FL will provide a maximum and minimum elevation for each mapped population polygon as well as the calculated density (based on number of observed plants and the area of the mapped polygon) within the 2-D study area. These data will be filed with FERC on 4/3/2017.
MADFW-13	Based on the eight year period of record (2008-2015) and the 2-D model, provide tables (similar to Tables 2.3-1 and 2.3-2 in the Addendum) showing each elevation, the flow (cfs) that corresponds to that elevation, and the percent of days that elevation is inundated for 24 hours, for 0 hours, or for some portion of the day (less than 24 hours but more than 0.0 hours) for May 15 through October 31. Please calculate the number of hours per day each elevation was inundated for each calendar day between May 15 and October 31 for the eight year period of record. We also recommend that FL calculate the mean and median number of hours per day (with standard deviations) – as well as the number of times per day each elevation was inundated for each calendar day (May 15 – October 31) *across* the eight year period of record. Data should include the full range of elevations and flows that state-listed species occur – or could occur, based on FL's delineation of suitable but unoccupied habitat - within the 2-D study area. All raw numerical data should be provided in editable spreadsheet format.	See the response to comment MADFW-11.
MADFW-14	Location and Digital Terrain Model Map(s), similar to Figure 2.5-23 provided for Transects 11A-11D), as appropriate to show the location and distribution of individual plants and/or populations for each species observed within the 2-D study area.	The MRSP does not describe the need for the development of DTM Maps showing the locations of plants within the 2-D study area, and is out of the scope of the MRSP.
MADFW-15	In our comments on Study Report 3.5.1, the Division requested that FL conduct additional field work using phonologically-targeted surveys in 2016 for Tufted Hairgrass (*Deschampsia cespitosa ssp. glauca*) (Hartman). FL did not acknowledge the Division's request for additional field work in its May 31, 2016 response to comments. In its June 29, 2016 determination, FERC recommended that "*the information requested by Massachusetts DFW be included in the addendum or FirstLight should indicate why the information cannot be provided*" Including the request for surveys. In an email to the Division dated June 27, 2016, Steve Knapp (Klein Schmidt Group) stated that "*throughout much of the by-pass and other rocky shorelines we observed perennial cespitose grasses that we suspected could be D. cespitosa; however, all individuals examined from June through September of 2014 had shattered seed heads, without sufficient features for identification. This was discussed with Karro Frost and Jesse Leddick during the October 22 site visit in 2014, but no conclusions were drawn at that time.*" In a second email dated December 2, 2016, Knapp stated that FL "*conducted extensive field surveys for listed plant species, including Deschampsia, over the course of 21 days in the field in 2014. FirstLight believes this effort fulfilled the intent of the study plan relative to listed plant species*." This Endangered, perennial grass species occurs only in the Connecticut River in Massachusetts, and its only extant population is located within the Bypass Reach. This species has high site fidelity; as a fairly long lived perennial species populations do not tend to move	FL followed the MRSP for surveys completed in 2014 and identified a possible *D. cespitosa ssp. glauca* individual. FL did receive and was unaware of specific location information which was obtained by the MADFW-NHESP in June of 2014. FL proposes to assume that these individuals are *D. cespitosa ssp. glauca* and conduct all requisite analyses based on this assumption. This information will be field with FERC on 4/3/2017. It would be beneficial if the location information, obtained by the MADFW-NHESP, in 2014 was provided to FL to include in this analysis.

Commenter	Comment	Responses
	around significantly from year to year. This species has been observed in the Bypass Reach many times, extensively and in essentially the same locations, since as early as 1980. Most recently, at one location near the center of the Bypass Reach, approximately 100,000 mature genets were observed (90% in flower) over approximately 10 hectares by independent observers in late June of 2014. Although this grass can be difficult to identify, we note that FL conducted surveys in the Bypass Reach on June 3 and June 11, 2016 (lower & mid-bypass reach) and did not return to conducted additional surveys until August 18th and later (email from FL to Division, dated 12/1/2016). This means that there was an 8-9 week period between the beginning and end of the identification window where the Bypass Reach was unsurveyed by FL botanists. By the time FL visited the site on August 18th, they were only able to identify a single location where cespitose grasses were observed with shattered seed heads, insufficient to make a positive identification. Additionally, while this observation was within the general habitat for *D. cespitosa ssp. glauca*, it appears that FL did not observe cespitose grasses in any other locations where the species is known to occur in the Bypass Reach. We believe that the observed, shattered seeds heads likely represent the target species. Indeed, the Division affirmed – both during the October 22, 2014 site visit and a phone call with FL representatives on March 30, 2016 – that this species had been previously observed within the Bypass Reach and that it was highly likely that the perennial cespitose grass observed by FL was *D. cespitosa spp. glauca*. However, the lack of field surveys in the Bypass Reach during the flowering/fruiting season and lack of positive identifications at known locations suggests that many plants went unobserved. We also note that additional field work related to this study occurred in 2015, and that field work related to other studies occurred in 2016; FL elected not to look for this plant in spite of the timing issues referenced in relation to the 2014 season and the Division's request for additional survey effort for this species in 2016 (Division comments on Study Report 3.5.1). The intent of the MRSP was to assess potential project impacts under existing and potential future operational scenarios on this and other state-listed plant species. It is impossible to do so in the absence of requisite data collection for a species known to occur in the Bypass Reach. Therefore, FL's failure to assess Project impacts on this species, or adequately explain why it could not do so, is not consistent with the intent of the MRSP or FERC's June 29, 2016 determination. Therefore, the Division reaffirms its request that FL conduct additional field surveys for *D. cespitosa spp. glauca* during the 2017 field season. FL botanists should conduct reconnaissance surveys every one to two weeks starting at the end of May until seed heads are observed. At this point, Division botanists are willing to accompany FL's botanists for several days to help confirm field identification and selection of survey areas. Alternatively, and consistent with our comments on Study Report 3.5.1, if FL collected data on all possible *D. cespitosa ssp. glauca* individuals observed during 2014 surveys (consistent with the MRSP and with the locations of known populations), FL may elect to assume that these individuals are *D. cespitosa ssp. glauca* and conduct all requisite analyses based on this assumption. For locations where *D. cespitose ssp. glauca* was observed in the 2-D study area, FL should use the 2-D hydraulic model, combined with measured elevation data for plant/population locations, to evaluate habitat suitability preferences and potential project impacts as outlined previously (see Comment #3 above).	
MADFW-16	In our comments on Study Report 3.5.1, the Division requested that FL conduct additional field work (phonologically-targeted surveys) for Wright's Spike-rush, Intermediate Spike-Sedge and Ovate Spike-sedge in 2016. The Division's request was based on the fact that *Eleocharis* species were observed during FL surveys on Fourth Island and above Fourth Island (near Transects 3 and 4, respectively), on Third Island, and between First and Second Islands. However, FL did not provide any information regarding whether these *Eleocharis* species were state-listed. In emails to the Division dated June 27 and December 2, 2016, Steve Knapp provided more detailed information regarding dates, locations, and target species of rare plant surveys undertaken in 2014. In 2014, FL conducted field work in and around Fourth Island on June 3, 2014 and the islands located in Sunderland on August 18 and 20, 2014 (email 12/1/2016, FL to Division). Mature achenes are required to definitively identify this species, which do not typically present until mid to late August. Therefore, the field work conducted by FL on and above Fourth Island would have been unable to definitively identify *Eleocharis* species level unless additional field surveys were conducted. If follow up surveys were not conducted to definitively identify *Eleocharis* species in and around Fourth Island where *Eleocharis* species were observed, the Division reaffirms its request that FL conduct additional field surveys for *Eleocharis* in these locations sufficient to allow definitive identification.	FL followed methods as outlined in the MRSP in 2014 while searching for rare *Eleocharis* species. As described in the email from June 27, 2016, care was taken to examine all "clump-forming" (versus mat-forming) *Eleocharis* species encountered. Few clump-forming *Eleocharis* were observed within the bypass in 2014. Those that were found were identified as *E. obtusa*, based on the size and shape of the tubercle relative to the achene. In *E. obtusa*, the tubercle is wide-based and nearly as wide as achene, with no constriction separating the tubercle from the achene. *Eleocharis* plants found elsewhere within the study area, primarily in and around Pauchaug Brook and the associated boat ramp, where either identified as *E. obtuse* or could not be identified because they did not have mature achenes until mid- to late-August. Subsequent site visits to Pauchaug produced a single specimen of E. intermedia on August 20, 2014, and a single plant of E. ovata on August 26, 2015. FL proposes to use these observations (from 2014 and 2015) and include the species in the analysis of Transect 11 (A-D). This analysis will be filed with FERC on 4/3/2017. While the 2014 observation was not re-located in 2015, the DTM developed as part of the October 2016 Addendum will be used to provide an elevation for the 2014 observation.
MADFW-17	In our comments on Study Report 3.5.1, the Division requested that FERC direct FL to orient transects at First, Second and Fourth Islands as previously agreed and that associated hydrological assessments be revised. However, the Division also noted that it would be willing to review supplemental elevation data collected by FL within occupied habitats at First, Second and Fourth Islands and, if deemed sufficient to enable all required hydrological assessments, the Division would support a subsequent request by FL to waive our request to recollect transect data at First, Second and Fourth Islands. FL has not provided any additional information regarding this request. Therefore, the Division requests that FERC require FL either re-collect data on the transects as previously agreed or provide the	Attachment D (Study No 3.5.1) includes an ArcGIS shapefile of all elevation data collected during the 2015 elevation survey for review. This data was previously provided to the MADFW in response to comment MADFW-6 in the May 2016 response to comments, as Attachment C (Study 3.5.1) which included an excel table with all elevation and species information for each of the surveyed elevation transects collected in 2015.

Commenter	Comment	Responses
	supplemental elevation data for review by the Division.	
MADFW-18	MADFW-8 RTE Plant Surveys-Transect Please provide, in editable spreadsheet format, raw numerical associated with the following figures provided in the October 2016 Addendum. Please limit data to May 15 through October 31: Figure 2.4-1 and similar (percent of time that potential habitat is inundated for a period of 24 hours). Figure 2.4-2 and similar (percent of time potential habitat is inundated for a period of 0.0 hours).	FL provided all raw numerical data used to develop the figures identified in the MADFW request in the October 2016 Addendum. FL will provided the additional data to include October on 4/3/2017 However, the modeling period for this and most other studies that used the HEC-RAS hydraulic model ended on September 30, 2015 due to the extent of approved flow data available from the USGS and FirstLight when the modeling was completed. So rather than change the modeled period, the data for 2015 will not include October 2015.
MADFW-19	For each transect, we request that FL provide the following: Exact elevation measurements (measured at the soil interface) for all plants observed; all raw numerical data should be provided in editable spreadsheet format. An ArcGIS shapefile with each transect (as a line) showing its location, orientation, and length. Baseline flow conditions to help standardize flow-related habitat suitability preferences across transects. For example, for *Prunus pumila* var. *depressa,* FL established transects at Fourth Island (Transect 3) as well as just below Vernon Dam (Transects 8 and 9). But, the absolute elevation recorded by FL (Feet-NGDV 1929) does not represent the habitat space occupied by the plant, as the plant is responding to site-specific flow and inundation conditions rather than height of a fixed point. Therefore, to help understand habitat suitability preferences for this species, it is important to measure the relative elevation between where *Prunus* was observed along a transect and a minimum, baseline flow condition at that transect area during its growing season (likely occurring in August/September). Similarly, it is also important to be able to compare this relative elevation difference across transects (e.g., between Transect 3 downstream of Cabot Station and Transects 8/9 just below Vernon Dam) in order to compare typical flow conditions experienced by the same species in different locations. Preliminary, we recommend using 120 cfs for the Bypass Reach (representing minimum flows between July 16th and November 15th) and 1,633 cfs for Reach 4 (representing minimum flows originating from the Deerfield Hydroelectric Project and Turners Falls Project). However, we request that FL work with the Division and other stakeholders to establish sensible minimum, baseline flow conditions for each distinct portion of the river where rare plant transects were established (including Reach 4, the Bypass Reach, the Impoundment, and just downstream of Vernon Dam) to aid in evaluating plant habitat suitability.	In the response to comment MADFW-6 in the May 2016 response to comments, FL provided, as Attachment C (Study 3.5.1), an excel table which provides all elevation and species information for each of the surveyed elevation transects collected in 2015. Attachment E (Study No. 3.5.1), of this response, contains an ArcGIS line shapefile showing the location, length, and orientation of the survey transects collected in 2015. FL proposes that the MADFW-NHESP use the data provided in the October 2015 Addendum to identify target elevations, based on the inundation duration data, for each species Stage vs discharge curves will be completed for the bypass reach and downstream of Cabot. Within the Turners Falls Impoundment, the water level as controlled by FirstLight at the Turners Falls Dam and pumping and generation at Northfield Mountain, are key factors on water levels throughout the impoundment at flows below about 30,000 cfs. Therefore FirstLight does not propose to develop stage vs discharge curves for this study in the impoundment. At locations within Reach 1 and 2 of the bypass reach and downstream of Cabot Station in Reach 4 and 5, FL will develop stage vs discharge curves for a range of flows stating at baseline conditions described in the comment and extending to 10,000 cfs in the bypass reach and downstream to 20,000 cfs. This data will be provided on 4/3/ 2017. However, example stage vs flow scatter plots showing this relationship (and the raw Excel data) for the transects located within the impoundment during a representative year, will be provided on 4/3/2017.
MADFW-20	Study Report 3.5.1, Additional Data Requested: Please provide, in editable spreadsheet format, raw numerical data associated with the following tables and figures from Study Report 3.5.1. Please limit data to May 15 through October 31: • Figure 4.3-10 and similar (% exceedance curves for each transect based on the eight year period of record). • Figures 4.3-12 and similar (spring maximum daily changes in WSEL for each transect). Please expand data to include July, August, September and October. • Tables 4.3-7 through Table 4.3-17.	These additional figures, tables and the raw data in Excel format will be provided on 4/3/2017.
MADFW-21	Table 4.3-11 of Study Report 3.5.1 provides predicted water surface elevations over a range of flows for Transect T-3 in the Bypass Reach. We request that FL provide tables (showing predicted water surface elevations over the full range of flows within the operational capacity of the project) for Transects 1 through 11.	As described in our response to MADFW-20, at locations within the impoundment, the water level (as controlled by FirstLight at the Turners Falls Dam and pumping and generation at Northfield Mountain) have major influences on the water level throughout the impoundment at low flow conditions. Therefore stage vs discharge relationships in the impoundment for flows below 30,000 cfs are much more like scatter plots than curves which are not as useful to determine a stage vs flow relationship. However, example stage vs flow scatter plots (and the raw Excel data) for the transects located within the impoundment during a representative year, will be provided on 4/3/2017.
MADFW-22	Figure 4.3-1 of Study Report 3.5.1 shows areas occupied by various state-listed plants within Reach 2 and the northerly portion of Reach 3 of the Bypass Reach. We request that FL provide a similar figure showing areas occupied by rare plants within other portions of Reach 3 not shown in Figure 4.3-1.	Updated mapping, which shows areas occupied by state-listed plants within all portions of the by-pass reach have been included as Attachment F (Study No 3.5.1) to this response.
MADFW-23	Section 4.4 (Invasive Plant Survey) confirmed that thirteen (13) terrestrial invasive plant species were identified and mapped within the study area. However, Study Report 3.5.1 did not provide maps showing locations where terrestrial invasive plant species were observed. We request that FL provide more detailed information on terrestrial invasive species observed within the Project area, including but not limited to maps as well as ArcGIS shapefiles. Relatedly, in our comments on Study No. 3.4.1 the Division noted that *Salix exigua* (not spp. *interior*), *Alnus glutinosa*, and *Salix purpurea* are known to occur within the Project area. These species were not mentioned in Study Report 3.4.1 or included in Appendix D. Per the FERC SPD (dated March 6, 2014), FL was required to note the presence of these invasive species as part of the data collection efforts for this study. In our comments on Study Report 3.4.1 we requested that FL confirm whether these species were observed during invasive	The MSRP (2014) stated that "The MIPAG list of wetland and aquatic invasive plant species will be utilized to identify targeted invasive species when conducting botanical meander surveys (Page 14 MSRP 2014)." *Salix exigua* (not spp. *interior*), *Alnus glutinosa*, *Salix purpurea,* and *Ligustrum obtusifolium* are not currently listed as invasive on the MIPAG and therefore, as described in the MRSP, they were not targeted for surveys. *Frangula alnus* is present within areas identified on Figure 4.4-1 as having percent cover of invasives. Attachment G (Study No. 3.5.1) includes an ArcGIS shapefile with point observations of invasive species.

Commenter	Comment	Responses
	plant surveys, or whether they were not searched for. FL has not provided any additional information regarding this request. Similarly, *Frangula alnus* (also known as *Rhamnus frangula*) and *Ligustrum obtusifolium* are considered invasive species and are known to occur within the Project area. These species are listed as observed species in Appendix D of Study Report 3.4.1, but no information was provided in the body of the report regarding location and/or extent of species observations. Please provide more detailed information, including maps and ArcGIS shapefiles, detailing findings for these species.	

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

Commenter	Comment	Responses
AW, AMC, NEFLOW -1	The study varied from the stated purpose in that FirstLight did not assess the effects of project operations on land use. … In several cases – Poplar Street, Riverview, Pauchaug, Rock Dam, and the entire by-passed reach, to name a few – project operations impact recreation not just because of water depth but because of project operations on land.	Land use of Project lands and the effects of land use on recreation use and potential were the subject of several of the other resource studies conducted for these projects including primarily Study 3.6.5 *Land Use Inventory* which examined land ownership and use of both Project and non-Project lands immediately adjacent to the Project. In addition, studies 3.6.1 *Recreation Use/User Contact Survey* and 3.6.4 *Assessment of Day Use and Overnight Facilities Associated with Non-motorized Boat* included assessments of how various recreation sites are utilized, and whether there are project operational or land use effects associated with public recreation opportunities or uses. Study 3.6.7 *Recreation Study at Northfield Mountain, including Assessment of Sufficiency of Trails for Shared Use* looked at use and operation of extensive Project lands associated with the Northfield Mountain Visitor Center, which are available and managed for a wide variety of public recreation opportunities. Thus, while the 3.6.6 study plan identified the objective of this study as being evaluating whether the operation of the Projects has an effect on the recreation facilities or land use within either Project, the land use effects were more thoroughly examined in the other study reports, and therefore were not repeated in this study. Rather Study 3.6.6 focused on the effects of Project operations on existing recreation site facilities and uses.
AW, AMC, NEFLOW - 2	This study, as with earlier recreation studies 3.6.1 and 3.6.5, gathered no new on-the-ground data. The desktop analysis was based solely on water levels at riverside put-ins and take-outs, state boat launches. FirstLight did not do additional field study that would have provided more complete information. In reviewing existing data, FirstLight apparently did not review all data from earlier studies. See the attached graphs showing the river elevations from the FirstLight logger located downstream of **Pauchaug Brook** in 2013 and 2014, both of which were more normal water years rather from this year's drought. These river loggers, installed for a different study, recorded flows regularly falling below the 181 ft. level that this study identified as crucial at Pauchaug Brook. The river loggers seem to suggest low water was present more often than the 15% stated in the study.	Comment acknowledged. As set forth in the FERC-approved Revised Study Plan, Study 3.6.6 was designed as a desktop study that relied primarily on information and data from other studies as well as project operational data. In accordance with the study plan methodology the study involved dedicated analysis of project operational and modeling data that was unique to this study and the primary recreation sites that were the focus of the study. With respect to the comment regarding 2013-2014 data from the river loggers located downstream of Pauchaug Brook, see response to CRWRC-3.
AW, AMC, NEFLOW - 3	The Pauchaug Brook boat launch, maintained by the Commonwealth of Massachusetts, was described as having moderate impacts. This site often has an impassable mud flat between the launch ramp and the actual river. Several participants at the study meeting similarly reported experiencing muddy conditions at Pauchaug Brook, and the river loggers confirm that those conditions exist occur frequently, even on a daily basis. The study reports suggest such conditions happens about 15% of the time, or maybe more frequently. It was rated as having only moderated difficulties in the report, which should be revised in regard to morning low water.	The 3.6.6 study report concluded with a summary of the effects of Project operation on the various water-access recreation facilities, including primarily the effects of water levels and flows. For this summary, qualitative categories of effects of Project operations (water levels and flows) were used, including no effects, minimal effects and moderate effects. This assessment of the overall effect was based primarily on the portion of time (from the duration analysis) that the usability of a facility was determined to be impacted by water levels or flows, or both. Of the water-access sites/facilities evaluated, most were found to be completely unaffected (0% of the time) by Project operations; a few sites were found to be minimally affected (~1%-10%) of the time; and only one site (Pauchaug Boat Launch) was found to be moderately affected (~11%-25%) by Project operations during the recreation season (May-October). However, the study did discuss the fact that the Pauchaug Boat Launch is particularly susceptible to sedimentation and the accumulation of sediment and mud which primarily occurs following spring high flows and other high flow events. There is no evidence, however, that the sedimentation occurs as a result of Project operations. Rather, the evidence suggests that sedimentation (and the resulting muddy conditions), is driven primarily by high river flows and also possibly by the location and orientation of the boat launch within a narrow bank cut, and sediment delivered on high flows from Pauchaug Brook.
AW, AMC, NEFLOW - 4	The reported 2-foot depth at the [Pauchaug] put-in is not as functional as suggested. Since the ramp slopes into the water, depths range from 0 inches to 2-feet or greater depending on how far down the ramp you go. With a trailered motor boat, a 2-foot depth can be reached. However, being a shallow concrete ramp, it can damage canoes and kayaks made from fiberglass, Kevlar, or wood and canvas that are launched there. And, if a mud flat greets the paddler, it is very difficult to access the water. The study should accurately describe the conditions at Pauchaug Brook.	The study results show that water levels can affect the depth at the Pauchaug Boat Launch, but even with these effects 80% or more of the time, there is at least 2 ft. of water depth at the launch, which is sufficient for launching both motorized and non-motorized water craft. In addition, while those launching canoes and kayaks may not have immediate access to the 2 ft water depth that is available at the end of the concrete launch ramp, the sloping bank conditions at Pauchaug appear to be similar to those encountered at paved/concrete launch sites on lakes and rivers throughout New England i.e., any shoreline boat launch facility will be shallow at the immediate shoreline interface.

Commenter	Comment	Responses
AW, AMC, NEFLOW - 5	The put-in at **Sunderland Bridge** downstream is rated as adequate, but experiences with conditions at that put-in suggest it is difficult to reach the river without scraping bottom in a canoe or kayak. Certainly, there is no 2-foot or 3-foot level of water at that put-in. The conclusion should be revisited and revised to more accurately reflect the conditions at Sunderland Bridge.	Comment acknowledged. The Sunderland Bridge boat launch site is an unimproved access site located well downstream of the Project and along a relatively gently sloping portion of the river edge. Thus, conditions at the site are such that there is shallow water at the launch site, and in the vicinity of the launch site, at various times. However, the modeling analysis shows that water level fluctuations are the result of a number of variables including hydrologically driven river flow conditions, flows from the Turners Falls Project, and to a lesser extent flows from the Deerfield River and operation of the Holyoke Project. The combined effects of these primary contributors to flows and water levels are captured in the water surface elevation plots that were utilized in the study analysis, which suggest that, overall, water level fluctuations have minimal effects on the boat launching conditions provided at Sunderland Bridge.
AW, AMC, NEFLOW - 6	Upriver, the **Riverview Boat Dock** is an example of where project operations impact put-ins on the river. This site sits across the road from the Northfield Mountain Recreation Center. It has a dock used for the Q-II sight-seeing boat, and motor boats on the river can also dock there when the riverboat is absent. At Riverview, however, project operations prevent even carry-in canoes and kayaks from reaching the river because the parking area is distant from the river. Therefore, project operations discourage or eliminate non-commercial use at this FirstLight sight. The Riverview conclusions should be revised to indicate the role of project operations on land. The Riverview needs a drive up, where users could remove a boat and then go to the parking lot, plus an adequate hand carried boat launch facility at this location. A user need exists here since other access sites are miles apart.	As noted in the comment, the Riverview Boat Dock was designed for and is primarily used for the Q2 river boat tours. However, the site is available for other recreation use as well, including use by both noncommercial motorized and non-motorized boats. As an example, this recreation site was used for the United States Canoe Association's National Championships in August 2016 (http://www.newenglandnationals.org/). The main parking area is by necessity located away from the boat dock (via the access road), in order to accommodate the Q2 passengers, but there is put-in access for non-motorized boats at both the dock and also adjacent to the pavilion/picnic area. The carry distance from the main parking lot to the boat dock is approximately 430 ft., and the carry distance from the pavilion parking and the river put-in is approximately 350 ft.
AW, AMC, NEFLOW - 7	The **Cabot Woods Fishing Access** to the natural riverbed is not analyzed properly. The report assumes that only anglers access here. While shad anglers use this area, they are not the only users. Many recreational kayakers would access the river here except that project operations make the journey down the bank hazardous. FirstLight had stairs here in the past (the foundations remain), but FirstLight failed to maintain or eliminate the stairs, making access much more difficult for anglers and others. The impact of project operations on recreation at this site should be rated as moderate to heavy with increased usage likely when flows are restored to the natural river channel (bypassed reach) under the new license.	The 3.6.6 report does not assume that Cabot Woods is used only by anglers. However, as the report notes, currently the primary water-access use at this site is fishing, as the results of the 3.6.1 User Survey showed. Thus, angler use was the focus of the 3.6.6 study analysis. As set forth in FL's May 31, 2016 Response to Stakeholder Requests for Study Modifications and/or New Studies, FL acknowledges that at one time there was a staircase at the Cabot Woods site, but there has been no staircase at the site since it was removed sometime before 1987. In addition, the potential use of the Cabot Woods site as a possible canoe/kayak put-in or take out, was specifically evaluated as part of the 3.6.3 Whitewater Boating Study. That report noted that the Cabot Woods Fishing Access is not suitable for whitewater boating access to the bypass reach due to steep slopes and because FL discourages in-water uses at the site, particularly swimming, due to the strong and unpredictable water currents that can occur at the site. The report noted that any access to the bypass reach would need to be limited to boaters skilled and experienced with whitewater boating.

Commenter	Comment	Responses
AW, AMC, NEFLOW - 8	Study results are highly misleading at **Poplar Street** and in the bypassed reach. . . . FirstLight should not have deviated from the study plan and should have looked at how project operation on land impacted recreation. Among the impacts of project operations at this site that were not included: • Boaters can't get safely up or down the bank at Poplar Street. FirstLight acknowledged that during the whitewater study when they set up a winch to get boats and paddlers up the slope. It doesn't' matter what the water level is. • FirstLight describes this site as the end of the portage around the Turners Falls Dam. At no other dam site on the Connecticut River is the terminus of a portage so inadequate. • FirstLight did not examine the effects of project operations on recreation in the bypassed reach below the Turners Falls Dam. Even though they examined only water levels in their study, they failed to mention that project operations dewater the bypassed reach and impact recreation in the river there as well. • A put-in that of considerably greater quality than at Poplar Street exists river left below the dam. It was used during the whitewater study. Water levels from project operations make this put-in unusable except during spillage. This was not addressed in the study. • Recreation in the bypassed reach is made impossible by project operations related to the flow of water. These impacts at Poplar Street and in the bypassed reach should be included in the study report and rated as heavy based on future use of the project under the new license.	All of issues raised in the bulleted comments were addressed in other studies and study reports. Regarding the Poplar Street Access, the suitability of Poplar Street as a take-out for whitewater boating and as the downstream terminus of the canoe portage was examined in Study 3.6.3 and Study 3.6.4, respectively. FL has previously recognized the limitations of Poplar Street as the downstream terminus for canoe portage and, in the Final License Application, has proposed to make improvements to the access as a put-in for canoe portage. Regarding the effects of project operations on recreation in the bypassed reach below the Turners Falls Dam, this was the subject of an entire study (3.6.3) designed to evaluate the potential for whitewater boating in the bypass reach. This same study also examined the effects of current project operations on bypass reach flows and boatability by examining the frequency of suitable flows in the bypass reach under existing project operations. Regarding the put-in location on river left below the Turners Falls Dam, this site was examined as part of the 3.6.2 Study Addendum, and was also discussed as a possible put-in site for potential whitewater boating of the bypass reach as part of Study 3.6.3 (See Section 4.4). In addition, the entire 3.6.3 study was designed to evaluate the potential for whitewater boating in the bypass reach under a wide range of flow conditions. Finally, FL disagrees that the rating for existing project operational effects (flows and water levels) at the existing Poplar Street access site should be rated "heavy". As described previously this study was designed to provide an overall, summary rating of the effects of Project operation on the various water-access recreation facilities, including primarily the effects of water levels and flows. For this summary, qualitative categories of effects of project operations (water levels and flows) were used, including no effects, minimal effects and moderate effects. This assessment of the overall effect was based primarily on the portion of time (from the duration analysis) that the usability of a facility was determined to be impacted by water levels or flows, or both. From the perspective of flows (at the Poplar Street Access site) and water levels, the impact rating of "none" is appropriate since the river shoreline at the site remains fully accessible for canoe/kayak put-in and take-out under the range of water surface elevations and flows produced by normal Project operations.
AW, AMC, NEFLOW - 9	The report fails to study the **portage from Barton Cover to Poplar Street**. Project operations make this 3.5-mile portage unreasonable except with the assistance of motor vehicles. The terminus is at Poplar Street with the very difficult or impossible put-in as described above [in AW, AMC, NEFLOW-8]. The impact of project operations is **heavy** and also related to water levels. If project operations put more minimum flow into the bypassed reach, a much easier, accessible, and safe portage route could be used. In addition, the take-out at Barton Cove is closed early in the fall and reopened in late spring, and is gated off. River users in spring and fall are denied an access point in this popular area because of the effect of project operations on land. Access should be extended to operate from ice-out to ice-in. The study should be revised to rate the impacts at the portage and Barton Cove as **heavy**.	Study 3.6.4 *Assessment of Day Use and Overnight Facilities Associated with Non-Motorized Boats* specifically examined the existing canoe portage at Turners Falls dam and alternative canoe portage options, including the possibility for a carry portage versus the existing vehicular portage. As with the 3.6.3 report, the 3.6.4 report noted that due to the nature of the bypass reach, use of any access sites to the bypass reach would be limited to boaters skilled and experienced with whitewater boating. Thus, a portage option that terminates at a put-in located in the bypass reach would not be suitable for novices or flatwater paddlers, because the paddlers would be faced with class II-III and/or class III-IV rapids (depending on the location in the bypass reach), regardless of the flow conditions in the bypass. (See Section 4.1 of Study 3.6.3). The comment regarding the times of year when Barton Cove should be operated is not addressed here, as it is essentially a request for a protection, mitigation, and enhancement measure.
CRWRC-1	The study did not assess the effects of project operation on the ability to recreate in certain areas. For example, the current minimum flows in the bypass reach prevent the use of boats in that stretch, but that kind of effect was not assessed in this study.	The suitability of the bypass reach for whitewater boating was evaluated fully as part of Study 3.6.3. That study report also included an assessment of the frequency of boating flows and suitable boating conditions under existing Project operations.

Commenter	Comment	Responses
CRWRC-2	*4.2.2. Pauchaug Boat Launch*. As we discussed at the Study Report meeting held on November 1, 2016, the presentation of water level data in this report leaves much to be desired. The analysis involves median monthly water elevations and water surface elevation curves for each summer month. What is most important is the daily fluctuation below a minimum level. What happens in the middle of the night when people aren't boating is irrelevant.	The analysis included in the report that examined water level impacts on the usability of the recreation facilities, including Pauchaug Boat Launch, was not based on median monthly water elevations. The median monthly elevations were provided as part of the bathymetric profile figures, to give the reader some idea of typical water depths at each of the recreation sites/facilities. The analysis of water level effects on a particular site was done using HOURLY water surface elevation data generated by the HEC-RAS hydraulic model over a 16 year period (2000-2015). Hourly WSEL data for the recreation months (May-October) over the entire period were developed into WSEL duration curves, which provide an effective way of evaluating the frequency that water elevations are at or above the critical water depth determined for each recreation facility, in order to maintain its functionality. A "daylight analysis" of water level fluctuations on recreation facilities discussed in the 3.6.6 report during for the recreation season of May – October is set forth in Attachment A (Study 3.6.6). When preparing the "daylight analysis," we discovered that the critical elevation for launching boats at the floating dock for the Munn's Ferry Camping Area had been misstated. We have corrected this error (see Attachment B Study 3.6.6). The error, however, did not change the outcome of the analysis. The boat dock is useable 100% of the time during the recreation season.
CRWRC-3	CRWRC looked at the actual logger data provided as part of Relicensing Study 3.2.2 in Excel format. The report states that 3 feet of water at the end of the boat ramp [Pauchaug] is necessary for launching and/or retrieving boat on trailers so a water surface elevation of 181 ft is necessary for the boat ramp to be usable for power boats. From this, we see that it's not unusual at all for river levels to drop below the 181ft level during the nigh-time early morning hours, making it difficult to launch boats until mid-morning or noon, or even later. In September of 2014, there were even a couple of stretches where the river levels was too low for the better part of two entire days. This happened twice. September of 2014 was more typical of dry summer conditions than the rest of the summer, which was on the wet side.	The 2013-2014 water level data provided by the CRWRC does not provide as good an assessment of water level impacts on specific recreation facilities as the modeled data used in the 3.6.6 study report. This is because one or two years of actual water level data reflect the specific hydrologic, hydraulic and operational conditions of a particular year or two, and do not look at the longer term effects of project operations. For the 3.6.6 study analysis, FL used modeled data for a 16-year period of record, which takes into account all types of water years and a wide variety of flow and operational conditions. In short, the water level duration curves used in the report, are based on the entire period of record (2000-2015) and are therefore a better way to assess long term effects of Project operations on existing recreation sites, facilities, and uses.
[CRWRC-4	*4.2.3 Munn's Ferry Boat Camping.* The results from Study 3.3.9, showing conditions when the river flows upstream and strange eddies, do not seem to have been considered.	FL used the HEC-RAS hydraulic model to look at flow conditions, including flow direction, at the sites most likely to experience changes in flow direction as a result of Northfield Mountain project operations. Our review of conditions at the model transect located closest to the Munn's Ferry boat dock indicated only limited occurrences of low upstream velocity periods, that would be attributable to Northfield Mountain Project generation operations. See Attachment A (Study 3.6.6).
CRWRC-5	*4.2.4 Boat Tour and Riverview Picnic Area.* This section evaluated the use of power boats at this location only. Study Report 3.6.4 listed the Riverview Picnic Area as a formal river access site. If that is what FirstLight considers this site to be, and dismisses the need for additional water trail access points, then Study 3.6.6 needs to assess project effects for paddlers in this location, including operational impacts that cause the river to flow upstream as shown in Study 3.3.9.	The Riverview site was evaluated for more than just powerboat use. But, it is true that the boat dock itself was designed primarily for Q2 use (see response to AW, AMC, NEFLOW - 6), and therefore that was the primary focus of the assessment. The study report does look at flow directional and velocity conditions in the vicinity of the Riverview sites, and concludes that when river flow is low and Northfield Mountain is generating, the Riverview area is subject to flow reversals as water moves upstream. However, the upstream velocities are low, typically ranging between 0 and -1 fps. These velocities are well within acceptable levels for flatwater paddle boats. Nonetheless, we have provided additional analysis in Attachment A (Study 3.6.6).
CRWRC-6	*4.2.5 Cabot Camp Access Area.* Study 3.6.4 listed the Cabot Camp Access Area as a formal river access site. If that is what FirstLight considers this site to be, and dismisses the need for additional water trail access points, then Study 3.6.6 needs to assess project effects for paddlers in this location, including operational impacts that cause the river to flow upstream as shown in Study 3.3.9.	FL used the HEC-RAS hydraulic model to look at flow conditions, including flow direction, at the sites most likely to experience changes in flow direction as a result of Northfield Mountain project operations. Our review of conditions at the model transect located closest to the Cabot Camp site indicated only limited occurrences of low upstream velocity periods which would be attributable to Northfield Mountain Project pumping operations. See Attachment A (Study 3.6.6).

Commenter	Comment	Responses
CRWRC-7	*4.2.10 Poplar Street Access Site and 4.2.11 Sunderland Bridge Boat Launch.* Our comment from Study 3.3.2 was that based on the August 11-16, 2012 graph downstream of the Turners Falls dam (Appendix C of Study 3.3.2), peaking flows out of the Cabot units can result in 5-ft sub-daily fluctuations in Montague and 4-foot subdaily fluctuations at the Sunderland Bridge in the middle of the summer. Flows rapidly decrease at midnight until mid-morning or mid-day, then steadily increase during the latter half of the day. At Poplar Street, our experience and anecdotal stories indicate that higher water levels can make launching a boat more dangerous and difficult. As for the Sunderland Boat launch, the graphs provided do not tell us the full story, and no user surveys were conducted in that area, despite CRWC's request during the review of the RSP.	FL's May 31, 2016 Response to Stakeholder Requests for Study Modifications and/or New Studies acknowledged that the hydraulic modeling work done for the reach of river downstream of Cabot Station shows that water surface elevations in that reach fluctuate depending on river flows and project operations on both the Connecticut and Deerfield rivers. But, as noted by FERC in it its Study Plan Determination Letter dated September 13, 2013, recreation access points downstream of the Poplar Street access are not integrally connected to the Project because they are affected by other hydropower projects on the Deerfield river. Nonetheless, the 3.6.6 study did evaluate the effect of water level fluctuations on boat launching conditions at Sunderland Bridge. As noted previously the water elevation data used for this analysis was the long-termed modeled elevations generated by the hydraulic model for the period 2000 – 2015. Use of the long-term record for this analysis provides a more accurate picture of the range and duration of water elevations experienced at Sunderland Bridge as result of the combined effects of the all the variables that affect water levels, including natural river flows, Project operations, and to a lesser extent flows from the Deerfield River and the operation of the Holyoke Project.. In its Study Plan Determination Letter dated September 13, 2013, FERC rejected CRWRC's request to conduct user surveys downstream of Cabot Station.
CRWRC-8	When we are given flow duration curves, that obscure the true issue of subdaily fluctuations of the river, we are little better off than we were at the beginning of this process. We knew then that river users complain about low water in the morning at Pauchaug and at the Barton Cove state boat ramps, for example. This study has done little more to add to the understanding.	FL disagrees, and believes the 3.6.6 study results provide additional understanding regarding the magnitude and duration of project operational effects, particularly as they relate to water levels and flows, on specific water-access recreational sites and facilities. In addition, Attachment A (Study 3.6.6).includes a "daylight hours" analysis of the effects of Project operation on Pauchaug Boat Launch and Barton Cove to provide further understanding.

STUDY NO. 3.3.1 ATTACHMENTS

Attachment A to Study 3.3.1.
Mussel Conference Call Notes and Proposed Reach 5 Mussel Analysis Plan

Mussels Conference Call 1/4/2017 10:00 AM

Attendees: Tom Sullivan (GSE), John Hart (GSE), Jason George (GSE), Ian Kiraly (GSE), Mark Wamser (GSE), Gary Lemay (GSE), Jim Donohue, (FL) Melissa Grader (USFWS), Ethan Nedeau (Biodrawversity), Misty-Anne Marold (NHESP), Jesse Leddick (NHESP), Pete Hazelton (NHESP)

Major Discussion Notes, Points of Agreement, Action Items

1. The group agreed that everyone will consider benthic velocity as 3" above the bed for this analysis.
2. Gary asked for NHESP to elaborate on the juvenile shear stress criteria. Pete stated that they came from an analysis of other empirical studies. Noted that the criteria are meant to cover the period between detachment from host fish, settling to the bed, and then initial substrate attachment before the juveniles burrow into the underlying substrate. While Pete agreed that velocities in April are likely too high for the juvenile criteria, the juvenile target period is June-October.
3. **[AI]** FirstLight has proposed to conduct a quasi-IFIM for the 15[2] transects in reach 5. The analysis will be short of a full-scale IFIM, but will be more detailed than the initial screening analysis that was proposed in the Revised Study Plan (RSP). It will act as a middle-ground between the two. GSE will circulate a written analysis plan to USFWS (Melissa and Brett) and NHESP (Jesse, Pete, Misty-Anne) for this analysis (see attachment A).
4. **[AI]** USFWS and NHESP will need time to review the written plan and discuss if this is appropriate to meet their needs.
5. GSE will evaluate the November 2016 ADCP velocity data and will incorporate it into the quasi-IFIM if possible. The objective of the data collection was to get bed elevations, so it's not known if the velocity data are usable.
6. GSE explained that the existing reach 5 model has been calibrated to water surface elevation information collected as part of pre-licensing baseline studies. The current model can be used to predict velocities across the channel, but they are not calibrated or verified.
7. GSE discussed the difference between the proposed approach and a full IFIM. The primary differences include:
    a. A full IFIM would typically include 2-3 velocity datasets that would help define the velocity distribution across the channel. The screening-level analysis in the October 2016 report included no velocity calibration. The proposed quasi-IFIM will incorporate existing reach 5 velocity data from November 2016 if GSE determines that it is appropriate to use the data in that manner.
    b. The quasi-IFIM will be based on the existing 15 reach 5 transects for which we have good bed elevation and substrate data. The full IFIM may include additional transects if GSE determines that the 15 transects do not fully represent all reach 5 mesohabitats.
8. NHESP asked where the farthest upstream transect (out of the 15 mussel transects) was located, and mentioned that it may be worth looking at the mesohabitat data to assess if the upper end of reach 5 is adequately represented. Tom said that GSE will look into this and the rest of the mesohabitat data to determine if the 15 current mussel transects represent all of the mesohabitats within the 22-mile-long Reach 5 study area **[AI]**.
9. Melissa asked if FL could have used an ADV with divers to calibrate benthic velocity data. GSE responded that we have looked into that possibility, however we have not found an economic way that we can incorporate benthic velocity data collection on a reach-wide scale over multiple flows. GSE explained that the ADCP data that we had previously collected was used to verify the logarithmic velocity distribution in the middle-lower portion of the water column; GSE therefore anticipates relying on the logarithmic velocity distribution for near-bed velocity predictions.

[2] As seen in the study plan below, FL is now proposing to use 16 transects in the proposed mussel assessment.

10. NHESP asked what the threshold would be for triggering a full-blown IFIM versus accepting the results of the quasi-IFIM. GSE said that they weren't sure at this point, and would need to review what we proposed in the study plan.

Attachment A-Proposed Reach 5 Mussel Analysis Plan

Goal

Conduct an enhanced screening level analysis of aquatic mussel habitat in the 22-mile-long stretch of the Connecticut River between the Route 116 bridge in Sunderland, MA and the Dinosaur Footprints river constriction. An addendum to the 3.3.1 study report will be filed by 4/3/2017 outlining the results of this analysis.

Background

An initial screening-level analysis was conducted for the 22-mile-long stretch of the Connecticut River between the Route 116 bridge in Sunderland, MA and the Dinosaur Footprints constriction (i.e., IFIM study reach 5) as described in the October 2016 3.3.1 study report. The results were based on 15 transects located throughout reach 5 that were at or near historic mussel survey locations conducted as part of Holyoke Hydroelectric project's license implementation work.

USFWS and NHESP raised concerns about the assessment's underlying substrate data and the level of model velocity calibration. FL has collected additional field data and proposes to conduct an enhanced screening-level analysis to address these concerns, even though it is beyond what was called for in the RSP's screening-level assessment (task 2a).

FirstLight (FL) collected detailed substrate data at or near[3] the 15 Reach 5 mussel transects from the initial screening level analysis, plus one additional transect at the mussel survey location just downstream of the Hadley dike (River Mile (RM) 99.2). This additional data collection has resulted in a total of 16 potential mussel transects with detailed substrate data.

An acoustic Doppler current profiler (ADCP) was used to collect new bathymetry data at 11 of the 16 transects. This also allowed FL to concurrently collect water surface elevations, transect flow, and water velocity data (mean column and vertical profiles[4]). Benthic velocities were not collected as FL is not aware of a methodology to collect benthic velocities that can be applied in a practical manner over a large, primarily unwadeable area like Reach 5.

Table 1 outlines the 16 mussel transects' sources for substrate, bathymetry, and velocity data. The Reach 5 flows were measured by the ADCP in real-time. Transects are identified by HEC-RAS river mile (RM) stationing, which are measured as miles upstream of the Connecticut River's mouth at Long Island sound. Figure 1 is a map showing the transect locations.

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[3] Some of the initial screening analysis transects were located near, but not directly over, surveyed mussel beds. For such transects, the newly-collected transect data were instead collected directly over the mussel survey locations.
[4] The ADCP unit used collects water velocities in variables-sized bins (usually 0.5 to 2.0 ft) from the water surface as close as 1-2 feet from the riverbed.

Table 1: Source and collection data for the 16 proposed mussel transects.

Transect River Mile (RM) Stationing	Substrate	Bathymetry	Velocity
106.3	FL, Nov 2016	FL, Nov 2016	FL, Nov 2016
101.1	FL, Nov 2016	FL, Nov 2016	FL, Nov 2016
100.2	FL, Nov 2016	FL, Nov 2016	FL, Nov 2016
99.2	FL, Nov 2016	FL, Nov 2016	FL, Nov 2016
96.7	FL, Nov 2016	TNC, 2014	None collected
96.4	FL, Nov 2016	TNC, 2014	None collected
96.3	FL, Nov 2016	TNC, 2014	None collected
94.8	FL, Nov 2016	TNC, 2014	None collected
94.3	FL, Nov 2016	TNC, 2014	None collected
93.1	FL, July 2016	FL, July 2016	FL, July 2016
92.8	FL, July 2016	FL, July 2016	FL, July 2016
92.4	FL, July 2016	FL, July 2016	FL, July 2016
92.0	FL, July 2016	FL, July 2016	FL, July 2016
90.8	FL, July 2016	FL, July 2016	FL, July 2016
89.4	FL, July 2016	FL, July 2016	FL, July 2016
88.5	FL, July 2016	FL, July 2016	FL, July 2016
FL = FirstLight; TNC = The Nature Conservancy			

The mussel analysis described in the October 2016 study plan was intended to address the screening-level analysis described in Task 2a of the RSP. If the screening-level analysis showed that certain habitat thresholds were met, then a detailed study as described in Task 2b was to be conducted. The threshold for triggering the detailed study analysis (conducting Task 2b) as noted in the RSP was if any binary habitat thresholds were exceeded (i.e., suitable habitat turned into not suitable habitat) within the Turners Falls dam operating range of approximately 16,000 cfs. Given the comments provided on the screening analysis from USFWS and NHESP, FL intends to combine most elements of the detailed analysis (Task 2b) into this enhanced screening effort an effort to meet the detailed study objectives while using available data.

Transect Representativeness

FL believes that these 16 transects are representative of all major Reach 5 mesohabitats. The Reach 5 mesohabitat distribution shows that Reach 5 consists of 89% run, 9% pool, <2% glide, and <1% backwater based on longitudinal habitat mapping, while the substrate distribution is approximately 70% sand, 18% gravel, 9% unknown (in pools too deep to assess substrate), <3% bedrock, and <1% silt. Reach 5 can be broken down into two general sections; the upper part of Reach 5 is primarily a run with gravel as the dominant substrate, while the lower part of Reach 5 is primarily a run with sand as the dominant substrate. The 16 transects that we have chosen represent a wide variety of runs (which make up nearly 90% of the reach) and include sand-dominated and gravel-dominated river reaches. Deeper pool areas were not surveyed for mussel presence in the HG&E surveys; therefore FL is not proposing to include any pool transects in this habitat analysis.

The Route 116 Bridge is near River Mile 109.5 and the downstream extent of Reach 5 is at River Mile 87.5, for a total reach 5 length of approximately 22 miles. FL's upstream-most transect in Reach 5 is at RM 106.3, about 3 miles downstream of Route 116 Bridge. The lowermost transect is near RM 88.5, about 1 mile upstream of the Dinosaur Footprints bedrock area where Reach 5 terminates.

Figure 2 shows the 16 transects overlain with the Reach 5 mesohabitats.

Benthic Velocity/Velocity Profile Analysis

Benthic velocities will be defined as the water velocity 0.25 ft (3 inches or about 7.5 cm) above the riverbed. Water velocities this close to the bed, while measureable for small-scale (wadeable) efforts or laboratory situations, are difficult and expensive to collect on a large-scale in unwadeable river reaches like the Reach 5 study area. Therefore, FL intends to use a rearrangement of the log-law velocity profile (ASCE Manual 110, Chapter 2), which calculates benthic velocity as a function of bed roughness (approximated by substrate), water depth, and mean column velocity. The equation, after some re-arrangement, is:

$$u = U * \frac{\ln\left(30*\frac{z}{k_s}\right)}{\ln\left(11*\frac{H}{k_s}\right)}$$, where

u = benthic velocity (ft/s);
U = mean column velocity (ft/s);
z = distance above the riverbed (ft);
k_s = bed roughness (ft);
H = water column depth (ft); and
Z = distance above the riverbed (ft) = 0.25 ft for all Reach 5 benthic velocity calculations.

Some questions have been asked regarding how applicable applying the log-law profile is versus collecting actual field data. FL examined this by fitting a logarithmic function for the data collected in Reaches 4 and 5. The resulting logarithmic function fit to the data reasonably approximated the theoretical functions based on larger substrates with greater bed roughness in Reach 4 relative to the finer substrates with lower bed roughness in Reach 5 (Figure 3a and 3b).

Description/Scope

This is a moderate level-of-effort between the 'screening' analysis proposed in the Revised Study Plan (RSP) and a full-scale IFIM study. The hydraulic model will be calibrated to currently available field data, which includes detailed substrate and bathymetry data, plus water surface elevations and depth-averaged water column data at a subset of the transects.

The analysis will be based on 16 transects with detailed substrate data located throughout Reach 5. The analysis will involve the following tasks.

Task 1 – Hydraulic Modeling

The objective of the hydraulic modeling is to produce the parameters needed to conduct the habitat modeling. Specifically, outputs will include cellular depth, mean column velocity, benthic velocity, and shear stress at several flows for each transect. Substrate is an additional parameter that will be needed for the habitat modeling, but it does not vary as a function of flow. We propose to conduct the hydraulic modeling with the following major steps:

1. The HEC-RAS one-dimensional hydraulic model will be used to model water surfaces throughout reach 5. The model will be calibrated to available water surface elevation data to estimate each transect's composite Manning's n-value as well as the energy grade line (EGL) slope (for calculating shear stresses).

2. HEC-RAS computes one EGL slope per cross-section; therefore FL will calculate cellular shear stress using the following equation:

   $\tau_{bed} = \gamma * R_h * S_f$, where
   τ_{bed} = shear stress acting on the streambed (psf)
   γ = specific weight of water = 62.4 lb/ft^3
   R_h = hydraulic radius (ft), which will be approximated as cellular water depth (ft); and
   S_f = friction slope, which will use the cross-sectional energy grade slope from HEC-RAS.

3. The calibrated HEC-RAS model results (water surface elevations for various simulated flows) will be imported into PHABSIM. PHABSIM's VELSIM module will then be used to calculate cellular mean column velocities across the transect. We will assume a constant manning's n value across the transect. The transects generally contain relatively uniform substrate, so we believe assuming a constant manning's n across each transect is a reasonable assumption for a study of this level-of-effort.

4. The VELSIM velocity results will be compared (i.e., validated) against mean column velocity data from the ADCP, at transects where velocity data are available. Velocity datasets are not available at all transects.
5. The VELSIM cellular mean column velocities across each transect will be converted to benthic velocities using the previously described log-law velocity profile equation.

FL proposes to model the flows in Table 2. These include flows similar to those recommended by NHESP in their comment letter. All scenarios at 16,000 cfs or less (1-5) will be run for low and high Holyoke impoundment levels of 99.47 ft NGVD29 and 100.67 ft NGVD29, respectively. All scenarios for flows greater than 16,000 cfs (6,7,8) will only be run for the low-Holyoke pond level as river levels at moderate and higher flows are primarily controlled by the hydraulic constriction at Dinosaur Footprints and not Holyoke pond levels.

Table 2: Proposed steady-state mussel and host fish habitat flows.

Scenario	Flow (cfs)
1	1,500
2	3,000
3	6,000
4	9,000
5	16,000
6	18,000
7	23,000
8	38,600

Task 2 – Steady-State Habitat Modeling

The objective of this task is to combine the substrate and hydraulic data (depth, velocity (benthic or mean column, depending on species[5]), and shear stress (mussels only)) with the binary habitat suitability criteria (HSC) that have been developed with the Delphi panel[6]. Cellular suitability values will be calculated as the product of suitabilities for all HSC, resulting in a composite suitability of 0 (doesn't meet one or multiple criteria) or 1 (meets all criteria) due to the binary HSC.

FL will provide steady-state results (flow vs. % suitable) at each of the 16 transects for all juvenile and adult state-listed mussels (yellow lampmussel, eastern pondmussel, tidewater mucket), plus the adult lifestages of potential host fish for the three state-listed mussels. The proposed adult host fish that we will model for each mussel species are included in Table 3. The HSC used for these species will be represented by habitat guilds, which have previously-established curves from other reaches within this study.

Results will be presented in figures (e.g., % suitable vs. flow) and tables (e.g., % of suitable habitat at different flows) on a transect-by-transect basis. If the stakeholders want to use the results to predict reach-wide mussel and host fish habitat, FL will also work with the stakeholders to determine an appropriate weighting methodology to apply habitat results from the 16 analysis transects to a full-reach habitat estimate using the representative transect methodology. Raw cellular analysis results will be made available to stakeholders in an appendix or upon request in an electronic format if the calculations are too cumbersome to fit in a paper format.

[5] All mussel species velocity HSC will be evaluated using benthic velocities, while the host fish will be evaluated using mean column velocities.
[6] The shear stress criteria proposed by NHESP have not been reviewed by the Delphi panel.

Table 3: Potential host fish for the three state-listed mussels in Reach 5. Bolded species will be used for the host fish assessment.

Mussel Species	Host Fish	Fish species guild
Yellow Lampmussel	**White perch; yellow perch;** possibly **striped bass**; potential species include banded killifish, chain pickerel, white sucker, smallmouth bass, largemouth bass	White perch – Deep slow Yellow perch– Deep slow Striped bass– Deep fast
Eastern Pondmussel	Unknown: anadromous or coastal **Yellow perch; banded killifish**;	Yellow perch– Deep slow Banded killifish – Shallow slow
Tidewater Mucket	**White perch; banded killifish**; **striped bass** possible but not tested.	White perch – Deep slow Striped bass – Deep fast Banded killifish – Shallow slow

Task 3 – Dual-Flow Habitat Modeling

When streamflow varies, habitat quality may decrease in some habitat cells, while increasing in others. A dual flow analysis is commonly used to calculate the quantity of habitat that is present over a flow range, such as those that may be expected during a minimum flow/peaking flow hydroelectric operation. A dual flow analysis is particularly geared toward assessing peaking operations' impact on low-mobility species such as mussels, as it assesses the amount of habitat that remains over a given cell over a range of flows. For immobile aquatic biota, a dual flow analysis typically assumes that a transect's available habitat is equal to the sum of the individual cells' minimum habitat for a given flow pair. This analysis is somewhat simplified when using binary HSC, as habitat is either described as 'suitable' (meets all habitat criteria) or 'unsuitable' (does not meet one or more habitat criteria).

FL proposes to conduct dual-flow analyses for the three target mussel species (yellow lampmussel, eastern pondmussel, tidewater mucket) for juvenile and adult lifestages. Dual flow analyses will not be conducted for the mussel host fish, as adult lifestages are generally assumed to be mobile and able to travel between areas of suitable and unsuitable habitat throughout a peaking cycle.

Dual flow habitat will be defined as habitat that is suitable across a given flow pair (e.g., 1,500 cfs to 16,000 cfs) plus all modeled flows in-between the pair. For example, a cell would be considered dual-flow habitat for the 1,500-16,000 cfs flow pair if steady-state habitat was suitable at 1,500, 3,000, 6,000, 9,000, and 16,000 cfs. Dual flow habitat will calculated independently for low and high Holyoke impoundment levels. The dual flow analysis will be run for all modeled steady-state flow combinations.

Results will be presented in tabular format comparing the amount of dual-flow habitat available at different flow combinations. Raw cellular analysis results will be made available to stakeholders in an appendix or upon request in an electronic format if the calculations are too cumbersome to fit in a paper format.

Task 4 – Comparison of Modeling Results with Mussel Abundance

Mussel survey data were collected by HG&E in 2005, 2009, and 2013. FL will compare the dual-flow modeling results with catch per unit effort (CPUE) data at each of the transect locations evaluated. General trends or patterns in state-listed mussel CPUE will be examined relative to the dual flow habitat suitability.

Task 5 –Stakeholder Result Consultation

The RSP stated that if any HSC thresholds change from suitable to unsuitable within FL's operating range (1,500 cfs to 16,000 cfs), then FL will be required to conduct the detailed assessment described in Task 2b of the RSP. In an attempt to address comments on the initial screening-level analysis, FL has incorporated nearly all of the extra analysis from Task 2b into this enhanced screening analysis. Upon completion of this analysis, FL will share the results with stakeholders and consult with them to confirm the results are adequate for informing flow management recommendations.

Task 6 – Study Addendum

A study addendum will be filed with FERC summarizing the results of each study plan task.

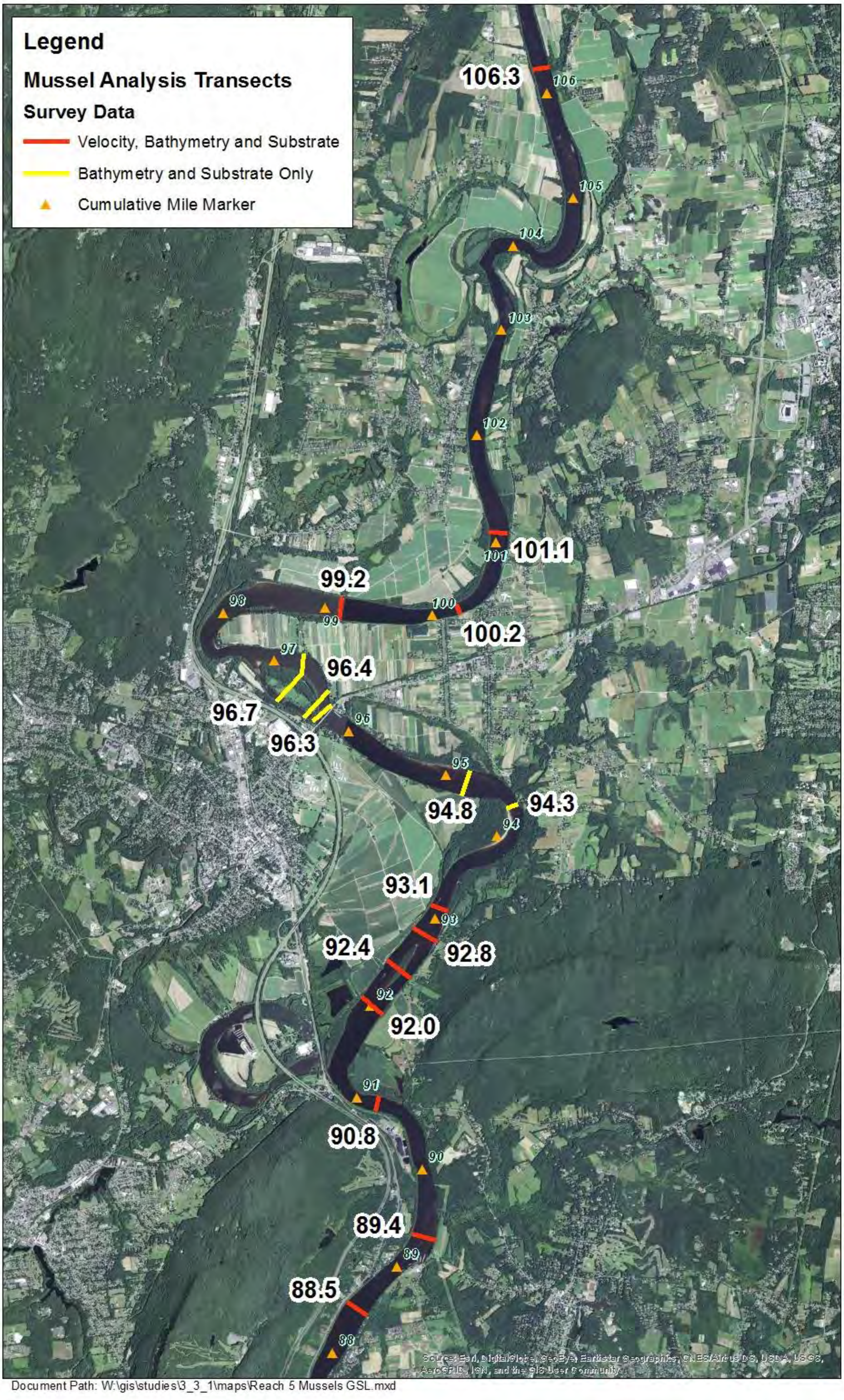


Figure 1: Proposed mussel analysis transects in reach 5.

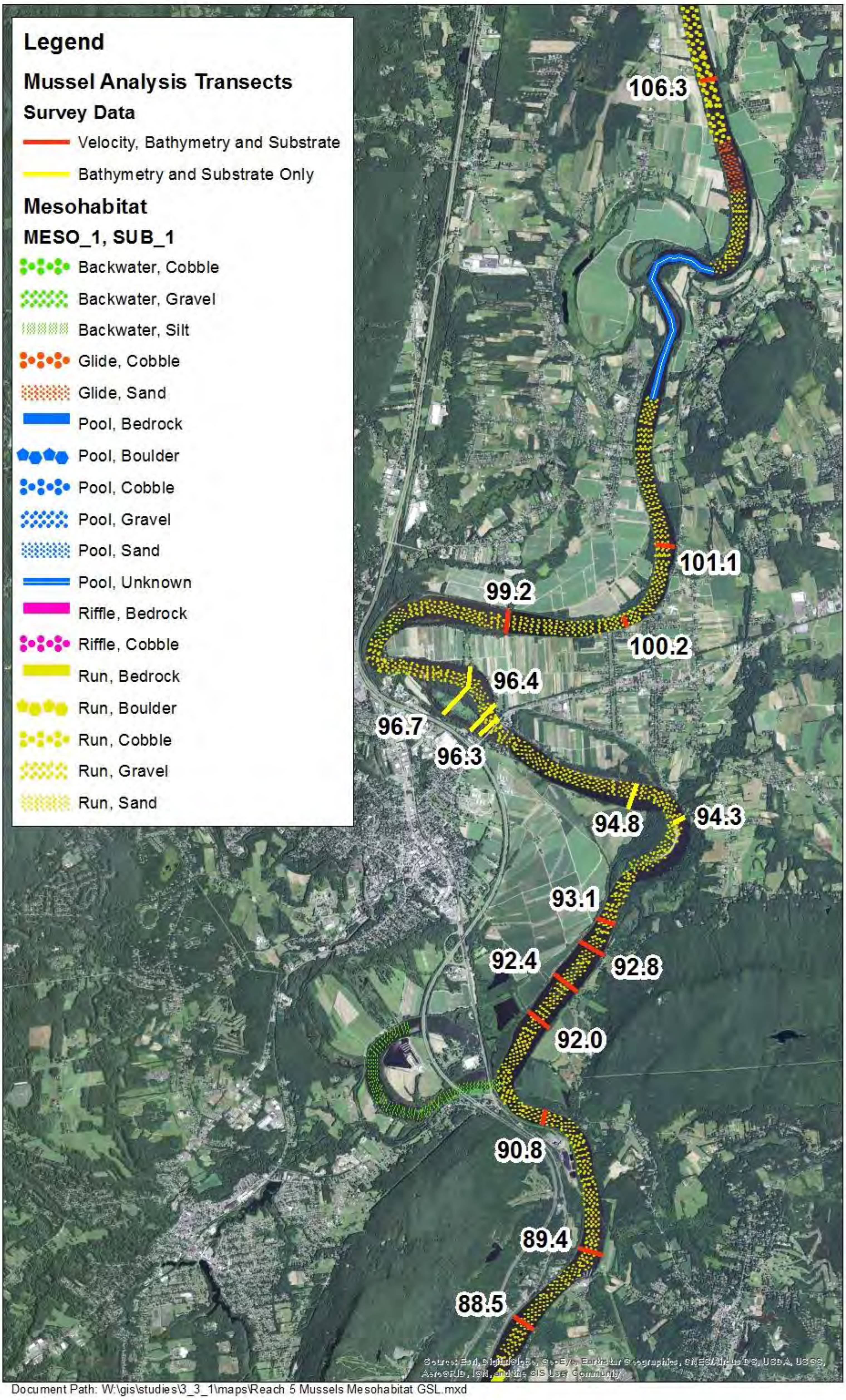
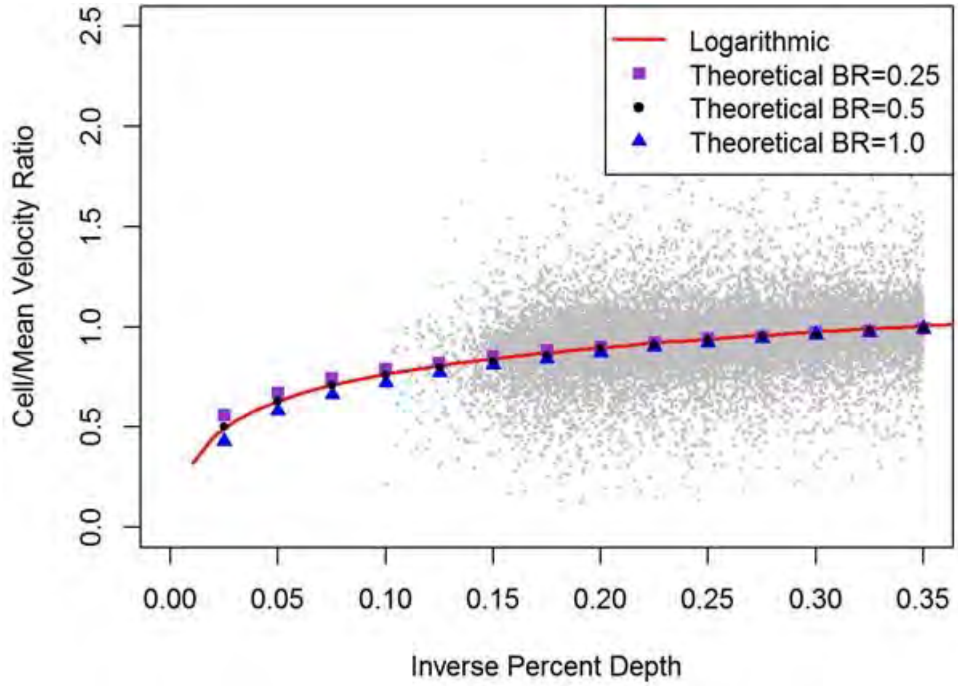
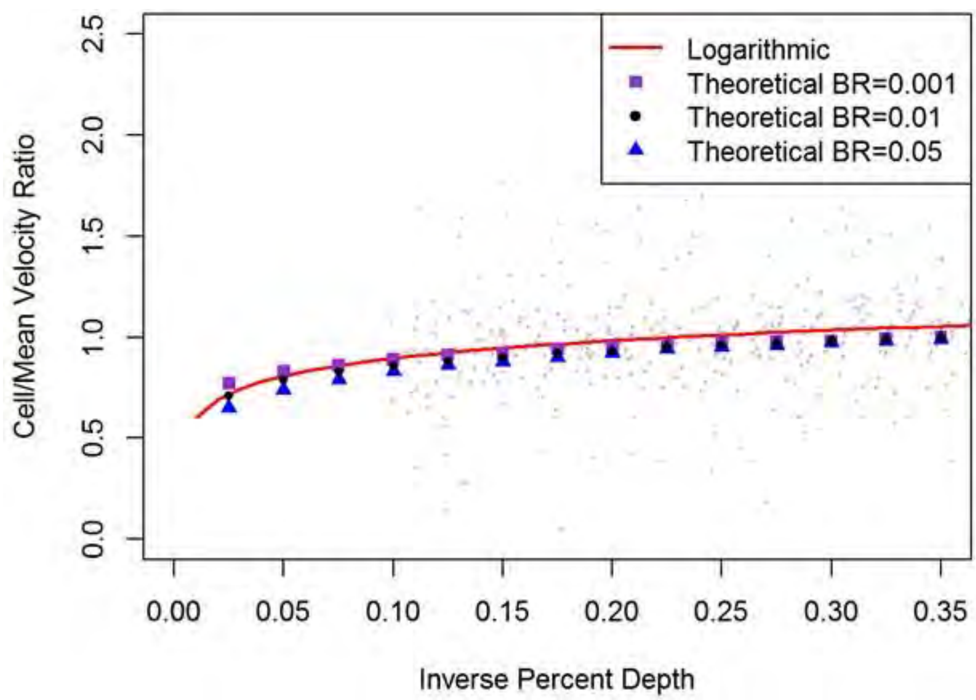


Figure 2: Proposed mussel analysis transects overlain with the Reach 5 mesohabitat mapping results.

Figure 3a (top) and 3b (bottom): Comparison of field-collected velocities in the lower 35% of the water column versus the log-law equation for Reach 4 (3a) and Reach 5 (3b). The x-axis is the % depth in the water column (e.g., 0.15 in a 10-ft deep area equals 1.5-ft above the bottom. The y-axis is the ratio of the cellular velocity to the mean column velocity (e.g., a value of 0.5 means the velocity at that depth is 50% of the mean column velocity). Each grey dot represents a field-measured ADCP cellular velocity. The red line represents the best-fit logarithmic line. The purple squares, black circles, and blue triangles represent log-law predicted cellular velocities at different bottom roughness (k_s) values





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Attachment B to Study 3.3.1.
Reach 1 Zone of Passage and Center - Channel Cross Section Locations

FirstLight Power Resources

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
RELICENSING STUDY 3.3.1

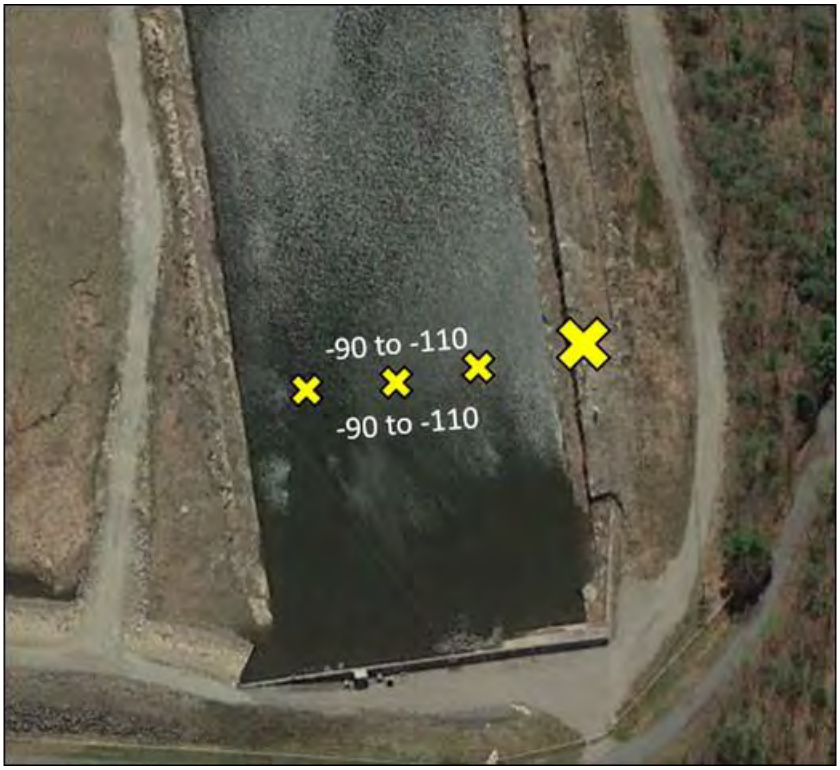
Reach 1 Zone of Passage and Center-Channel Cross Section Locations

Path: W:\gis\studies\3_3_1\maps\Reach_1_ZOP_and_CenterChannel.mxd

STUDY NO. 3.3.2 ATTACHMENTS

Attachment A to Study 3.3.2.

Figure A-18. The Upper Reservoir monitoring station consisting of an Orion receiver with double 3-element Yagi (location indicated by large X) and three, in-water dropper antennas (location indicated by small x) that were suspended mid-depth using 8-lb. downrigger weights. The test tag produced power levels ranging from -110 to -90 dB.



STUDY NO. 3.3.3 ATTACHMENTS

Attachment A to Study 3.3.3.
Memo Rate of Juvenile American Shad Entrainment at NMPS

Stakeholders have indicated that they need to know the rate of entrainment of juvenile American Shad at Northfield Mountain Pumped Storage Project (NMPS) to assess the impact of the facility on the restoration of this anadromous species. In 2015, FirstLight deployed hydroacoustic monitoring equipment in the NMPS intake/tailrace to estimate the number of juvenile shad entrained as they emigrate past the Project. A single split-beam system with four transducers was installed at NMPS. Each transducer was mounted to a pole and affixed to the top of a concrete wall. The transducers were installed at an elevation of approximately 178 feet msl, aimed downward and slightly away from the intake structure, approximately 10° up from vertical. Viewed from the front of the intake, each transducer was aimed along the center line of one of the four intake bays. Unfortunately, milling was a major issue and no estimate of entrainment resulted from this effort. Radio telemetry was also used to estimate entrainment of juvenile shad at NMPS. However, poor tag retention and low survival of test fish, along with limited detection of test fish yielded questionable results. In its comment letter dated December 13, 2016, USFWS indicated that it is not appropriate to base an entrainment estimate on numbers of tagged fish detected in the upper reservoir due to potential tag loss upon entrainment. Given that hydroacoustics evaluation is not feasible at NMPS, and given the concerns with tag loss at NMPS, FirstLight proposes to base entrainment estimates of juvenile shad at NMPS on a previous robust netting study conducted in 1992. The numbers of adult shad that passed Turners Falls at the time of the study were similar to current passage numbers, and NMPS pumping was also similar. Therefore, FirstLight believes the previous entrainment study conducted at NMPS in 1992 (filed into the record on March 18, 2014 and attached as Appendix A) is still applicable.

In 1991 and 1992, a number of methods were used to assess the impact of the operation of the NMPS facility on juvenile American Shad in the Connecticut River, including trawls, seining, electrofishing, and netting in the Upper Reservoir (LMS 1993). The objectives were to determine the temporal and spatial distribution of juvenile American Shad in the vicinity of the NMPS intake and to estimate entrainment of juvenile shad during pumping operations. Of the study methods, netting in the Upper Reservoir was used to determine an entrainment estimate.

The netting study had a robust sampling scheme and 23 entrainment samples were collected from August 9 to October 27, 1992 by deploying a 5' x 34' framed net at the opening of the discharge tunnel in the upper reservoir during pumping operations. The area of the net represented about 11% of the area of the tunnel opening, such that only a portion of the total volume of water pumped was actually filtered through the net. The net was maintained at the same elevation for the duration of the sampling program. The net was deployed after pumping began (typically near 23:30) and continued to sample for up to 5.5 hours. Eight flow meters mounted in the mouth of the frame allowed the volume of sampled water to be calculated.

The efficiency of the net frame was also assessed based on 13 sampling events in which marked juveniles (both alive and dead) were introduced into plant flow and the number recaptured was recorded. The net efficiency calculation accounted for the percentage of water that was sampled by the net relative to total volume pumped, and was ultimately used to adjust the juvenile entrainment estimate.

Throughout the entrainment sampling events, it was determined that the net sampled about 6.5-13.9% of the pumping cycle flow. During the 80.2 hours and 8,204,756 m3 of water sampled, 331 juvenile shad were collected during sampling events from August to late October. For net efficiency testing, 262 shad overall, or 8.2% of the marked fish released, were recaptured in the entrainment net during the 13 efficiency sampling events. The extrapolation of counts based on the total volume of water pumped and net efficiency yielded an estimate of 37,260 juvenile shad that were entrained during the late summer to fall migration season of 1992.

The overall mean volume of water filtered through the net (11.7%) was close to the percent of the outlet area occupied by the net frame, indicating that the net was fishing effectively. While there was variability in the weekly entrainment net catch rate, the peak catch rate coincided with the expected seasonal peak of the shad migration. Juvenile catch was greatest in mid-October corresponding to a period of decreasing water temperatures, consistent with O'Leary and Kynard (1986). The estimated entrainment of juvenile shad at NMPS was 37,260 individuals (standard error = ±11,900), which included a 74% adjustment for net efficiency. The sampling design consisted of several sampling events over the duration of the migration period and allowed for a reduction of bias in the sampling results. The consistency of the net recovery results and the volume of NMPS flow that was filtered during each sampling event supports the reliability of the entrainment estimate for juvenile shad at NMPS.

To demonstrate that the 1992 juvenile shad entrainment estimate at NMPS described above is still applicable today the number of adult American Shad in the Turners Falls impoundment and NMPS operations were compared between the two periods. The juvenile entrainment assessment of 1992 occurred during August, September and October, which included the typical period of outmigration of juvenile shad from rearing areas in rivers to the ocean. Mean monthly discharge of the Connecticut River as reported for USGS Gage No. 01170500 (Connecticut River at Montague City, MA) ranged from 5,545 cfs in August to 6,926 cfs in October, 1992 and between 4,975 cfs in September and 10,100 cfs in October, 2015 (Table 1).

Table 1. Mean monthly discharge (cfs) of Connecticut River based on USGS Gage No. 01170500 Connecticut River at Montague City, MA.

Month	1992	2015
August	5,545	5,554
September	6,005	4,975
October	6,926	10,100

Additionally, the numbers of adult American shad that passed into the Turners Falls impoundment were similar in 1991-1992 and 2015-2016 (Table 2). This would most likely result in comparable numbers of juvenile shad passing the NMPS tailrace during these two periods, assuming similar larval and juvenile survival.

FirstLight has filed information (Supplemental Information Relevant to U.S. Fish and Wildlife Service Notice of Study Dispute at 2, Project Nos. 1889-081 and 2485-063, filed Mar. 28, 2014) into the record to clarify that there has been less overall utilization of NMPS since the 1992 study was conducted and consequently a decrease in the amount of pumping, and that there has been no significant change in pump discharge since the Project was constructed. Overall pumping between 1992 and 2015 during the emigration of juvenile American Shad (August through October) demonstrated higher pumping in 1992 than 2015 (Figures 1-3). Pumping relative to the time of day between 1992 and 2015 was similar, with most pumping occurring between midnight and the early morning hours, though pumping appeared to be more frequent overall in 1992 (Figures 4-5). In 1992, pumping typically extended approximately an hour further into the morning, and also occurred occasionally with one-unit during the daytime hours. Alternatively, no pumping occurred during the day in August-October 2015. Using the 1992 study results would provide an estimate of entrainment that would overstate the amount of entrainment at the Project today.

Since the number of adult shad in the Turners Falls Impoundment was similar and NMPS pumping in 2015 as compared to 1992 was less, assessing the impact of the operation of the NMPS facility on emigrating juvenile American Shad using the 1992 study results would provide a conservative estimate of juvenile American Shad entrainment.

Table 2. American shad passage into the Turners Falls Impoundment, 1980-2016

Year	American Shad
1980	298
1981	200
1982	11
1983	12,705
1984	4,333
1985	3,855
1986	17,858
1987	18,959
1988	15,787
1989	9,511
1990	27,908
1991	54,656
1992	60,089
1993	10,221
1994	3,729
1995	18,369
1996	16,192
1997	9,216

Year	American Shad
1998	10,527
1999	6,751
2000	2,590
2001	1,540
2002	2,870
2004	2,192
2005	1,581
2006	1,810
2007	3,248
2008	3,995
2009	3,814
2010	16,768
2011	16,798
2012	26,727
2013	35,293
2014	39,914
2015	58,079
2016	54,069

Figure 1. NMPS pumping in MW in August 1992 and August 2015.

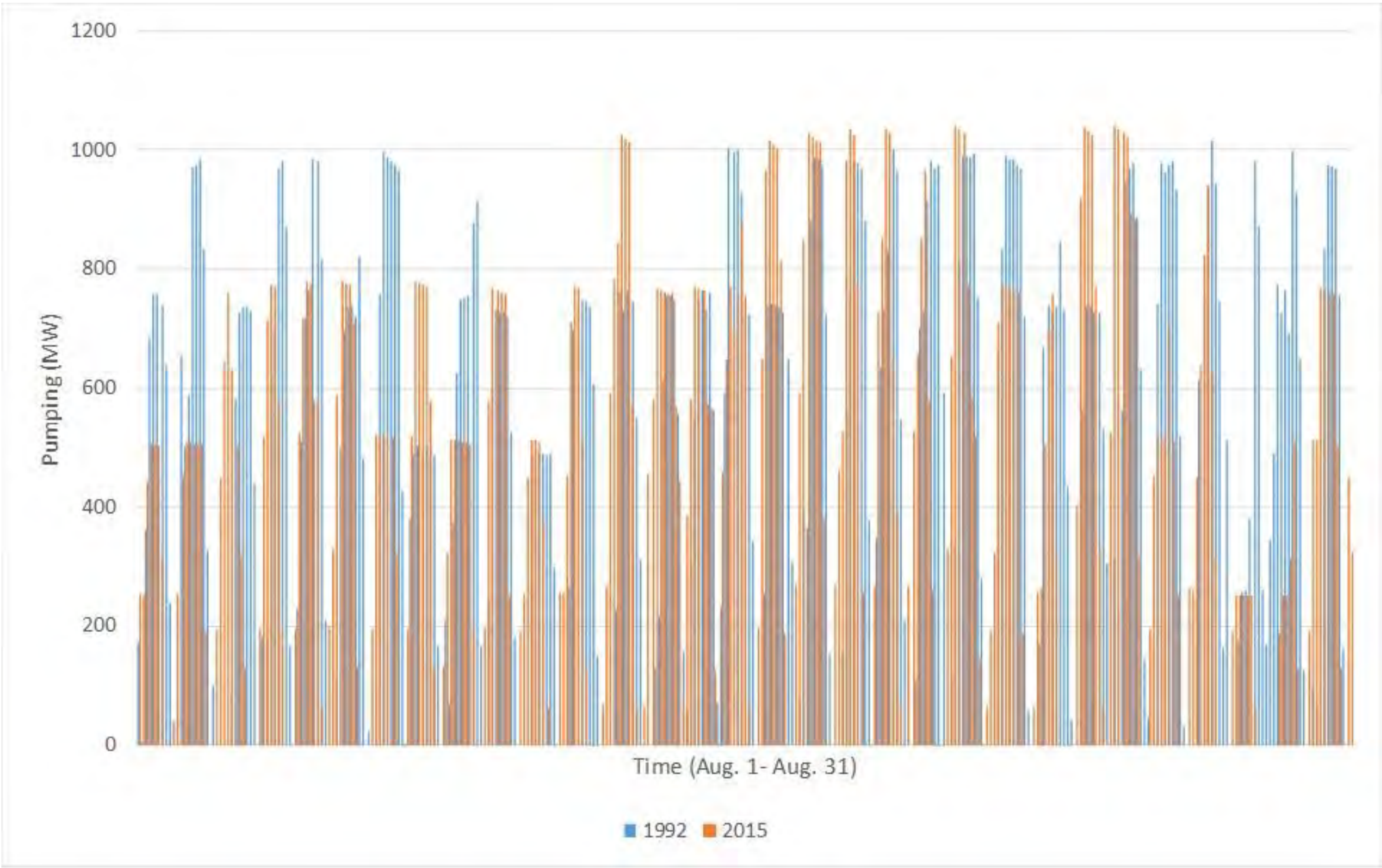


Figure 2. NMPS pumping in MW in September 1992 and September 2015.

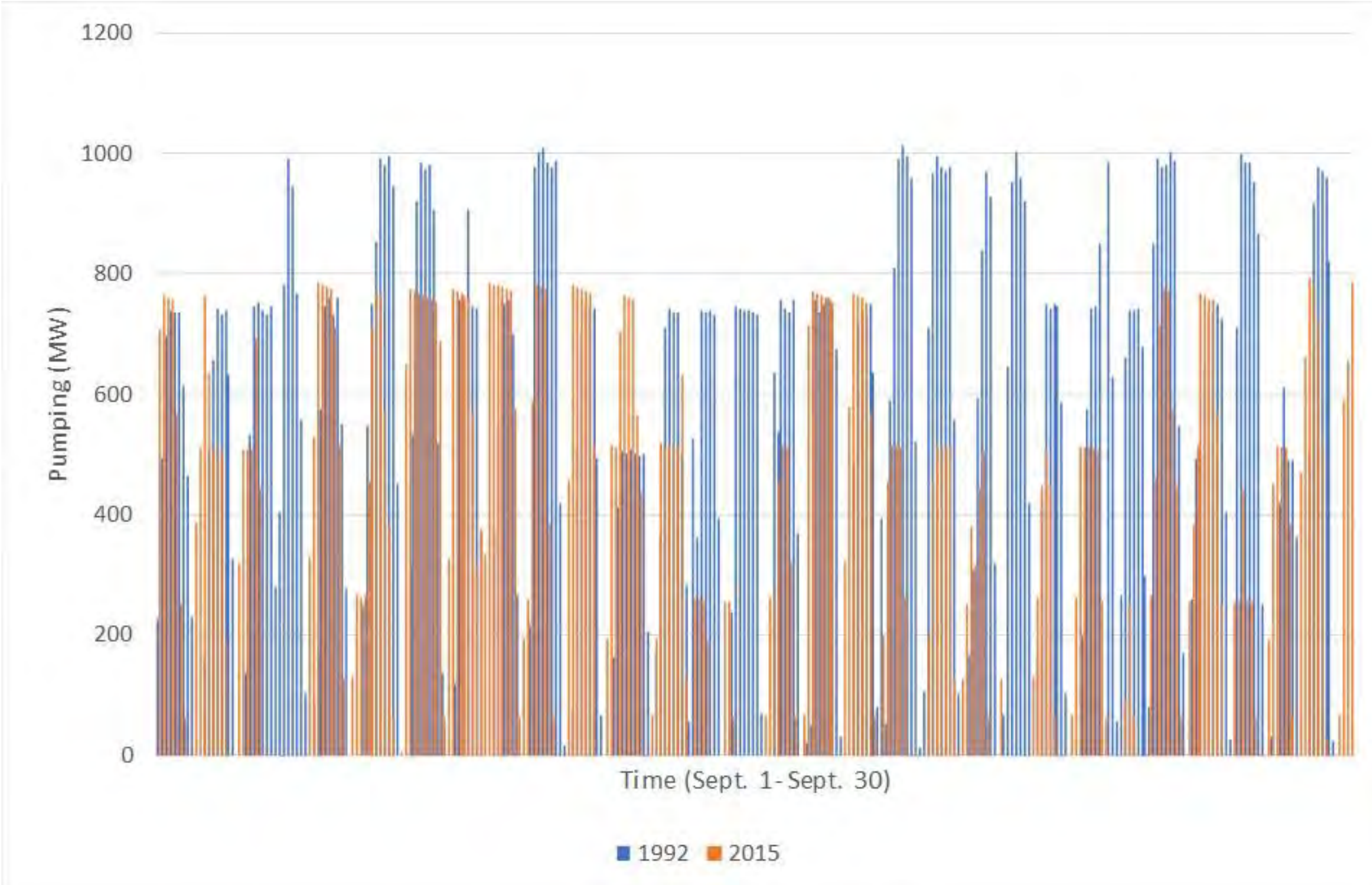


Figure 3. NMPS pumping in MW in October 1992 and October 2015

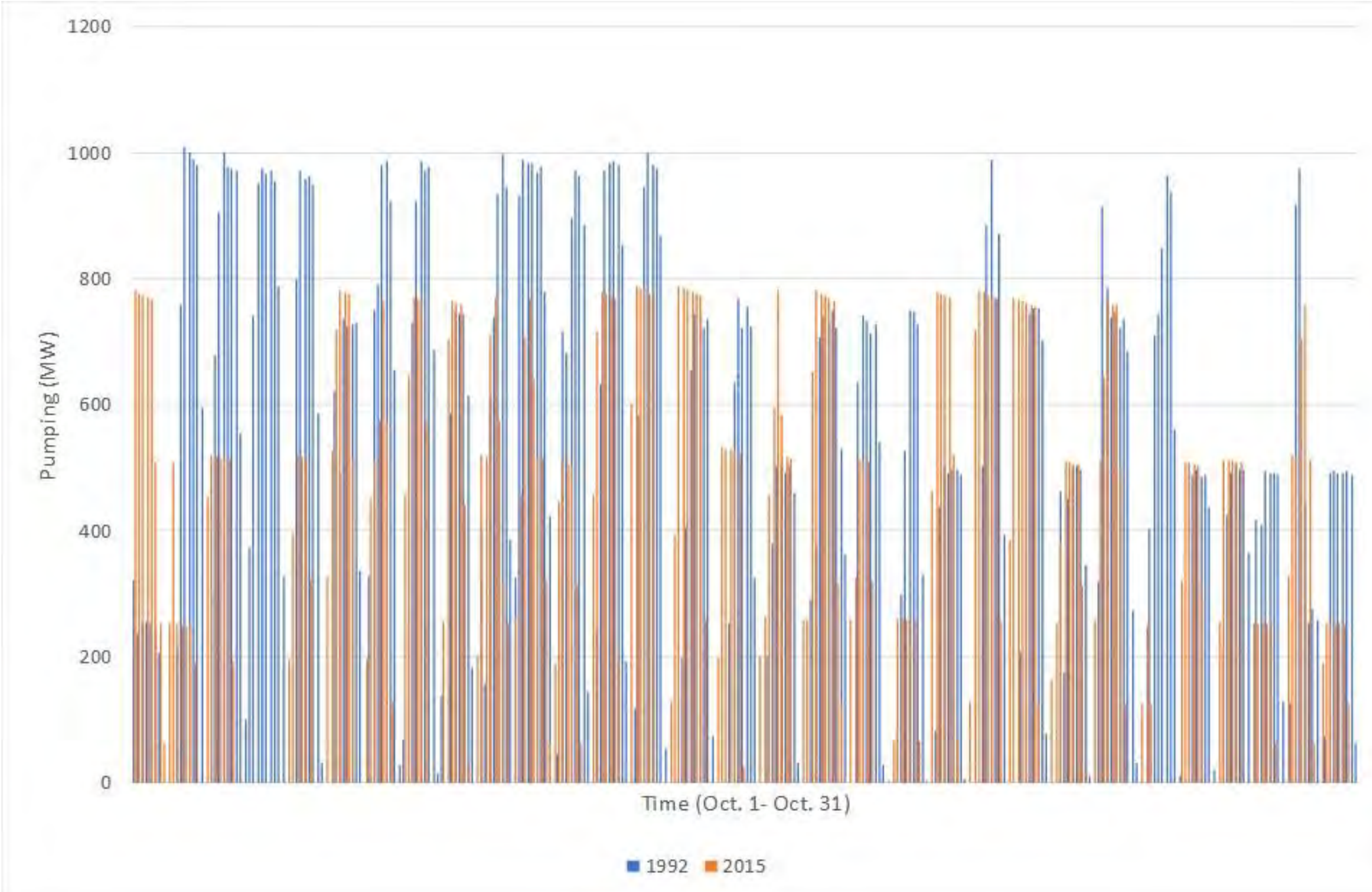


Figure 4. Frequency of pumping at Northfield Mountain in August/September/October 1992 relative to the time of day

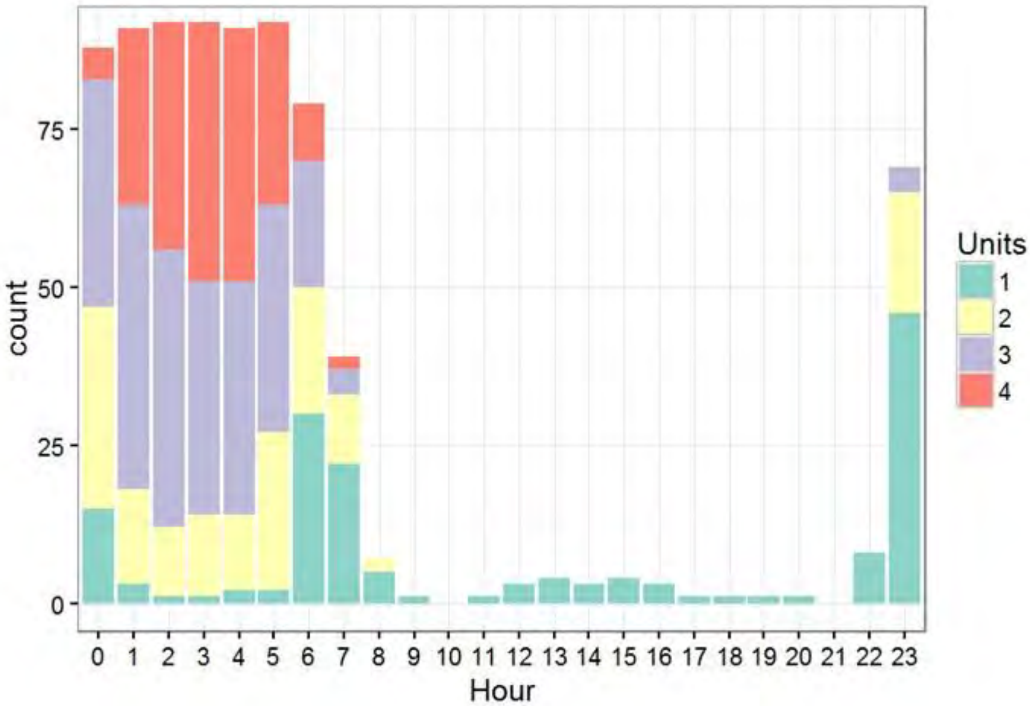
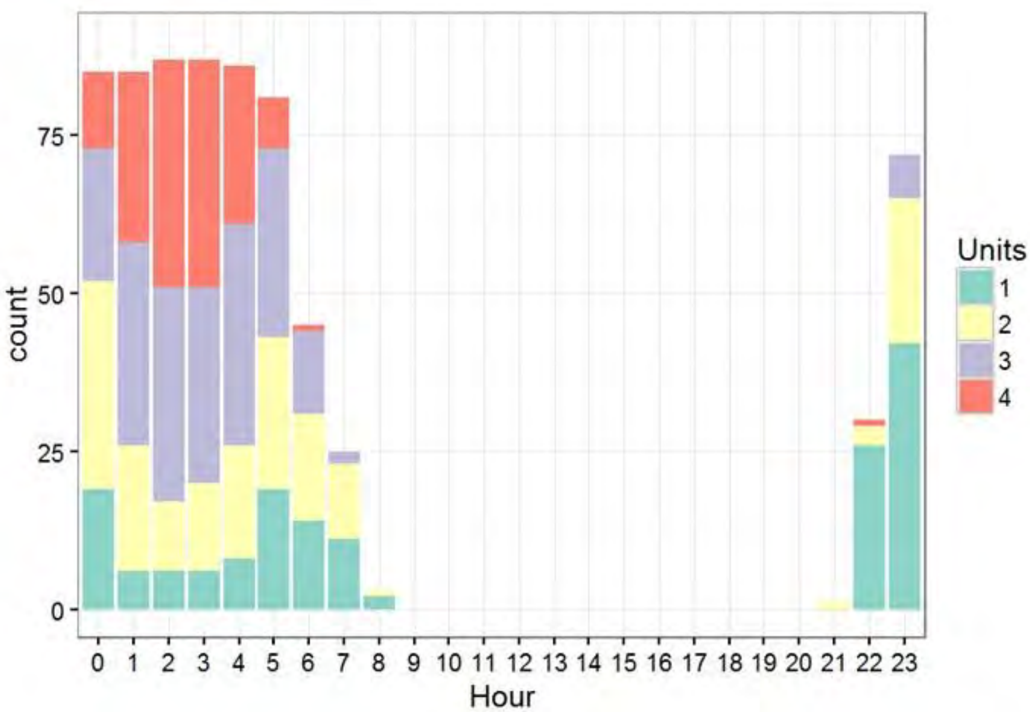


Figure 5. Frequency of pumping at Northfield Mountain in August/September/October 2015 relative to the time of day



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Lawler, Matusky & Skelly Engineers (LMS). (1993). Northfield Mountain Pumped-Storage Facility 1992 American shad studies draft report. FERC Project No. 2485. Prepared for Northeast Utilities Service Company, Berlin, CT.

O'Leary, J. A. and B. Kynard. 1986. Behavior, length, and sex ratio of seaward-migrating juvenile American shad and blueback herring in the Connecticut River. North American Journal of Fisheries Management. 15:529-536.

Prepared for

NORTHEAST UTILITIES SERVICE COMPANY

Berlin, Connecticut

NORTHFIELD MOUNTAIN

PUMPED-STORAGE FACILITY

1992 AMERICAN SHAD STUDIES

DRAFT REPORT

February 1993

Northfield: FERC Project No. 2485

Prepared by

LAWLER, MATUSKY & SKELLY ENGINEERS
Environmental Science & Engineering Consultants
One Blue Hill Plaza
Pearl River, New York 10965

Project No. 298-011/012/013

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EXECUTIVE SUMMARY

In accordance with a Memorandum of Agreement between the Northeast Utilities Service Company (NUSCo) and the resource agencies responsible for the management of migratory fish on the Connecticut River, NUSCo conducted studies in 1992 to assess the impact of the Northfield Mountain Pumped-Storage Facility (NMPSF) on American shad. The objectives of this study were to estimate the number of juvenile shad entrained by the NMPSF to provide a basis for calculating the impact of the facility on the river's shad population.

The NMPSF system consists of a riverine intake, an underground powerhouse and control room, and an upper storage reservoir, located approximately 800 ft above, and 8000 ft east, of the river. The NMPSF has four units each having the capacity to pass up to 5000 cfs in the generation mode and up to 3600 cfs in the pumping mode depending upon the upper reservoir elevation.

The study plan involved sampling for shad ichthyoplankton in the NMPSF nearfield region, electrofishing for juvenile shad at 10 stations, two each in five strata encompassing the length of Turners Falls Pool, and entrainment net sampling in the upper reservoir. Eleven ichthyoplankton samples were taken from 21 May to 22 July (nine of them at night), 13 electrofishing surveys were conducted at night from 23 June to 20 October, and 23 entrainment samples were taken during the plant's pumping cycle from 9 August to 27 October. Thirteen net efficiency tests were run in conjunction with entrainment sampling.

Peak densities of shad ichthyoplankton (life stages combined) were collected on 18 June. No significant difference in shad ichthyoplankton densities was detected among sampling stations. By life stage, peak densities of eggs and yolk-sac larvae were collected on 11 June and on 18 June for post yolk-sac larvae. While the seasonal peaks in the various life stages followed an expected pattern of maturation, quantitatively, a much greater density of post yolk-sac larvae was observed compared to both eggs and yolk-sac larvae. This difference in density may have been due to sampling methodology and gear biases.

A significant difference in the Catch-Per-Unit-Effort (CPUE) of juvenile shad was detected among sampling strata; the greatest CPUE of shad occurred in the strata located farthest upstream of the plant. CPUE did not differ significantly among sample dates. Greatest shad growth in Turners Falls Pool occurred from June through August; shad lengths (TL) remained near 82 to 83 mm from mid-September through late October, due either to the cessation of the growing season or the influx of individuals from upstream areas.

A total of 331 shad were collected during the 80.19 hours and in the 8,204,756 m^3 of water sampled during the entrainment netting program. The net filtered between 6.46 and 13.92% of the plant flow during sampling. Greatest entrainment catch rates were recorded in mid-October and they generally corresponded to a period of rapidly decreasing water temperature, peaking near 14 to 15°C. The length of shad collected in the entrainment samples generally corresponded to the length of shad collected from Turners Falls Pool.

INTRODUCTION

The American shad (*Alosa sapidissima*) is an important anadromous species that uses the Connecticut River for reproduction and as a juvenile rearing habitat. In 1992, 721,359 adult shad were counted at Holyoke Dam and 60,089 of them migrated upstream of Turners Falls Dam. Juvenile American shad found in and above Turners Falls Pool may potentially be exposed, during either their development or out-migration, to the Northfield Mountain Pumped-Storage Facility (FERC Project: 2485) located 5.3 miles above Turners Falls Dam. The NMPSF pumps water from the Connecticut River to a storage reservoir and then generates electricity by releasing water from the reservoir. During the pumping phase, juvenile American shad may be carried with the water (i.e., entrained) into the upper reservoir. Assuming no survival nor return to the river, juvenile shad entrained are removed from the river population.

In September 1990 Northeast Utilities Service Company (NUSCo) entered into a Memorandum of Agreement (MOA) with the natural resource agencies having responsibility for the management of migratory fish in the Connecticut River. The MOA outlined a program to further improve downstream fish passage at the Holyoke and Turners Falls projects and investigate impact at the Northfield Project. In response to the MOA, NUSCo undertook studies at Northfield in 1991 and 1992 of juvenile Atlantic salmon (Harza 1992a; LMS 1992) and in 1991 of juvenile American shad (Harza 1992b). This report summarizes work completed in the second year (1992) of American shad studies.

Previous studies of American shad in relation to the NMPSF involved an evaluation of the behavior of adult shad in relation to the operation of the NMPSF (Layzer 1974), documentation but not quantification of shad spawning in Turners Falls Pool (with some emphasis on the NMPSF nearfield area) (Layzer 1978), and an analysis of juvenile shad entrainment using radiotelemetry (Layzer 1978). The studies of adult shad behavior in relation to the NMPSF and the documentation of shad spawning were conducted prior to the expansion of the shad population to areas above Turners Falls Dam. They were of an exploratory nature and thus provided no quantitative information on shad ichthyoplankton densities in Turners Falls Pool or ichthyoplankton entrainment by the NMPSF. The radiotelemetry study of juvenile shad entrainment (Layzer 1978) was limited to the out-migration period and did not provide a quantitative measure of entrainment. Only 11 of the 86 tagged juvenile shad that were monitored near the plant were in the vicinity of the facility while it was pumping and none of them entered the intake.

Studies by NUSCo in 1991 (Harza 1992b) provided information on densities of American shad ichthyoplankton in the NMPSF nearfield region, the temporal and spatial distribution of juvenile shad in Turners Falls Pool, and juvenile shad entrainment. The basic sampling program was maintained in 1992. The most important difference was that the net collection of juvenile shad coupled with net efficiency tests rather than hydroacoustics were used to estimate the total number of juvenile shad entrained by the plant. Other modifications included: (1) shad ichthyoplankton were sampled at an additional three stations in the NMPSF nearfield area; (2) juvenile shad temporal and spatial distribution sampling was conducted at 10 stations (all sampling was performed by electrofishing); and (3) the entrainment sampling study period was extended and major changes were made to the sampling gear and methodology. The 1992 study plan, presented to the resource agencies in June, is appended to this report (Appendix B).

The objective of the 1992 study program was to assess impact of the operation of the NMPSF on American shad in the Connecticut River. This report presents the results of the river sampling for ichthyoplankton and juveniles, and the sampling of entrained juveniles at the NMPSF. The impact assessment will be presented in a separate report.

STUDY AREA AND PLANT OPERATION

The NMPSF is located approximately 5.3 miles upstream of Turners Falls Dam, which forms the Turners Falls Pool portion of the Connecticut River (**Figure 1**). The plant is operated by the Western Massachusetts Electric Company and includes a riverine intake area, an underground operational area that houses the turbines and control room, as well as a storage reservoir located 800 ft above, and 8000 ft east, of the river. The NMPSF has four units each having the capacity to pass up to 5000 cfs in the generation mode and up to 3600 cfs in the pumping mode depending upon the upper reservoir elevation. From one to four units are

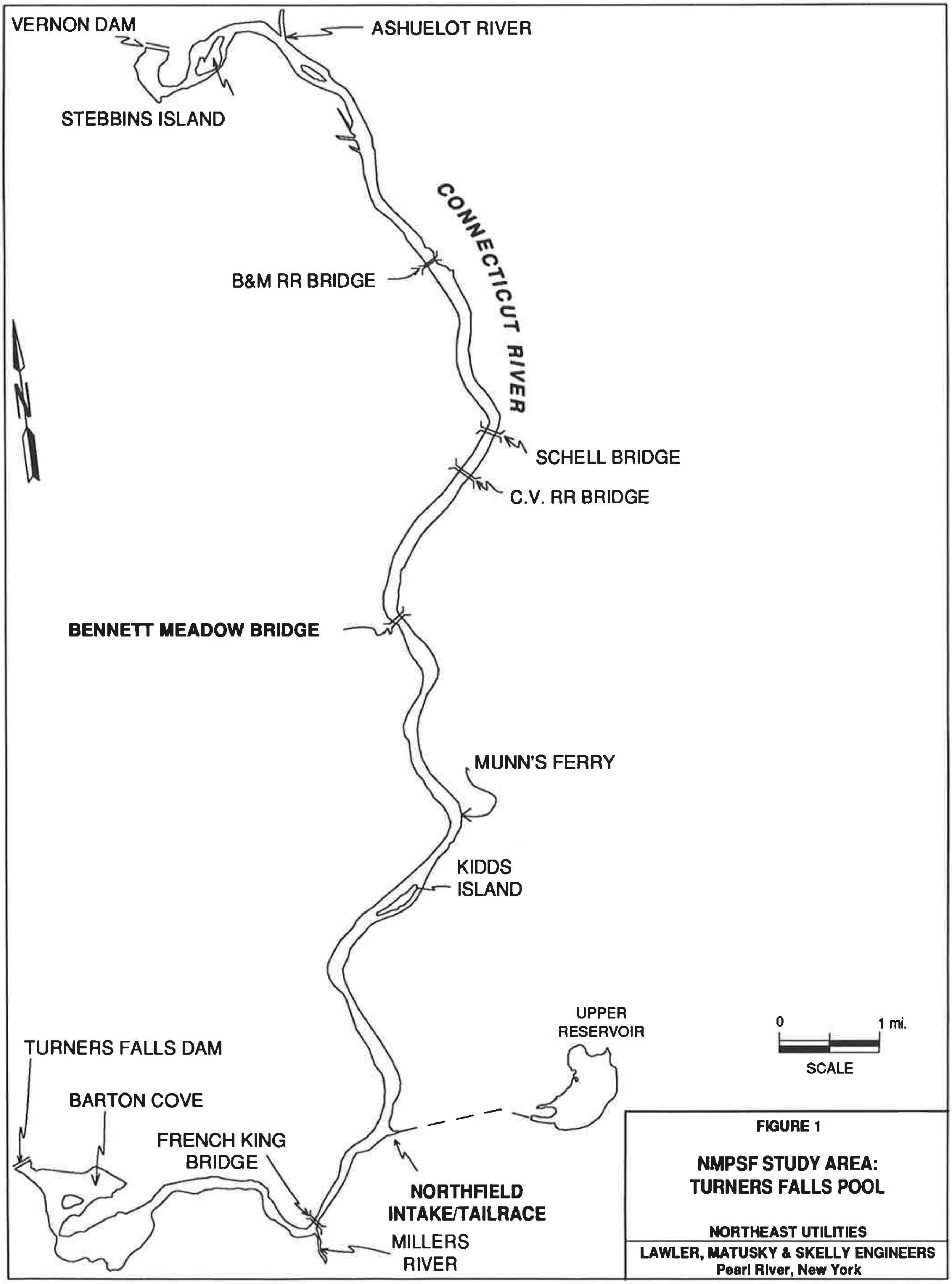

FIGURE 1

NMPSF STUDY AREA:
TURNERS FALLS POOL

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Pearl River, New York

used during both the generating and pumping phases. Pumping begins at approximately 23:30 with one unit and can potentially increase incrementally to two, three, or four units by 02:00 and is generally completed by 07:00; however, no set operational schedule is followed.

METHODS

Ichthyoplankton

Eleven shad ichthyoplankton samples were taken from 21 May to 22 July. Sampling was focused on the NMPSF nearfield region and within that area, nine sampling stations were established, three each in three strata located north, south, and adjacent to the intake (**Figure 2**). For each sample, a 10 min oblique tow (beginning at the water surface) was made at each station. Tows were made over the stern into the river flow. One replicate sample was taken from each longitudinal strata per sample. The plankton tow net consisted of a 0.5 m square frame having 0.5 micron net mesh, supported by a benthic-sled device (**Figure 3**). A rigid plastic detachable cup was attached to the cod-end of the net to facilitate the retrieval of the sample. Recordings of a General Oceanics (model 2030) digital flowmeter attached across the face of the net frame provided the basis for the calculation of the volume sampled.

Sampling commenced at dark, which for the time of year occurred near 21:00. Two of the 11 samples were taken during the daytime following a nighttime sample to measure the diurnal variability in the density of shad ichthyoplankton. Ichthyoplankton and debris collected in the net were washed into its cod-end, collected, and immediately preserved in a 5% formalin solution.

Ichthyoplankton were sorted, stored, and later identified. Starting with the initial sorting of ichthyoplankton from debris, the sampling processing procedure followed a multi-tiered quality control approach to reduce the probability of missing organisms. During sorting, samples were checked twice, once each by two different individuals to reduce the influence of systematic personal biases from the sorting procedure. A final quality control procedure involved a check of a randomly chosen sample by a third individual.

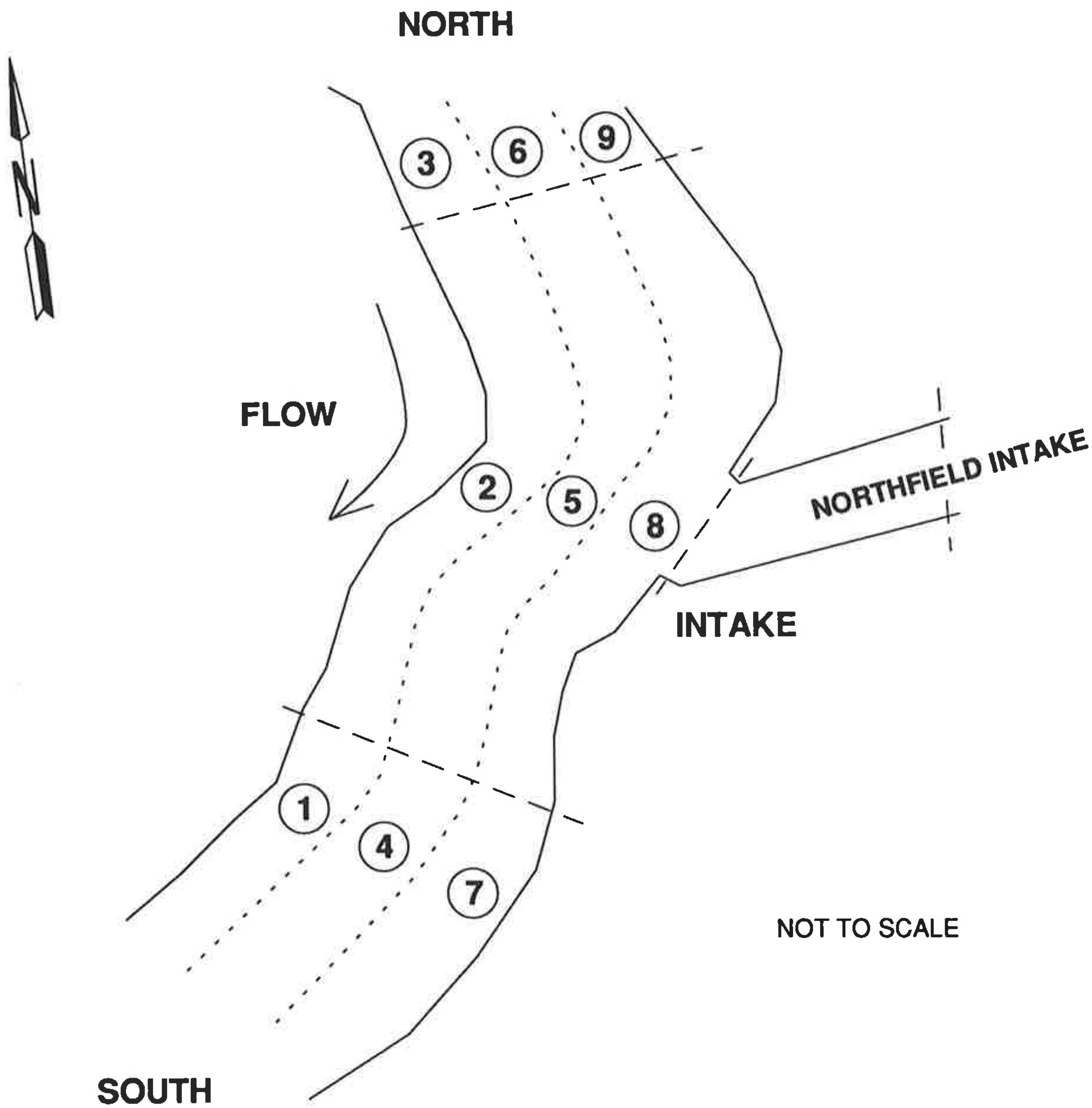

FIGURE 2
LOCATION OF
ICHTHYOPLANKTON
SAMPLING STATIONS:
NMPSF NEARFIELD AREA

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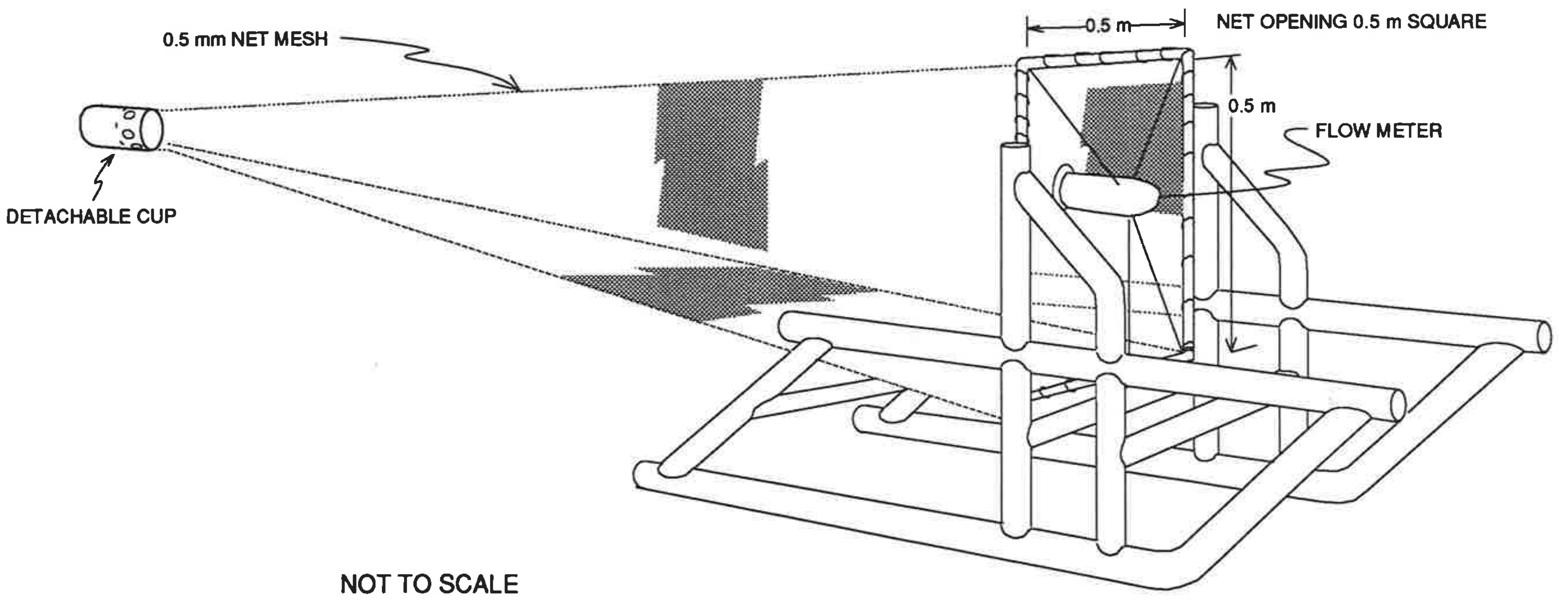

FIGURE 3

BENTHIC SLED USED FOR ICHTHYOPLANKTON SAMPLING

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Juvenile Shad Spatial and Temporal Distribution

The temporal and spatial distribution of juvenile shad in Turners Falls Pool was determined via boat-electrofishing at night. Thirteen electrofishing surveys were conducted from 23 June to 20 October. Samples were collected approximately bi-weekly from late June to late August and weekly from early September through late October. The purpose of intensifying the sampling effort beginning in September was to increase the chances of quantifying juvenile shad spatial and temporal distribution during the fall out-migration.

Turners Falls Pool was divided into five longitudinal strata; one stratum included the NMPSF nearfield region (**Figure 4**). Two sampling stations were established in each strata and samples were taken at these stations on each sampling event. The strata and stations used in 1992 were selected based on work conducted in 1991 (Harza 1992a). Twenty minute electrofishing runs were made in an upstream direction at each station. All fish collected were counted and the lengths of all American shad were recorded. All shad were either immediately released or preserved for other study tests. Catch-Per-Unit-Effort (CPUE) or the number of shad collected per minute of sampling was used to standardize the electrofishing catch data.

Entrainment Netting

Sampling

Twenty-three juvenile shad entrainment samples were taken from 9 August to 27 October. Sampling was conducted in the NMPSF upper reservoir with a 15 ft x 34 ft net frame, the area (47.36 m^2) of which represented approximately 11% of the area of the tunnel opening which carried flow into the reservoir. The frame was deployed from a 65 ton crane, which held the net in approximately the center of the pump-back outflow (**Figure 5**). The frame supported a single 80 ft long net having several sections of varied size mesh sizes aimed at dissipating the force of the flow. The bottom of the net frame was held in position by cables running through steel blocks attached to a concrete sill at the base of the outlet structure. The crane's main and auxiliary line was thus used to control the position of the net frame.

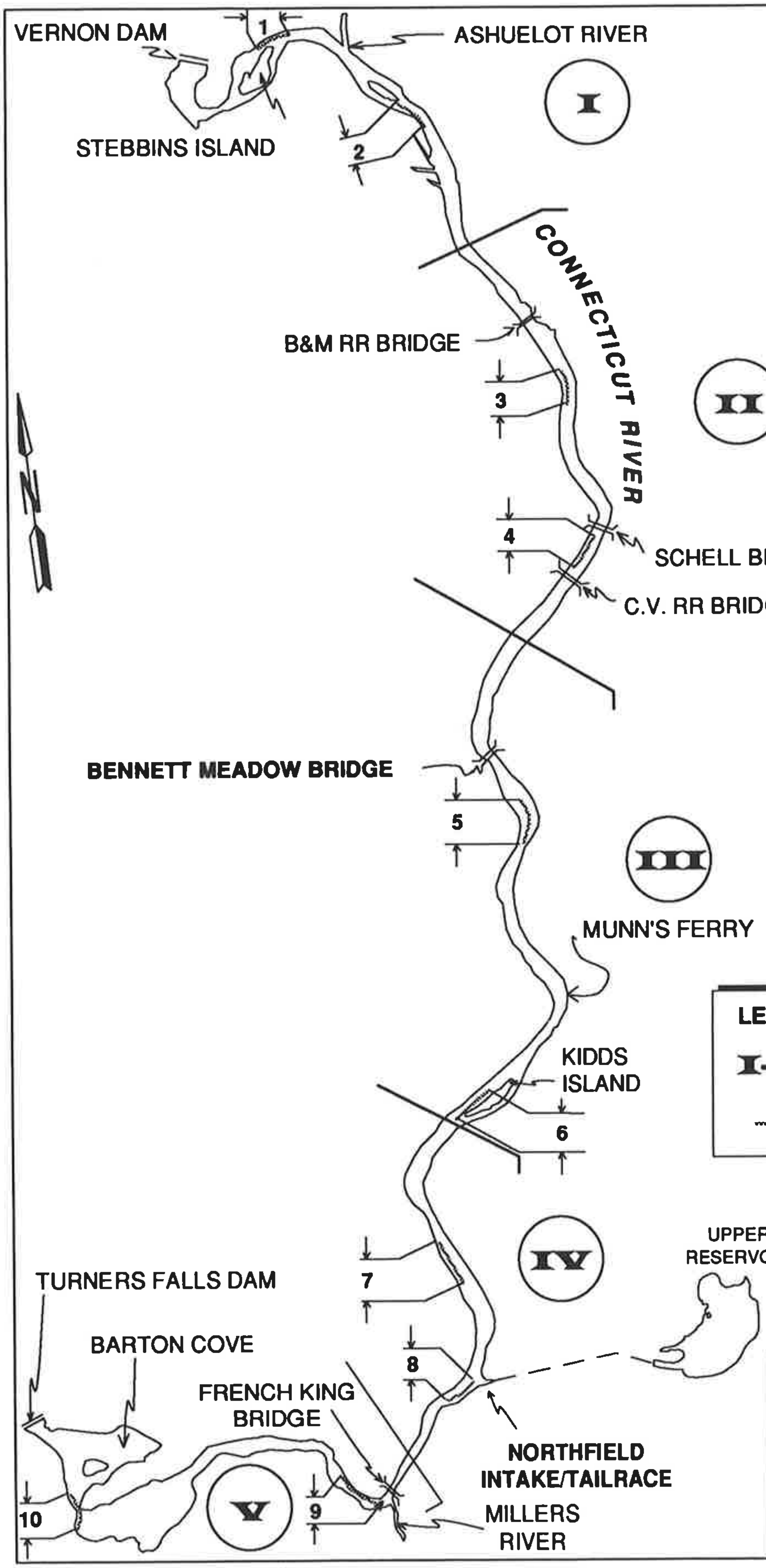

FIGURE 4
LOCATION OF SAMPLING STRATA AND ELECTROFISHING STATIONS ON TURNERS FALLS POOL

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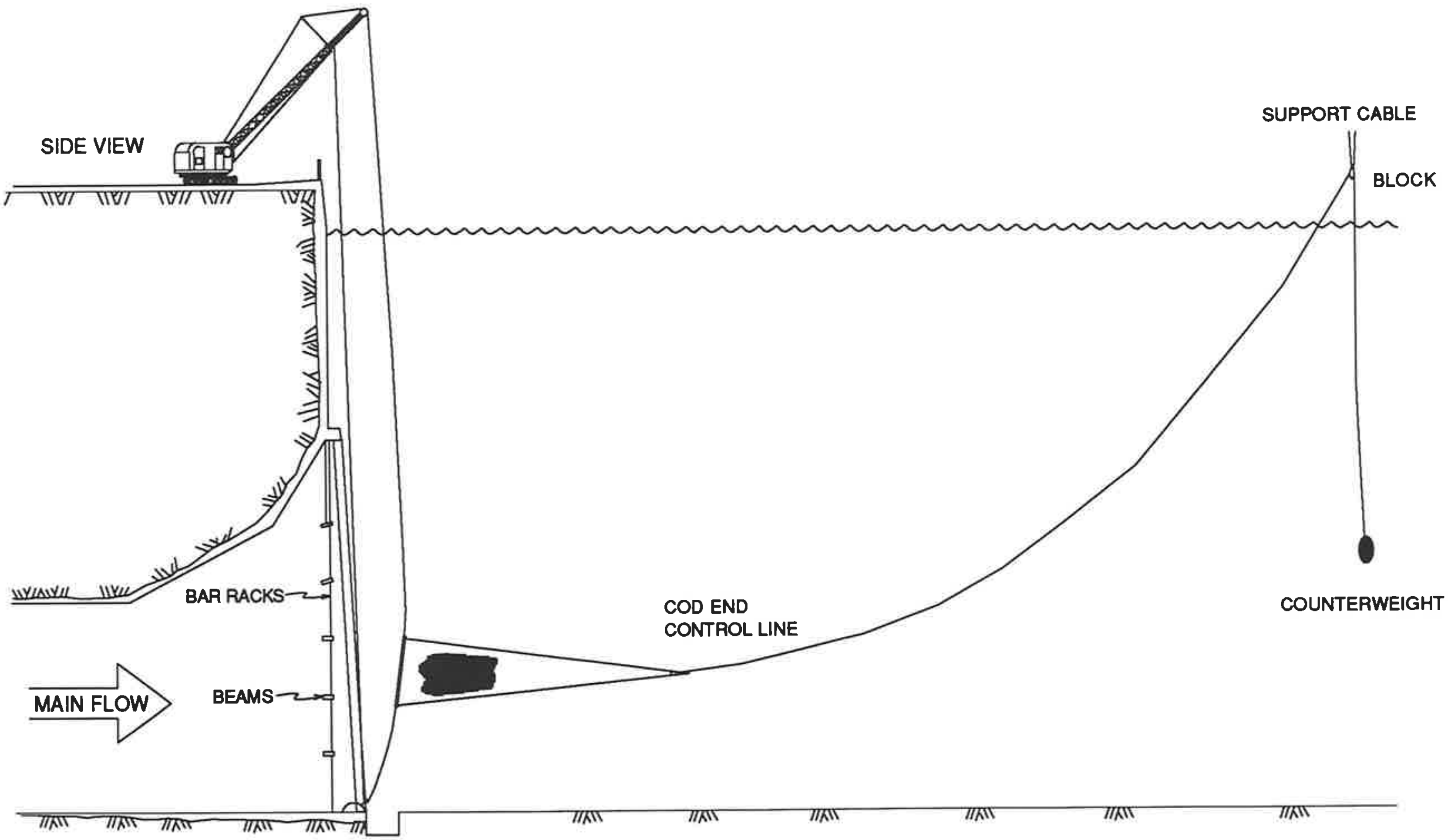

FIGURE 5

DEPLOYMENT OF THE ENTRAINMENT NET WITH COD-END CONTROL LINE

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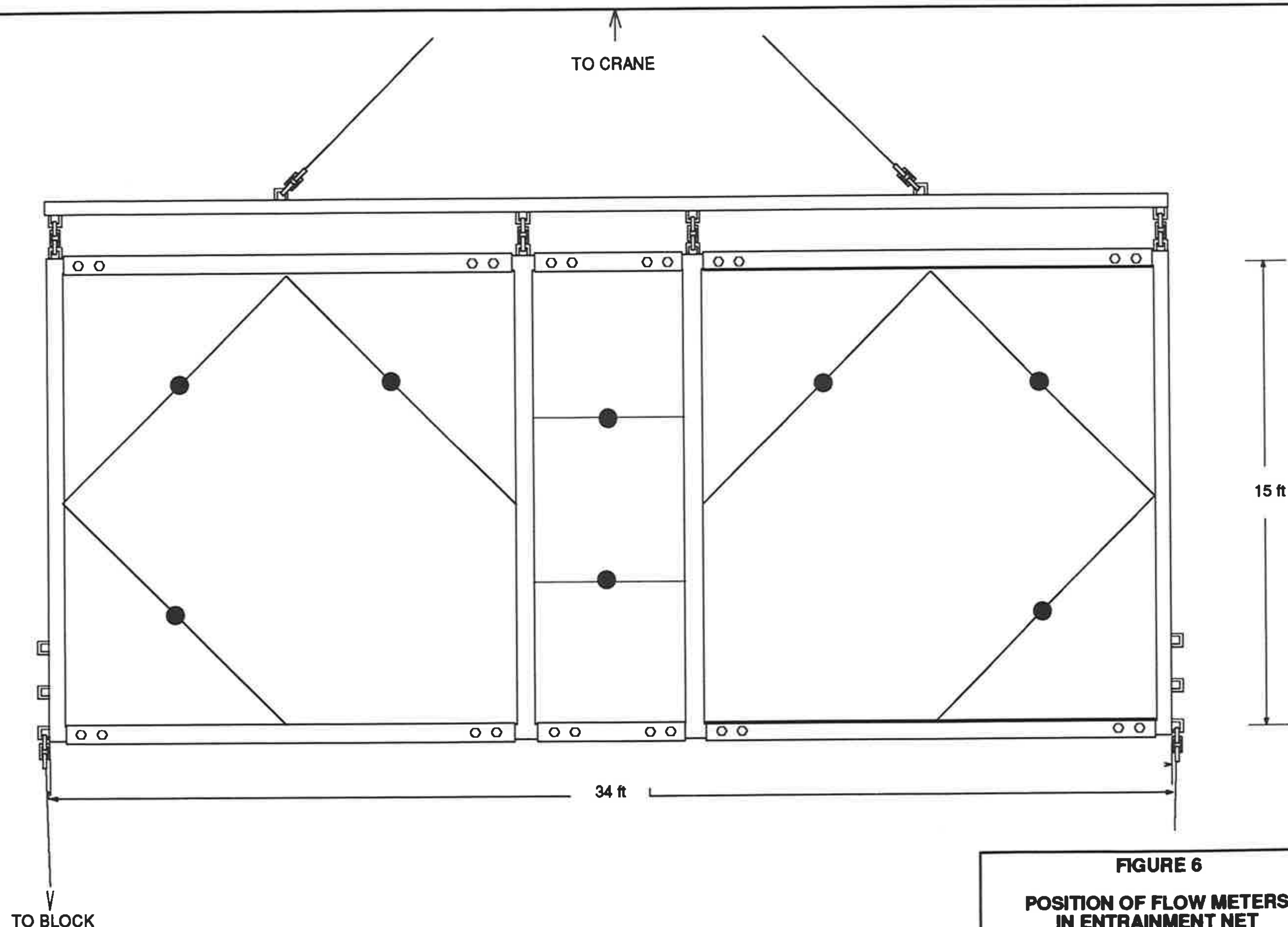
A control line with a 150 lb counter weight supported by a block attached to a cross-reservoir cable, was attached to the cod-end of the net to stabilize the frame.

The original sampling plan called for the net frame to: (1) be deployed from a 40 ton crane; (2) support two 60 foot nets deployed side-by-side; (3) collect multiple samples during a pumping cycle; and (4) be held at several outlet elevations during the sampling period. However, the original gear and sampling plan needed to be modified, due to the turbulent forces encountered during sampling. Modifications to the gear included: (1) the use of a 65 ton crane to control the net frame and cables; (2) the placement of a bridle and swivel on the lower frame bar to prevent the support cables from twisting; (3) changing from a double to single net arrangement to reduce the effect of torsional forces on the net; and (4) the addition of a net cod-end control line to prevent the net frame from spinning. Operational changes included: (1) keeping the net at one elevation for the duration of the sampling period; (2) keeping the net away from the bottom of the outlet channel where turbulent forces were believed to be greatest; (3) taking one sample per pumping cycle; and (4) sampling with a maximum of 3 units pumping.

The net was deployed after pumping was initiated, which during most evenings occurred near 23:30 and was fished for up to 5.5 hours. On those occasions when the plant went from 3 to 4 pumps or in the latter part of the season when debris loads became excessive, samples were less than 2 hours in length.

Eight flow meters were mounted in the mouth of the net frame to measure the water volume sampled (**Figure 6**). Flow meters were read previous to the deployment of the net and immediately after the net was retrieved from its fishing position. To determine total flow on any given sampling occasion, meter total counts were related to the percent of the net area that each sampled, so that the contribution of each to the total would be appropriately represented.

Samples were collected by boat and sorted twice for quality assurance. The lengths of all shad that were intact upon collection were recorded. In most entrainment samples, shad heads or tails accompanied full bodied individuals in the entrainment net. The convention



LEGEND

● Flowmeter location

FIGURE 6

POSITION OF FLOW METERS IN ENTRAINMENT NET

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for including these individuals into the data base was to include heads, but not tails to avoid duplication in the total counts. Only the individual body parts that were conclusively identifiable as shad were included.

Net Efficiency Testing

Thirteen individual tests of net efficiency were made throughout the extent of the entrainment study program. Efficiency test fish were injected into the plant flow through a an existing service port in unit 2, located on the river side of the pump-turbine unit and between the surge chambers and the unit.

A steel tank, 24 in. in length by 12 in. in diameter, was attached to the service port by an 8 ft length of 2.5 in., high pressure hose (**Figure 7**). The head differential at the service port was such that 50 psi of water pressure existed at the injection location. A 1.5 in. diameter ball valve controlled water flow out of the service port. The efficiency test injection procedure involved filling the tank with water from the service port. Between 20 and 30 marked shad were counted into the tank; the number live and dead at the time of introduction was noted. The tank was then sealed and pressurized (150 psi) service air was introduced into the tank, simultaneous to the opening of the service port ball valve. The pressurization of the tank coupled with the opening of the service port ball valve, created a mass movement of water and fish into the plant flow. The injection of groups of 20 to 30 fish normally took less than 30 seconds. The injection procedure was repeated consecutively until all fish were injected. After injection, the service port valve was shut off simultaneously with the service air and the system was de-pressurized.

All efficiency test fish were marked with neutral red dye. Fish were introduced into the dye for 15 to 20 minutes (USFWS 1982) and oxygen was bubbled into the solution at a rate of 1 to 2 liters per minute. Normally, dissolved oxygen levels near 8 mg/L were maintained in the dye solution. Dead fish were given a ventral caudal fin clip just prior to injection, so that their recapture rates could be compared to those of live released fish. Shad used for efficiency testing were acquired from electrofishing surveys on Turners Falls Pool or from shad sampling at the Cabot Station at Turners Falls Dam.

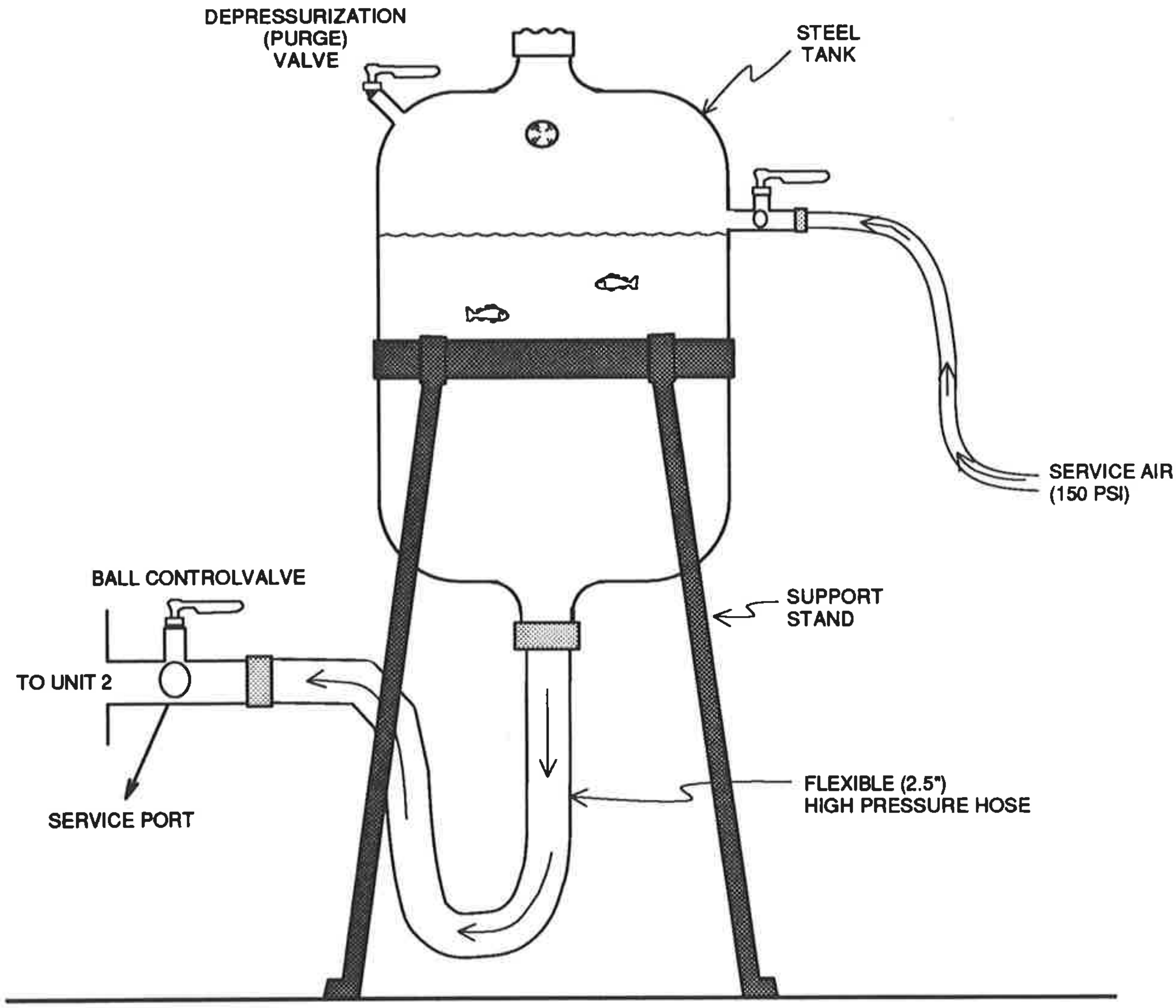

FIGURE 7

EFFICIENCY TEST
INJECTION TANK APPARATUS

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Estimate of Shad Entrainment

The entrainment of larval and juvenile shad was estimated on a weekly basis. For shad eggs and larvae, the total number entrained was estimated by multiplying the density (No. collected/1000 m^3 filtered) by the total volume of water pumped by the plant each week. The density of shad eggs and yolk-sac and post yolk-sac larvae was averaged by life stage over all 9 sampling stations (plus 3 replicates) for each sampling event, which generally corresponded to the weekly interval used for the calculation of entrainment.

The general methodology given by Casella et al. (1986) was used to estimate the number of juveniles entrained and to calculate 95% confidence limits for the estimate. The expanded catch by week was calculated with the following equation:

$$\bar{T} = \sum_{i=1}^{N} = \left(\frac{V_i}{Y_i}\right) X_i \qquad (1)$$

where:

- $\bar{T}$ = total expanded catch
- V_i = volume pumped in week *i*
- γ_i = volume sampled in week *i*
- X_i = number of juvenile shad collected in week *i*

The procedure and equations (Elliot 1971) used to calculate the variance for this estimate are provided in Appendix A.

The net efficiency adjustment was derived by dividing the total of the recaptures of marked fish by the sum of the expected recaptures. The sum of the expected recaptures was derived by summing the product of the number of fish released by the percentage of the plant flow that was filtered by the net during sampling over all efficiency tests. The net efficiency estimate was used to adjust the total estimated entrainment catch of juvenile shad and the associated 95% confidence limits.

RESULTS

Ichthyoplankton

Life Stages Combined

The highest shad ichthyoplankton densities were observed on 18 June (**Table 1**) and the effect of the sampling event on the density of shad ichthyoplankton was significant (ANOVA; $p < 0.05$). However, neither the effect of sampling station (ANOVA; $p > 0.05$), nor the interaction between the sampling event and station (ANOVA; $p > 0.05$) were significant. There was a significant difference (t-Test; $p < 0.05$) between the nighttime density of shad ichthyoplankton (80.36/1000 m^3) recorded on 30 June and the daytime (5.05/1000 m^3) density recorded on 1 July. The diurnal difference in density was less pronounced later in the season. The ichthyoplankton density recorded on the evening of 13 July (2.89/1000 m^3) was not significantly (t-Test; $p > 0.05$) different from the density (0.74/1000 m^3) recorded during the daytime on 14 July.

Sampling Stations Combined

The greatest densities of shad eggs and yolk-sac larvae were recorded on 11 June and on 18 June for post yolk-sac larvae; only one juvenile shad was collected in the ichthyoplankton program (**Table 2**; **Figure 8**). The seasonal distribution of the peak density of each life stage was generally consistent with the expected pattern of maturation of the juvenile shad. Quantitatively however, a relatively large number of post yolk-sac larvae were collected compared to shad eggs and yolk-sac larvae.

TABLE 1

DENSITIES (No./1000 m^3) OF AMERICAN SHAD ICHTHYOPLANKTON IN THE NMPSF NEARFIELD AREA OF THE CONNECTICUT RIVER IN 1992: LIFE STAGES COMBINED

	SAMPLE DATE											
STATION	21 MAY	28 MAY	4 JUN	11 JUN	18 JUN	24 JUN	30 JUN	1 JUL[a]	13 JUL	14 JUL[a]	22 JUL	MEAN
1	0.00	0.00	0.00	22.09	198.21	313.17	509.16	0.00	0.00	6.62	0.00	95.39
2	0.00	0.00	0.00	85.78	31.77	101.63	6.96	0.00	6.64	0.00	0.00	21.16
3	0.00	0.00	5.18	5.94	14.54	30.64	0.00	0.00	8.26	0.00	0.00	5.87
4	0.00	25.21	18.47	36.11	43.75	28.58	89.29	0.00	0.00	0.00	0.00	21.95
5	0.00	0.00	0.00	53.00	32.43	89.00	14.17	6.09	0.00	0.00	0.00	17.70
6	25.06	0.00	12.09	114.49	91.28	17.59	13.36	33.39	0.00	0.00	0.00	27.93
7	0.00	6.10	10.41	0.00	93.91	46.98	21.85	0.00	0.00	0.00	5.94	16.84
8	0.00	28.03	15.65	71.91	123.57	278.98	20.19	0.00	0.00	0.00	0.00	48.94
9	0.00	11.29	18.79	206.31	1063.03	93.46	48.27	5.98	11.11	0.00	0.00	132.57
Mean:	2.78	7.85	8.95	66.18	188.05	111.12	80.36	5.05	2.89	0.74	0.66	43.15
Total:	25.06	70.64	80.58	595.63	1692.48	1000.04	723.25	45.46	26.00	6.62	5.94	

[a]Daytime sample.

TABLE 2

TOTAL DENSITIES (No./1000 m^3) OF AMERICAN SHAD ICHTHYOPLANKTON IN THE NMPSF NEARFIELD AREA OF THE CONNECTICUT RIVER IN 1992: SAMPLING STATIONS COMBINED

	LIFE STAGE		
SAMPLE DATE	**EGG**	**YOLK-SAC**	**POST YOLK-SAC**
21 May	0.00	25.06	0.00
28 May	42.53	22.51	5.61
4 Jun	51.38	29.20	0.00
11 Jun	116.74	414.43	64.46
18 Jun	40.63	99.31	1552.54
24 Jun	15.08	15.17	969.79
30 Jun	0.00	0.00	723.25
1 Jul	0.00	0.00	39.37
13 Jul	0.00	0.00	26.00
14 Jul	0.00	0.00	6.62
22 Jul	0.00	0.00	5.94
Mean:	24.21	55.06	308.51
Total:	266.36	605.68	3393.59

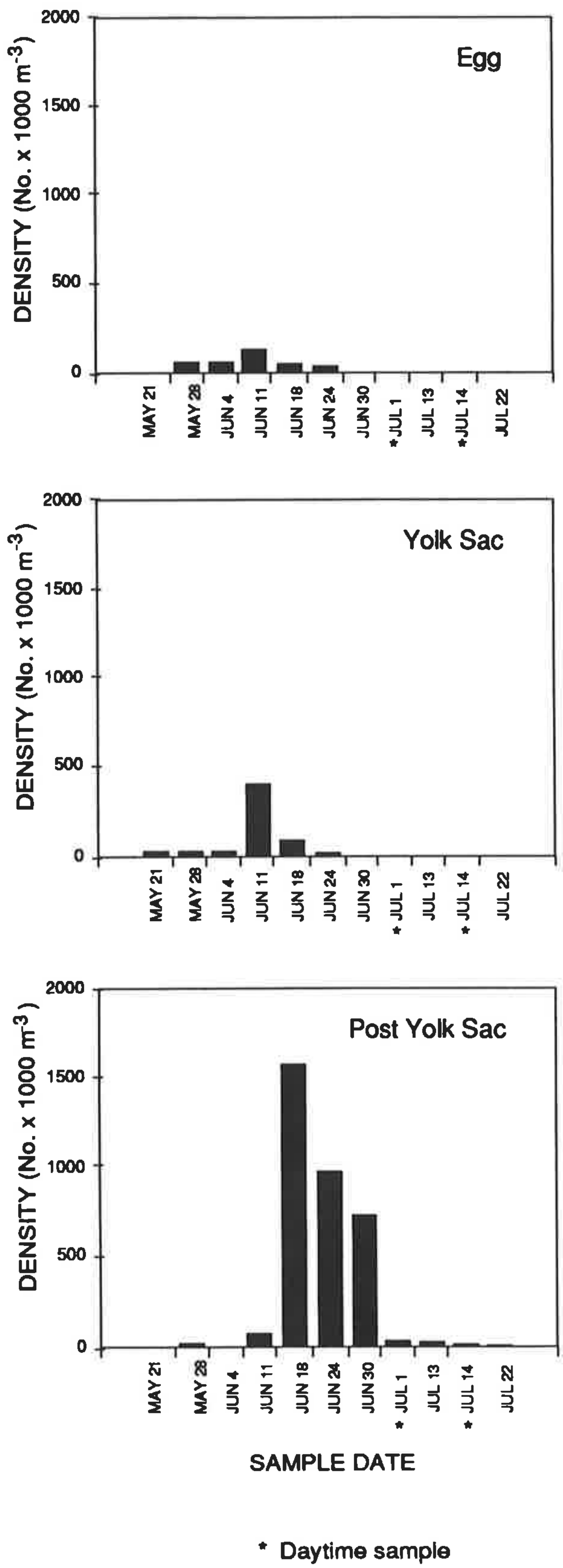

FIGURE 8

DENSITIES OF AMERICAN SHAD ICHTHYOPLANKTON BY SAMPLE DATE

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Juvenile Shad Spatial and Temporal Distribution

The mean CPUE of juvenile shad by strata ranged from 1.53 in strata V to 6.86 in strata I (**Table 3**). A significant difference in CPUE among strata was detected (ANOVA; $p < 0.05$) (See **Table 3** for pairwise comparisons.) The CPUE for juvenile shad peaked at 8.47 on 8 September. No distinct seasonal pattern in juvenile shad abundance was observed; CPUE did not differ significantly (ANOVA; $p > 0.05$) among sample dates. Shad growth in Turners Falls Pool was greatest from late July to early September (**Figure 9**). The mean length (TL) of shad remained near 82-83 mm from late September through the end of the sampling program, possibly due both to the cessation of the growing season and the influx of fish from upriver areas.

Entrainment Netting

Sampling

Three-hundred-thirty-one shad were collected during the 80.19 hours and in the 8,204,756 m^3 of water sampled during the entrainment netting program (**Table 4**). The net filtered between 6.46 and 13.92% of the plant flow during sampling (mean = 11.69%). Greatest entrainment catch rates were recorded in mid-October and they generally correspond to a period of rapidly decreasing water temperature, peaking near 14 to 15°C (**Figure 10**). The length of shad collected in the entrainment samples generally corresponded to the length of shad collected from Turners Falls Pool (**Figure 9**).

Net Efficiency Testing

A total of 3187 marked shad was injected into unit 2 for efficiency tests and 262 or 8.22% were recovered in the entrainment net (**Table 5**). The recovery rate by sample date ranged from 3.54% to 15.52%. There was no significant difference (χ^2-Test; $p > 0.05$) in the recovery rate of dead (8.39%) and live (6.77%) fish (**Table 6**). Some of the marked (i.e., dyed) fish collected were missing their tails; thus their release group could not be determined.

TABLE 3

ELECTROFISHING CATCH-PER-UNIT-EFFORT (CPUE)
FOR JUVENILE AMERICAN SHAD IN TURNERS FALLS POOL OF THE CONNECTICUT RIVER IN 1992

SAMPLE DATE	STRATA I	II	III	IV	V	MEAN	TOTAL
22 Jun	0.50	0.10	0.00	0.05	0.00	0.13	0.65
6 Jul	12.22	3.49	0.00	0.00	0.00	3.14	15.70
19 Jul	12.95	5.64	3.05	0.55	2.04	4.85	24.23
2 Aug	8.30	1.95	9.70	0.20	2.70	4.57	22.85
17 Aug	5.20	5.40	0.09	7.05	0.50	3.65	18.24
1 Sep	11.82	4.00	7.58	5.97	2.25	6.32	31.62
8 Sep	13.50	4.30	14.35	9.30	0.90	8.47	42.35
14 Sep	3.15	1.35	1.55	1.80	1.56	1.88	9.40
22 Sep	3.70	5.25	9.40	4.04	2.60	5.00	24.99
29 Sep	1.45	5.95	0.20	3.35	2.50	2.69	13.44
7 Oct	3.15	3.64	7.66	1.85	3.05	3.87	19.35
13 Oct	8.65	1.70	3.80	2.10	1.35	3.52	17.60
18 Oct	4.65	1.40	1.85	0.60	0.45	1.79	8.95
Mean[a]:	6.86^{x}	3.40^{y}	4.56^{xy}	2.84^{y}	1.53^{y}		
Total:	89.23	44.17	59.23	36.86	19.89		

[a]Means sharing a common letter are not significantly different.

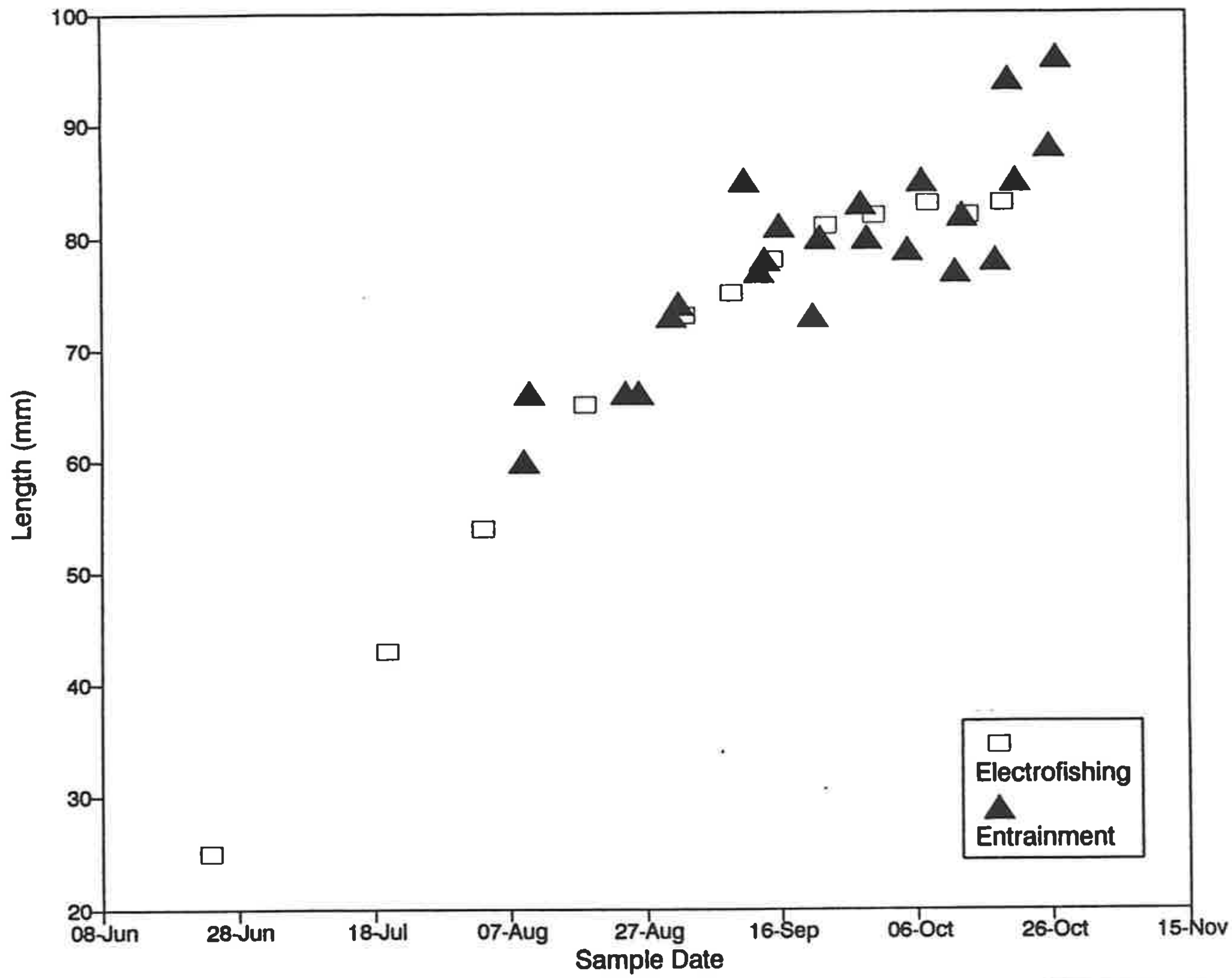

FIGURE 9

LENGTH OF AMERICAN SHAD IN ELECTROFISHING AND ENTRAINMENT SAPLES

NORTHEAST UTILITIES

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TABLE 4

ENTRAINMENT SAMPLING PROGRAM SUMMARY FOR JUVENILE AMERICAN SHAD

SAMPLE DATE	MAXIMUM No. OF PUMPS SAMPLED	SAMPLE DURATION (HRS)	VOLUME PUMPED (m^3)	VOLUME SAMPLED THROUGH NET (m^3)	PERCENT FLOW SAMPLED	CATCH	No. CAUGHT/HR	No. CAUGHT/m^3
9 Aug	3	1.65	1,181,098	132,569	11.22	1	0.61	7.54e-06
10 Aug	2	5.20	3,473,029	358,778	10.33	7	1.35	1.95e-05
23 Aug	3	5.37	4,891,421	650,798	13.30	21	3.91	3.23e-05
26 Aug[a]	3	1.23	766,601	101,791	13.28	2	1.63	1.96e-05
31 Aug	3	5.17	4,760,729	658,030	13.82	9	1.74	1.37e-05
1 Sep	3	5.68	5,130,723	663,393	12.93	5	0.88	7.54e-06
11 Sep	2	4.93	3,390,287	449,461	13.26	4	0.81	8.90e-06
13 Sep	3	5.30	4,593,641	639,541	13.92	22	4.15	3.44e-05
14 Sep	3	5.53	5,602,838	684,567	12.22	10	1.81	1.46e-05
16 Sep	3	5.67	6,016,137	639,238	10.63	13	2.29	2.03e-05
21 Sep[a]	3	1.27	1,007,755	117,709	11.68	7	5.51	5.95e-05
22 Sep	3	4.58	4,513,139	505,921	11.21	13	2.84	2.57e-05
28 Sep	3	3.58	3,109,963	275,023	8.84	8	2.23	2.91e-05
29 Sep[a]	3	1.33	2,045,386	132,117	6.46	13	9.77	9.84e-05
5 Oct	3	4.97	4,523,290	566,921	12.53	32	6.44	5.64e-05
7 Oct[a]	3	2.08	1,596,988	200,829	12.58	33	15.87	1.64e-04
12 Oct[a]	3	1.10	888,016	105,468	11.88	18	16.36	1.71e-04
13 Oct[a]	3	1.63	1,255,503	140,763	11.21	10	6.13	7.10e-05
18 Oct	3	4.03	3,518,297	427,264	12.14	59	14.64	1.38e-04
20 Oct	2	3.03	1,950,879	216,716	11.11	10	3.30	4.61e-05
21 Oct[a]	3	1.35	1,009,989	115,368	11.42	13	9.63	1.13e-04
26 Oct	2	2.93	1,904,853	225,799	11.85	11	3.75	4.87e-05
27 Oct	2	2.58	1,795,963	196,692	10.95	10	3.88	5.08e-05
Total:		80.19	68,926,524	8,204,756		331		
Mean:		3.49	2,996,805	356,729	11.69	14	5.20	5.43e-05

[a]Sampling terminated due to 4 units pumping.

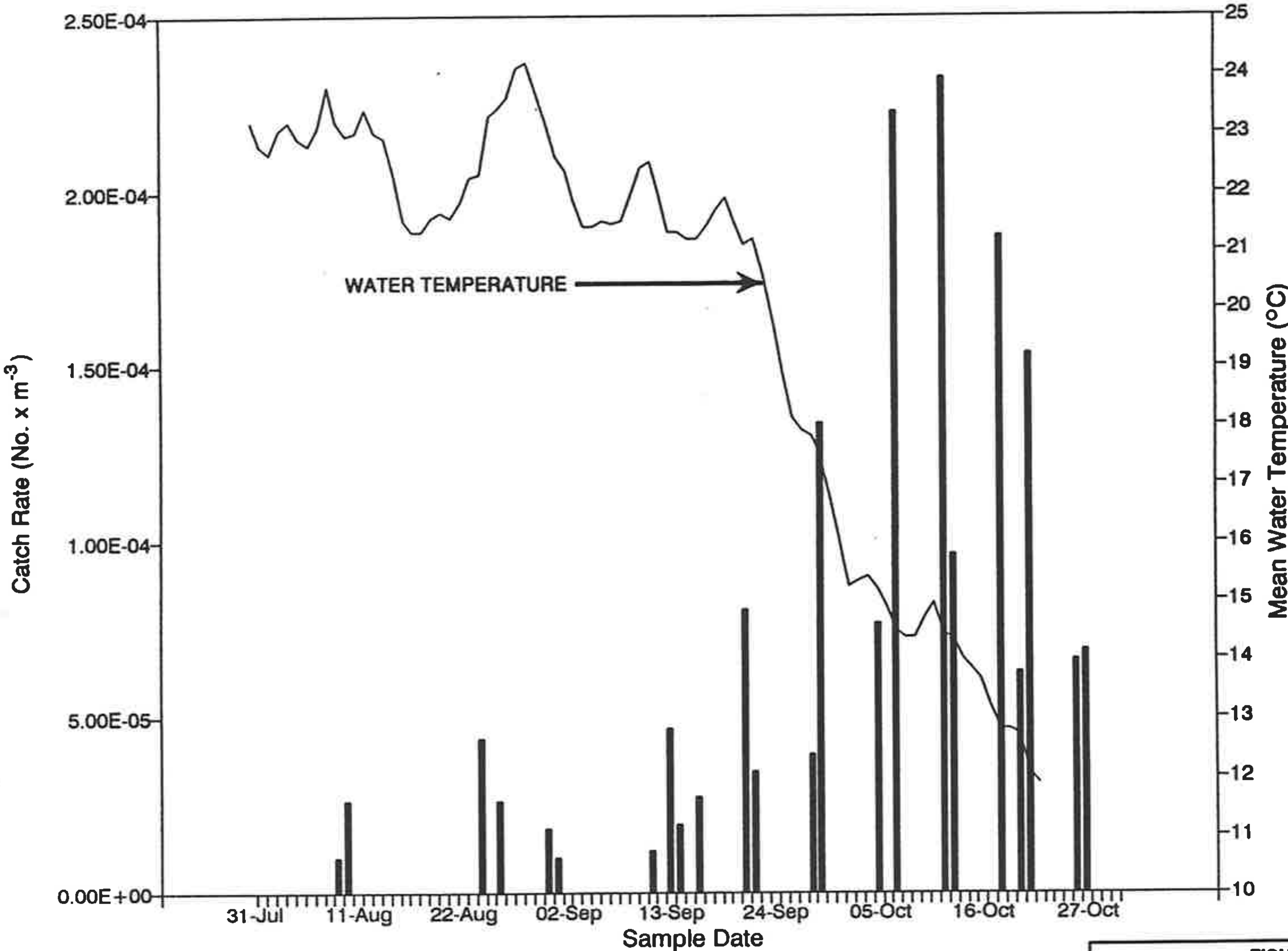

FIGURE 10

ENTRAINMENT NET CATCH RATE FOR AMERICAN SHAD

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TABLE 5

ENTRAINMENT NET EFFICIENCY TESTING RECOVERY DATA: RELEASE GROUPS COMBINED

DATE	No. RELEASED	No. RECOVERED	PERCENT RECOVERED
14 Sep	367	15	4.09
16 Sep	172	11	6.40
22 Sep	120	16	13.33
28 Sep	198	7	3.54
29 Sep	174	27	15.52
07 Oct	188	12	6.38
12 Oct	185	28	15.14
13 Oct	147	11	7.48
18 Oct	524	51	9.73
20 Oct	500	42	8.40
21 Oct	140	11	7.86
26 Oct	163	15	9.20
27 Oct	309	16	5.18
Total:	3187	262	
Percent Recovered:			8.22

TABLE 6

RECOVERY RATE SUMMARY BY RELEASE GROUP

	RELEASE GROUP		
	DEAD	**LIVE**	**UNKNOWN[a]**
No. RELEASED:	2,360	827	0
No. RECOVERED:	198	56	8
PERCENT RECOVERED[b]:	8.39	6.77	

[a]Release group could not be determined.
[b]No significant difference ($p > 0.05$) in the recovery rate of dead and live released fish.

Estimate of Shad Entrainment

Ichthyoplankton Program (eggs and yolk-sac and post yolk-sac larvae)

The estimated number of shad ichthyoplankton entrained summed by week was 1,175,900 for eggs (**Table 7a**), 2,744,000 for yolk-sac larvae (**Table 7b**), and 10,525,600 for post yolk-sac larvae (**Table 7c**).

Entrainment Netting Program

The total estimated entrainment including late summer pre-migratory and fall migratory juvenile shad was 37,260 including the 73.65% (**Table 8**) adjustment for net efficiency (**Table 9**).

DISCUSSION

The estimation of shad ichthyoplankton entrainment assumes one way movement (i.e., only movement into the plant) and passiveness on the part of the ichthyoplankton. Some shad ichthyoplankton pumped to the upper reservoir may survive and return alive to the river during generation. For some types of turbines, entrainment mortality for ichthyoplankton may be as low as 5% (Cada 1991), which would be a major consideration in the plant's impact. The assumed passiveness of the later stages such as the post yolk-sac larvae and early juvenile stages of the shad ichthyoplankton is also questionable. The more advanced stages such as the post yolk-sac larvae may exhibit avoidance behavior of the intake or the ability to resist the pump-up flow.

While the seasonal distribution of peaks in egg, yolk-sac, and post yolk-sac larvae generally agreed with expectations in the pattern of development of larval shad, markedly greater densities of post yolk-sac larvae shad were collected than of eggs or yolk-sac larvae. This difference was probably the result of gear selectivity. The sampling gear for example, may have been more effective at catching post yolk-sac larvae than either eggs or yolk-sac larvae. Shad eggs are known to be heavier than water (Chittenden 1969), thus a concentration of eggs in the lower water column may reduce their susceptibility to the sampling gear compared

TABLE 7(a)

ESTIMATED TOTAL ENTRAINMENT OF AMERICAN SHAD EGGS FROM THE CONNECTICUT RIVER IN 1992

WEEK	START DATE	VOLUME PUMPED (m^3)	MEAN DENSITY (No./1000 m^3)	*SE*	*N*	95% LOWER LIMIT	95% UPPER LIMIT	No. ENTRAINED
5	1 May	55,408,126	ND	ND	ND	ND	ND	ND
6	8 May	56,396,819	ND	ND	ND	ND	ND	ND
7	15 May	50,164,176	0.00	0.00	12	0.00	0.00	0
8	22 May	64,134,021	3.54	2.22	12	-1.33	8.42	227,200
9	1 Jun	45,828,176	4.28	1.46	12	1.08	7.49	196,200
10	8 Jun	56,874,346	9.73	6.95	12	-5.57	25.03	553,300
11	15 Jun	49,839,359	3.39	2.86	24	-2.53	9.68	168,700
12	22 Jun	48,563,437	0.63	0.63	12	-0.75	2.01	30,500
13	1 Jul	55,115,704	0.00	0.00	12	0.00	0.00	0
14	8 Jul	48,277,860	0.00	0.00	24	0.00	0.00	0
15	15 Jul	40,548,705	ND	ND	ND	ND	ND	ND
16	22 Jul	53,339,849	0.00	0.00	12	0.00	0.00	0
17	1 Aug	46,782,741	ND	ND	ND	ND	ND	ND
Total:								1,175,900

ND = No data collected.

TABLE 7(b)

ESTIMATED TOTAL ENTRAINMENT OF AMERICAN SHAD YOLK-SAC LARVAE FROM THE CONNECTICUT RIVER IN 1992

WEEK	START DATE	VOLUME PUMPED (m^3)	MEAN DENSITY (No./1000 m^3)	*SE*	*N*	95% LOWER LIMIT	95% UPPER LIMIT	No. ENTRAINED
5	1 May	55,408,126	ND	ND	ND	ND	ND	ND
6	8 May	56,396,819	ND	ND	ND	ND	ND	ND
7	15 May	50,164,176	2.10	1.54	12	-1.29	5.49	105,300
8	22 May	64,134,021	1.88	1.26	12	-0.91	4.66	120,300
9	1 Jun	45,828,176	2.43	0.87	12	0.51	4.36	111,500
10	8 Jun	56,874,346	34.54	15.83	12	-0.30	69.37	1,964,300
11	15 Jun	49,839,359	8.28	2.59	24	2.92	13.97	412,400
12	22 Jun	48,563,437	0.63	0.44	12	-0.34	1.60	30,200
13	1 Jul	55,115,704	0.00	0.00	12	0.00	0.00	0
14	8 Jul	48,277,860	0.00	0.00	24	0.00	0.00	0
15	15 Jul	40,548,705	ND	ND	ND	ND	ND	ND
16	22 Jul	53,339,849	0.00	0.00	12	0.00	0.00	0
17	1 Aug	46,782,741	ND	ND	ND	ND	ND	ND
Total:								2,744,000

ND = No data collected.

TABLE 7(c)

ESTIMATED TOTAL ENTRAINMENT OF AMERICAN SHAD POST YOLK-SAC LARVAE FROM THE CONNECTICUT RIVER IN 1992

WEEK	START DATE	VOLUME PUMPED (m^3)	MEAN DENSITY (No./1000 m^3)	*SE*	*N*	95% LOWER LIMIT	95% UPPER LIMIT	No. ENTRAINED
5	1 May	55,408,126	ND	ND	ND	ND	ND	ND
6	8 May	56,396,819	ND	ND	ND	ND	ND	ND
7	15 May	50,164,176	0.00	0.00	12	0.00	0.00	0
8	22 May	64,134,021	0.47	0.47	12	-0.56	1.50	30,000
9	1 Jun	45,828,176	0.00	0.00	12	0.00	0.00	0
10	8 Jun	56,874,346	5.37	3.30	12	-1.90	12.64	305,500
11	15 Jun	49,839,359	129.38	86.30	24	-49.17	319.31	6,448,100
12	22 Jun	48,563,437	70.54	24.95	12	15.64	125.45	3,425,800
13	1 Jul	55,115,704	3.28	2.78	12	-2.84	9.40	180,800
14	8 Jul	48,277,860	1.36	0.65	24	0.01	2.80	65,600
15	15 Jul	40,548,705	1.07[a]	0.64	ND	ND	ND	43,400
16	22 Jul	53,339,849	0.50	0.50	12	-0.59	1.58	26,400
17	1 Aug	46,782,741	ND	ND	ND	ND	ND	ND
Total:								10,525,600

[a]Estimated mean from the previous and subsequent week.
ND = No data collected.

TABLE 8

ENTRAINMENT NET EFFICIENCY CALCULATION

SAMPLE DATE	VOLUME PUMPED (m^3)	VOLUME SAMPLED THROUGH NET (m^3)	PERCENT VOLUME SAMPLED	No. FISH RELEASED	EXPECTED No. RECOVERED	NET CATCH
14 Sep	5,602,838	684,567	12.22	367	45	15
16 Sep	6,016,137	639,238	10.63	172	18	11
22 Sep	4,513,139	505,921	11.21	120	13	16
28 Sep	3,109,963	275,023	8.84	198	18	7
29 Sep	2,045,386	132,117	6.46	174	11	27
7 Oct	1,596,988	200,829	12.58	188	24	12
12 Oct	888,016	105,468	11.88	185	22	28
13 Oct	1,255,503	140,763	11.21	147	16	11
18 Oct	3,518,297	427,264	12.14	524	64	51
20 Oct	1,950,879	216,716	11.11	500	56	42
21 Oct	1,009,989	115,368	11.42	140	16	11
26 Oct	1,904,853	225,799	11.85	163	19	15
27 Oct	1,795,963	196,692	10.95	309	34	16
Total:					356	262
Percent:						73.65

TABLE 9

ESTIMATED NUMBER OF JUVENILE SHAD ENTRAINED FROM THE CONNECTICUT RIVER IN 1992: ENTRAINMENT NET SAMPLING

WEEK	START DATE	PLANT VOLUME PUMPED (m^3)	VOLUME SAMPLED THROUGH NET (m^3)	PLANT VOLUME (m^3)/ NET VOLUME (m^3)	CATCH	EXPANDED CATCH	
18 & 19	8 Aug	90,554,304	491,347	184.3	8	1,474	
20	22 Aug	74,213,920	1,410,619	52.6	32	1,684	
21	1 Sep	48,784,305	663,393	53.6	5	368	
22	8 Sep	40,135,410	1,773,569	22.6	36	815	
23	15 Sep	46,649,835	756,947	61.7	20	1,233	
24	22 Sep	54,998,106	913,061	60.2	34	2,048	
25	1 Oct	57,435,837	767,750	74.8	65	4,863	
26	8 Oct	62,688,226	246,231	254.6	28	7,129	
27	15 Oct	44,129,471	759,348	58.1	82	4,765	
28	22 Oct	61,645,394	422,491	145.9	21	3,064	
	Total:	581,234,808	8,204,756		331	27,442	
	Variance $(S^2)^a$ =						7.681e + 07
	Standard Error (SE) =						8.764e + 03
	Total Unadjusted Catch:					27,442	± 8,764
	Total Catch Adjusted for Net Efficiency (73.65%):					37,260	± 11,900

[a]See Appendix A for the procedure and equations used to determine the variance for the total entrainment estimate.

to larvae. The distribution of early life stages may also contribute to the observed differences in densities. Larvae may move at a different rate in the river currents than eggs so that densities at a given location could be a function of upstream spawning activities and river flow conditions.

A similar pattern in the distribution of juvenile shad observed in this study was found in 1991 (Harza 1992b). Based on CPUE data from both years, juvenile shad were more abundant in regions upstream of Kidds Island (see **Figure 1**) and the region immediate to the NMPSF riverine intake seemed not to be an important area for shad. Generally, fewer shad ichthyoplankton were collected in the NMPSF nearfield region in 1991 (Harza 1992b) than in 1992. Differences in sampling methodology between years may account for the observed differences in shad ichthyoplankton numbers.

The consistency of the net efficiency recovery results and the fact that a substantial portion of the plant flow was filtered on each sampling occasion indicates that the sampling methodology provided a reliable estimate of entrainment. The overall mean of the volume of plant flow filtered (11.69%) was very close to the percentage of the outlet area occupied by the net frame (11%), which suggests that the net was fishing effectively. Considering the size of the outlet structure and the shear volume of water pumped, a relatively small (73.65%) adjustment of the total catch for net efficiency was required.

While there was considerable variability in the weekly entrainment net catch rate, the peak catch rate corresponded with the expected seasonal peak of shad migration. The increase in the entrainment net catch rate corresponded to a period of rapidly decreasing water temperature and, in fact, peaked at a water temperature (14 to 15°C) at which shad migrations in the Connecticut River have been observed to peak (O'Leary and Kynard 1986). A very similar entrainment catch rate pattern was observed in 1991 (Harza 1992b). In 1991, upper reservoir entrainment net catch rates peaked during the first week of October at a water temperature of 15°C (Harza 1992b). In both years, catches declined to early September levels in late October possibly due to the fact that the bulk of the shad had already passed the plant.

Juvenile American shad were observed in the upper reservoir during entrainment sampling and it is possible that the entrainment samples included some shad which were resident in the upper reservoir. However, this effect was believed to have been minor. The entrainment net was always set after the plant began pumping, thus some degree of flushing of fish from the outlet area could be expected. Moreover, it would have been difficult for shad resident in the upper reservoir to have entered the sample after the net was set due to the velocities (on the order of 2 to 3 m/s) observed during multiple unit pumping. Shad are also surface oriented during the times (approximately 23:30 to 05:00) that entrainment samples were taken, which would tend to keep them away from the net which was fishing at depth.

CONCLUSIONS

1. The estimated total number of juveniles entrained from the entrainment netting program, was 37,260 including a 73.65% adjustment for net efficiency.

2. Both the consistency of the net efficiency recovery results and the fact that a significant portion of the plant flow was filtered on each sampling occasion support the reliability of the total entrainment estimate for juvenile shad.

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APPENDIX A

Calculation of the Variance for the Estimate of the Total Number of Juvenile Shad Entrained (Table 9)

Total entrainment and its variance of the number of juvenile shad entrained as reported in **Table 9** was calculated using the following equations (Casella et al. 1986):

$$\bar{T} = \sum_{i=1}^{N} = \left(\frac{V_i}{Y_i}\right) X_i \qquad (1)$$

$$Var(T)=\sum_{i=1}^{N} = \left(\frac{V_i^2}{\gamma_i^2}\right)\left(\frac{X_i^2+\hat{c}^2 X_i^2}{(1+\hat{c}^2)}\right) \qquad (A\text{-}1)$$

where:

$\bar{T}$ = expanded catch (by week) during week *i*

V_i = volume pumped during week *i*

γ_i = volume sampled during week *i*

X_i = number of juvenile shad collected during week *i*

$\hat{c}^2$ = contagion coefficient

Values for the variables in the above equation except for the contagion coefficient ($\hat{c}^2$) were directly measured and are provided in **Table 9.** The contagion coefficient is a measure of the relationship between the mean and the variance. (See Elliot (1971) for a detailed discussion of contagious distributions.) The contagion coefficient ($\hat{c}^2$) or the reciprocal of the exponential product (k) of the negative binomial distribution (1/k) (Casella et al. 1986), provides a measure of the "excess variance or clumping of the individuals in a population" or sample (Elliot 1971). Following Elliot (1971), the negative binomial distribution can be used to fit "patchy" or "clumpy" patterns of data (i.e., where the population variance is equal to or greater than the arithmetic mean).

To estimate k the following relationships were used (Elliot 1971):

$$k=\frac{x'}{y'}$$

where:

$$x'=\bar{x}^2-\frac{s^2}{n}$$

$$y'=s^2-\bar{x}$$

and:

$\bar{x}$ = sample mean
s^2 = sample variance

From the juvenile shad entrainment data (**Table 4**), a mean entrainment catch rate (i.e., No. fish/m^3) ($\bar{x}$) and associated variance (s^2) estimate was derived by week from the two to three entrainment samples taken per week (n) (**Table A-1**).

The weekly estimates of k were then examined to determine if they could be pooled into a single value. This was done by plotting the reciprocal of k (i.e., 1/k) against the mean catch rate ($\bar{x}$) (**Figure A-1**). This plot reveled no relationship between these two variables (**Figure A-1**). Therefore, k can be considered a constant (k_c) equalling (**Table A-1**):

$$k_c=\frac{\sum x'}{\sum y'}=\frac{-1.29e-04}{-2.30e-04}=0.5634$$

The contagion coefficient or reciprocal of k_c equals 1.78. This value was used in equation A-1 to derive the variance associated with the estimate of the total number of juvenile shad entrained reported in **Table 9.**

TABLE A-1

ENTRAINMEMT CATCH RATE DATA FOR THE CALCULATION OF THE "k" STATISTIC

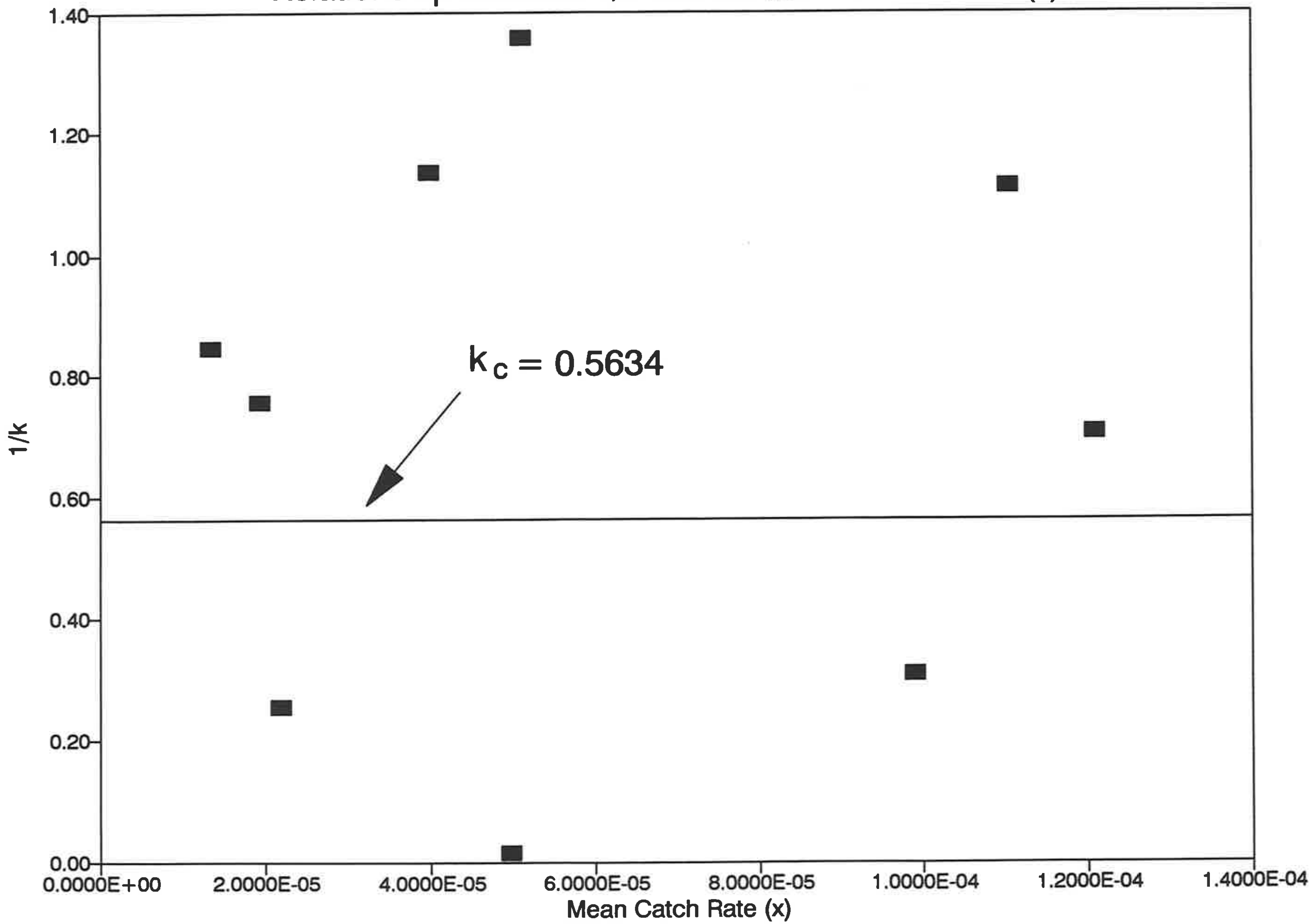
WEEK	START DATE	MEAN WEEKLY CATCH RATE (No. Caught/m^3) ($\bar{x}$)	VARIANCE (S^2)	NUMBER OF SAMPLES TAKEN (n)	x'	y'	1/k	k
18&19	08-Aug	1.3520e-05	8.50e-06	2	-4.25e-06	-5.02e-06	0.846577	1.181227
20	22-Aug	2.1860e-05	9.50e-06	3	-3.17e-06	-1.24e-05	0.256164	3.903747
21[a]	01-Sep	7.5370e-06		1				
22	08-Sep	1.9300e-05	1.34e-05	3	-4.47e-06	-5.90e-06	0.756999	1.321006
23	15-Sep	3.9900e-05	2.77e-05	2	-1.38e-05	-1.22e-05	1.135115	0.880968
24	22-Sep	5.1060e-05	4.10e-05	3	-1.36e-05	-1.01e-05	1.358256	0.736238
25	01-Oct	1.1030e-04	7.61e-05	2	-3.80e-05	-3.42e-05	1.112217	0.899105
26	08-Oct	1.2080e-04	7.07e-05	2	-3.53e-05	-5.01e-05	0.705298	1.417841
27	15-Oct	9.8970e-05	4.57e-05	3	-1.58e-05	-5.14e-05	0.307432	3.252749
28	22-Oct	4.9770e-05	1.50e-05	2	-7.48e-07	-4.83e-05	0.015486	64.57327
Total:				23	-1.29e-04	-2.30e-04		

$$k_c = \frac{\sum x'}{\sum y'} = \frac{-1.29e-04}{-2.30e-04} = 0.5634$$

[a]One sample taken; variance not calculated.

Figure A-1

Relationship Between 1/k and the Mean Catch Rate (x)



Attachment B to Study 3.3.3.
Amended Table 3.2.3-1 Summary of Juvenile Shad Release Events

Release Location	Release Date (2015)	Release Time	Count	Cumulative Total	Generation at Cabot (No. of Units)*	Generation at Station No. 1 (No. of Units)*	Pumping at NMPS (No. Units)
Upper Canal	October 4	20:45	8	8	3	0	1
Lower Canal	October 4	22:25	9	17	1	0	1
Upstream of TFD	October 12	19:20	20	37	1	0	2
Upstream of NMPS	October 12	20:45	20	57	5	0	2
Upstream of TFD	October 13	20:45	20	77	3	0	3
Upstream of NMPS	October 13	21:05	24	101	3	0	3
Upstream of TFD	October 15	19:45	23	124	2	0	3
Upstream of NMPS	October 15	20:10	24	148	2	0	3
Upstream of NMPS	October 16	20:55	24	172	3	0	2
Upstream of NMPS	October 19	19:10	24	196	3	0	3
Upstream of NMPS	October 20	20:10	22	218	4	0	2

Attachment C to Study 3.3.3.
Operational Data Generation Data Aug to Nov 2015 (Excel)

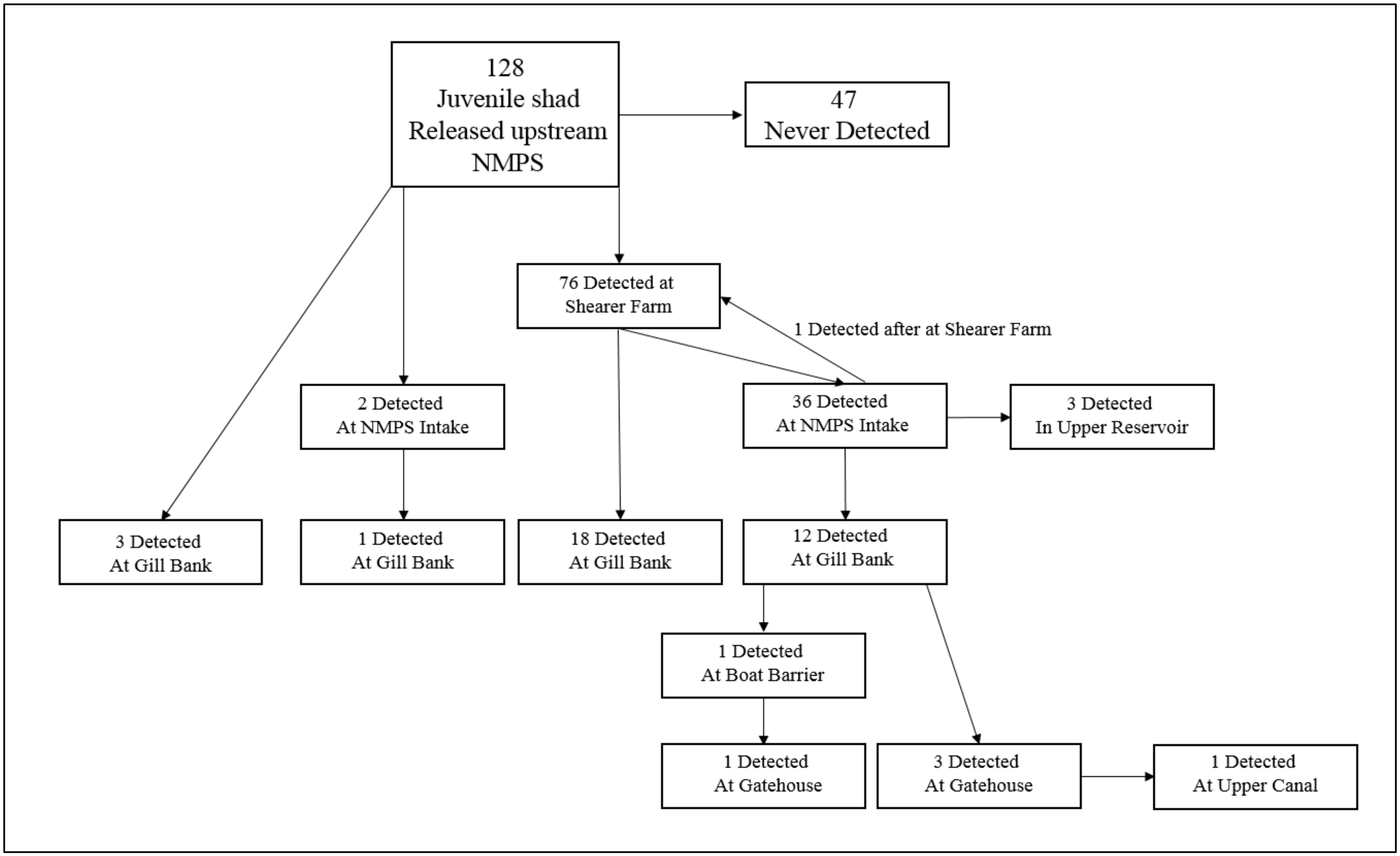
See Excel file Attachment_C_Study_3_3_3

Attachment D to Study 3.3.3.
Amended Table 4.1.4-2. Summary of Concurrent Sampling Results to Determine Juvenile Shad Passage Routes through the Canal.

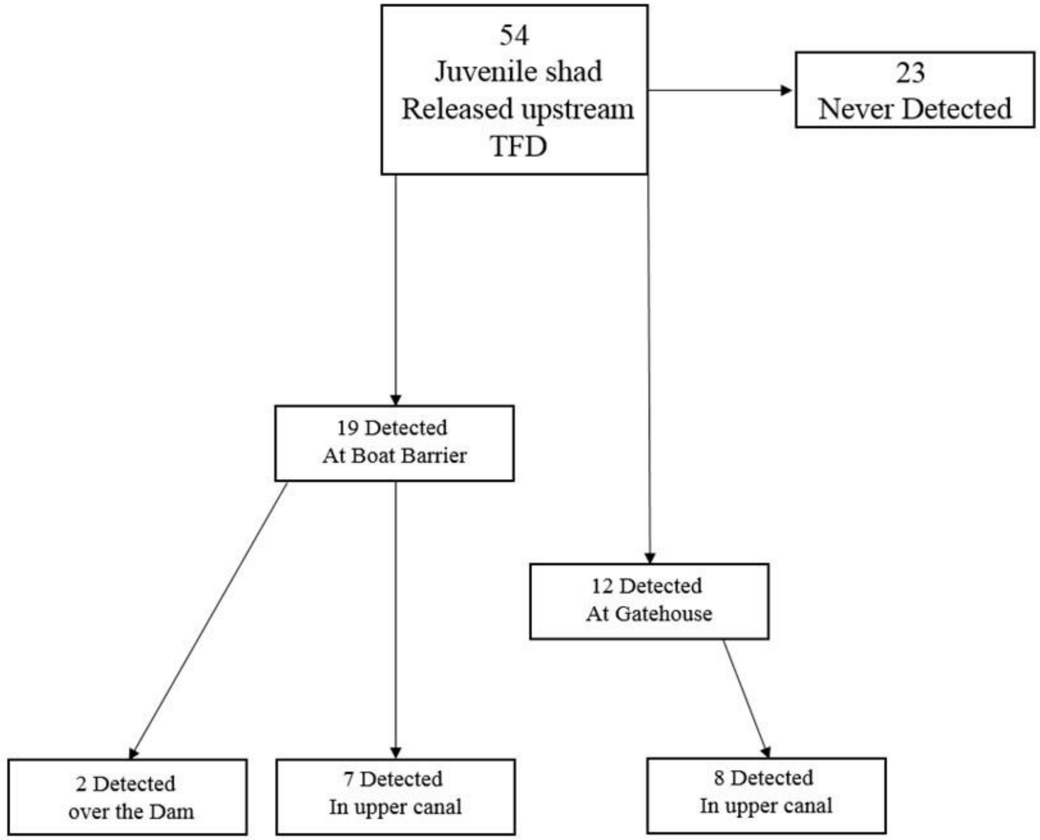
Date	Start Time	End Time	Unit 1 Gen. (MW)		Unit 2 Gen. (MW)		Unit 3 Gen. (MW)		Unit 4 Gen (MW)		Unit 5 Gen. (MW)		Unit 6 Gen. (MW)		Total Count	% Bypass	% Cabot Station
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max			
9/9/2015	15:45	18:15	0	10.81	-	-	-	-	-	-	-	-	0	10.35	1,545	0%	100%
9/10/2015	18:45	21:00	-	-	-	-	-	-	-	-	-	-	-	-	293	100%	0%
9/15/2015	16:00	22:00	10.01	10.53	0	10.28	-	-	0	10.29	0	10.58	10.18	10.55	2,002	63%	37%
9/17/2015	16:30	22:12	0	10.48	0	10.69	-	-	0	10.43	0	10.44	0	10.27	4,153	43%	57%
9/21/2015	15:30	22:30	9.92	10.42	-	-	-	-	-	-	-	-	-	-	237	67%	33%
9/23/2015	15:30	22:30	9.84	10.19	-	-	-	-	-	-	-	-	-	-	197	12%	88%
9/28/2015	15:30	22:00	8.07	10.19	-	-	-	-	-	-	-	-	-	-	145	14%	86%
9/30/2015	15:30	22:00	8.91	9.36	8.85	9.30	9.06	9.48	9.09	9.56	9.18	9.57	9.20	9.62	12,617	7%	93%
10/12/2015	16:20	21:50	0	10.52	9.76	10.52	0	10.63	0	10.52	0	10.26	0	10.32	2,945	14%	86%
10/13/2015	16:20	22:00	0	10.31	0.01	10.52	-	-	-	-	-	-	0	10.08	2,414	43%	57%
10/14/2015	15:30	22:00	0	10.12	6.82	10.43	-		0	10.53	-	-	-	-	172	100%	0%
10/19/2015	16:00	22:00	0	10.37	8.61	10.58	-	-	-	-	0	10.63	0	10.67	3,187	31%	69%
10/21/2015	15:30	22:00	0	10.10	8.23	10.48	-	-	0	10.45	-	-	0	10.57	2,011	34%	66%
10/26/2015	15:40	22:00	0	10.49	9.86	10.54	-	-	-	-	0	10.61	9.88	10.40	3,404	61%	39%
10/28/2015	15:45	22:00	-	-	7.82	9.98	-	-	0	10.62	-	-	0	10.17	3,001	54%	46%
															Mean	**43%**	**57%**

Attachment E to Study 3.3.3.
Table Fate of Juvenile Shad Releases

Attachment E: The fate of all juvenile shad released above NMPS



Attachment E: The fate of all juvenile shad released above TFD



Attachment F to Study 3.3.3.
Table Fate of Juvenile Shad Releases Upstream of TFD

The table shows the 18 juvenile that passed through Gatehouse into the canal or passed over Turners Falls Dam. Nine of these fish moved from the boat barrier site (S3) to the receiver directly in front of Gatehouse (T9). The mean time it took to travel between these two receivers (last detection at S3 to the first detection at T9) was 22 minutes and 7 seconds. The median travel time between those two locations was 20 minutes and 58 seconds, with a minimum time of 11 minutes and 34 seconds and a maximum time of 39 minutes and 6 seconds. Eight of the remaining fish were first detected at T9, therefore the travel time from receiver to receiver within the Impoundment could not be calculated.

Sixteen fish moved through the Gatehouse (T9) and into the canal (T10). The mean time it took to travel between these two receivers (last detection at T9 to the first detection at T10) was 58 seconds. The median travel time between those two receivers was 44 seconds, with a minimum of 22 seconds and a maximum of 2 minutes and 59 seconds.

Frequency/Code	Fate	Release Location	Detection History	Duration – Boat Barrier to Gatehouse (S3 to T9)	Min:Sec	Duration Gatehouse to Upstream Canal (T9 to T10)	Min:Sec
150.600 45	Through Gatehouse into canal	Upstream of TFD	S3, T9, T10	10/12/2015 9:45:58 PM to 10/12/2015 9:58:32 PM	11:34	10/12/2015 10:02:14 PM to 10/12/2015 10:02:36 PM	00:22
150.600 31	Through Gatehouse into canal	Upstream of TFD	T9, T10			10/12/2015 9:25:54 PM to 10/12/2015 9:26:50 PM	00:56
150.600 34	Through Gatehouse into canal	Upstream of TFD	S3, T9, T10, T17	10/12/2015 8:55:21 PM to 10/12/2015 9:13:15 PM	17:54	10/12/2015 9:17:29 PM to 10/12/2015 9:17:53 PM	00:24
150.600 35	Through Gatehouse into canal	Upstream of TFD	T9, T10, T17			10/12/2015 9:36:18 PM to 10/12/2015 9:37:02 PM	00:44
150.600 39	Through Gatehouse into canal	Upstream of TFD	S3, T9, T10	10/12/2015 8:59:35 PM to 10/12/2015 9:18:34 PM	18:59	10/12/2015 9:21:26 PM to 10/12/2015 9:22:10 PM	00:44
150.600 46	Through Gatehouse into canal	Upstream of TFD	S3, T9, T10	10/12/2015 8:57:11 PM to 10/12/2015 9:18:31 PM	21:20	10/12/2015 9:20:01 PM to 10/12/2015 9:20:23 PM	00:22
150.600 47	Through Gatehouse into canal	Upstream of TFD	T9, T10			10/12/2015 9:34:20 PM to 10/12/2015 9:34:50 PM	00:30
150.600 49	Through Gatehouse into canal	Upstream of TFD	T9, T10, T17			10/12/2015 9:25:56 PM to 10/12/2015 9:27:42 PM	01:46
150.600 51	Through Gatehouse into canal	Upstream of TFD	T9, T10			10/12/2015 9:27:27 PM to 10/12/2015 9:27:56 PM	00:29
150.600 52	Through Gatehouse into canal	Upstream of TFD	S3, T9, T10	10/12/2015 9:16:48 PM to 10/12/2015 9:37:46 PM	20:58	10/12/2015 9:40:02 PM to 10/12/2015 9:40:26 PM	00:24
150.600 55	Through Gatehouse into canal	Upstream of TFD	S3, T9, T10, T172	10/13/2015 3:52:04 AM to 10/13/2015 4:31:10 AM	39:06	10/13/2015 4:48:32 AM to 10/13/2015 4:49:50 AM	01:18
150.600 62	Passed over TFD	Upstream of TFD	S3, T9, T15	10/12/2015 9:17:55 PM to 10/12/2015 9:33:51 PM	15:56		
150.600 56	Through Gatehouse into canal	Upstream NMPS	S1, T3, T5, T9, T10			10/13/2015 9:16:06 PM to 10/13/2015 9:17:24 PM	01:18
150.380 60	Through Gatehouse into canal	Upstream of TFD	T9, T10			10/13/2015 10:48:04 PM to 10/13/2015 10:48:44 PM	00:40
150.600 29	Passed over TFD	Upstream of TFD	S3, T9, T11	10/13/2015 10:57:12 PM to 10/13/2015 11:21:17 PM	24:04		
150.600 26	Through Gatehouse into canal	Upstream of TFD	S3, T9, T10	10/13/2015 11:33:41 PM to 10/14/2015 12:02:45 AM	29:16	10/14/2015 12:08:45 AM to 10/14/2015 12:10:02 AM	01:17
150.380 37	Through Gatehouse into canal	Upstream of TFD	T9, T10			10/16/2015 4:03:11 AM to 10/16/2015 4:06:10 AM	02:59
150.380 39	Through Gatehouse into canal	Upstream of TFD	T9, T10			10/16/2015 4:49:02 AM to 10/16/2015 4:50:24 AM	01:22

Attachment G to Study 3.3.3.

Table 5-3. Alternate summary of passage-related maladies and severity of maladies, including all fish with loss of equilibrium, of juvenile American Shad passed through the Turners Falls Hydroelectric Project, Turners Falls, MA.

No. of Fish Examined	Passage Maladies*** Injuries and LOE	LOE only	Mechanical	Pressure/ Shear	Pressure /Mechanical	Shear	Mechanical/ Shear	Undetermined	Predation*	Severity Minor	Severity Major	Tag Tear**
Cabot Station Unit 2												
115	19 (0.165)	9 (0.078)	4 (0.035)	0 (0.000)	0 (0.000)	5 (0.043)	1 (0.009)	9 (0.078)	0 (0.000)	13 (0.113)	6 (0.052)	0 (0.000)
Station No. 1 Units 2/3												
65	25 (0.385)	17 (0.262)	1 (0.015)	0 (0.000)	0 (0.000)	4 (0.062)	0 (0.000)	20 (0.308)	0 (0.000)	16 (0.246)	9 (0.138)	0 (0.000)
Station No. 1 Unit 1												
68	30 (0.441)	16 (0.235)	3 (0.044)	0 (0.000)	0 (0.000)	9 (0.132)	1 (0.015)	17 (0.250)	0 (0.000)	19 (0.279)	11 (0.162)	0 (0.000)
Bascule Gate 1: 1,500 cfs												
42	17 (0.405)	8 (0.190)	8 (0.190)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	8 (0.190)	0 (0.000)	10 (0.238)	7 (0.167)	1 (0.024)
Bascule Gate 1: 2,500 cfs												
34	23 (0.676)	9 (0.265)	9 (0.265)	0 (0.000)	0 (0.000)	2 (0.059)	1 (0.029)	9 (0.265)	0 (0.000)	11 (0.324)	12 (0.353)	2 (0.059)
Bascule Gate 1: 5,000 cfs												
49	37 (0.755)	20 (0.408)	11 (0.224)	0 (0.000)	0 (0.000)	2 (0.041)	3 (0.061)	21 (0.429)	2 (0.041)	26 (0.531)	13 (0.265)	0 (0.000)
Combined												
125	77 (0.616)	37 (0.296)	28 (0.224)	0 (0.000)	0 (0.000)	4 (0.032)	4 (0.032)	38 (0.304)	2 (0.016)	47 (0.376)	32 (0.256)	3 (0.024)
Bascule Gate 4: 1,500 cfs												
41	29 (0.707)	9 (0.220)	12 (0.293)	1 (0.024)	0 (0.000)	6 (0.146)	0 (0.000)	10 (0.244)	0 (0.000)	20 (0.488)	9 (0.220)	0 (0.000)
Bascule Gate 4: 2,500 cfs												
40	27 (0.675)	8 (0.200)	11 (0.275)	0 (0.000)	0 (0.000)	5 (0.125)	3 (0.075)	8 (0.200)	0 (0.000)	21 (0.525)	6 (0.150)	0 (0.000)
Bascule Gate 4: 5,000 cfs												
41	26 (0.634)	8 (0.195)	12 (0.293)	1 (0.024)	0 (0.000)	4 (0.098)	1 (0.024)	8 (0.195)	0 (0.000)	19 (0.463)	7 (0.171)	0 (0.000)
Combined												
122	82 (0.672)	25 (0.205)	35 (0.287)	2 (0.016)	0 (0.000)	15 (0.123)	4 (0.033)	26 (0.213)	0 (0.000)	60 (0.492)	22 (0.180)	0 (0.000)
Cabot Station and Station No. 1 Combined Controls												
67	6 (0.090)	5 (0.075)	1 (0.015)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	5 (0.000)	0 (0.000)	5 (0.075)	1 (0.015)	0 (0.000)
Bascule gates Combined Controls												
75	17 (0.227)	15 (0.200)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	1 (0.000)	14 (0.187)	0 (0.000)	14 (0.187)	3 (0.040)	0 (0.000)

*Predator-related injuries not related to passage

**Flesh tear at tag site not related to passage

***LOE only numbers are also included in Injury and LOE column

Table 5-4
Alternate summary of malady data and malady-free estimates including fish with loss of equilibrium for recaptured juvenile American Shad passed through the Turners Falls Hydroelectric Project, November 2015. Combined controls released into the tailrace downstream of the three stations. Proportions are given in parentheses.

	Cabot Station	Station No. 1	Station No. 1	Bascule Gate 1				Bascule Gates 4				Cabot Station Combined Controls	Bascule Gates Combined Controls
	Unit 2	Unit 2/3	Unit 1	1,500 cfs	2,500 cfs	5,000 cfs	Combined	1,500 cfs	2,500 cfs	5,000 cfs	Combined		
Number released	120	90	90	60	60	62	182	60	60	60	180	71	75
Number examined for maladies	115 (0.958)	65 (0.722)	68 (0.756)	42 (0.700)	34 (0.567)	49 (0.790)	125 (0.687)	41 (0.683)	40 (0.667)	41 (0.683)	122 (0.678)	67 (0.944)	75 (1.000)
Number with passage related maladies	19 (0.165)	25 (0.385)	31 (0.456)	16 (0.381)	23 (0.676)	38 (0.776)	77 (0.616)	29 (0.707)	26 (0.650)	26 (0.634)	81 (0.664)	6 (0.090)	17 (0.227)
Visible injuries	10 (0.087)	5 (0.077)	14 (0.206)	8 (0.190)	12 (0.353)	17 (0.347)	37 (0.296)	17 (0.415)	17 (0.425)	16 (0.390)	50 (0.410)	1 (0.015)	1 (0.013)
Loss of equilibrium only	9 (0.078)	17 (0.262)	16 (0.235)	18 (0.429)	19 (0.559)	20 (0.408)	37 (0.296)	9 (0.220)	8 (0.200)	8 (0.195)	25 (0.205)	5 (0.075)	15 (0.200)
Scale loss only	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	1 (0.029)	1 (0.020)	3 (0.024)	2 (0.049)	1 (0.025)	2 (0.049)	5 (0.041)	0 (0.000)	0 (0.000)
1 hr mortality w/ no visible injury or LOE	0 (0.000)	3 (0.046)	1 (0.015)	0 (0.000)	1 (0.029)	0 (0.000)	1 (0.008)	1 (0.024)	0 (0.000)	0 (0.000)	1 (0.008)	0	1
Number without passage related maladies	95 (0.826)	40 (0.615)	37 (0.544)	26 (0.619)	11 (0.324)	11 (0.224)	48 (0.384)	12 (0.293)	14 (0.350)	15 (0.366)	41 (0.336)	61 (0.910)	58 (0.773)
Malady free rate	(0.927)	(0.860)	(0.761)	(0.819)	(0.643)	(0.680)	(0.717)	(0.559)	(0.573)	(0.584)	(0.572)		
SE	(0.030)	(0.047)	(0.055)	(0.069)	(0.088)	(0.073)	(0.046)	(0.082)	(0.083)	(0.082)	(0.049)		
90% CI (+/-)	(0.049)	(0.077)	(0.090)	(0.114)	(0.145)	(0.120)	(0.076)	(0.135)	(0.135)	(0.135)	(0.081)		

*Maladies include both visible injuries and LOE, some maladies (particularly LOE) maybe due to tagging/recapture.

Table 5-5

Summary Table of survival and malady-free estimates for juvenile American Shad passed through the Turners Falls Hydroelectric Project, October 2015.

	Cabot Station	Station No. 1	Station No. 1	Bascule Gate 1				Bascule Gate 4			
	Unit 2	Unit 2/3	Unit 1	1,500 cfs	2,500 cfs	5,000 cfs	Combined	1,500 cfs	2,500 cfs	5,000 cfs	Combined
1 h Survival %	95.0	67.8	76.6	69.4	47.7	75.6	63.0	64.2	59.0	73.6	64.8
90% CI (±)	3.3	8.2	7.9	11.0	11.4	10.2	6.7	11.0	11.2	10.7	6.7
Malady-Free %	92.7	86.0	76.1	81.9	64.3	68.0	71.7	55.9	57.3	58.4	57.2
90% CI (±)	4.9	7.7	9.0	11.4	14.5	12.0	7.6	13.5	13.5	13.5	8.1
Alternate * Malady-Free Estimate %	91.7	67.6	61.4	77.0	41.8	31.7	49.7	37.9	42.0	47.3	43.1
90% CI (±)	8.5	11.7	11.5	11.5	15.2	13.5	10.6	15.6	16.3	16.7	9.8

*Alternate Malady-Free estimates assigns all fish with loss of equilibrium as maladies.

Attachment H to Study 3.3.3.
Revised Appendix C Table

Appendix C

Incidence of maladies, including injury, scale loss, and temporary loss of equilibrium (LOE) observed on released wild juvenile American Shad passed through Cabot Station Unit 2, Station 1 Unit 1, Staion 1 Units 2/3, Bascule Gates 1 and 4 at 1,500, 2,500 and 5,000 cfs, October 2015. Combined controls released into the tailrace downstream of the stations.

Date	Test Lot	Fish ID	Live/Dead		Maladies	Passage and/or Tagging	Passage Malady*	Passage Maladies	Photo	Malady Severity	Probable Cause
					Cabot Unit 2						
10/14/15	1	021	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/14/15	1	026	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/14/15	1	029	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/14/15	1	033	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/14/15	1	034	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/15/15	2	002	dead	1h	Operculum Damage	Yes	No	Yes	Yes	Major	Shear
10/15/15	2	010	dead	1h	Missing Both Eyes	Yes	Yes	Yes	Yes	Major	Shear
10/15/15	2	014	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/15/15	2	015	alive		Cut left. Operculum	Yes	Yes	Yes	No	Minor	Undetermined
10/15/15	2	020	dead	24h	Bruise on Head	Yes	Yes	Yes	Yes	Major	Mechanical
10/15/15	2	025	alive		LOE, right Operculum Damage	Yes	Yes	Yes	No	Major	Shear
10/15/15	2	033	dead	24h	Ruptured right Eye, Min. Hemm left Eye	Yes	Yes	Yes	Yes	Major	Shear
10/15/15	2	037	alive		r. Laceration on Caudal Peduncle	Yes	Yes	Yes	No	Major	Mechanical
10/15/15	2	056	dead	24h	Lg. Bruise-top of Head and Body, LOE, Cut on Rt. Side of Tail	Yes	Yes	Yes	Yes	Major	Mechanical
10/15/15	2	060	alive		Hemm Snout	Yes	Yes	Yes	No	Major	Mechanical
10/15/15	2	074	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/15/15	2	078	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/15/15	2	084	dead	24h	Bulging and Hemm, Left Eye	Yes	Yes	Yes	Yes	Major	Shear
10/15/15	2	085	alive		LOE	Yes	No	No	No	Minor	Undetermined
					Station 1 Units 2/3						
10/16/15	1A	001	dead	24h	LOE. Bulging l. eye	Yes	Yes	Yes	Yes	Major	Shear
10/16/15	1A	004	dead	1h	Necropsied, no obvious injuries	Yes	Yes	Yes	No	Major	Undetermined
10/16/15	1A	016	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	025	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	026	dead	1h	Necropsied, no obvious injuries	Yes	Yes	Yes	No	Major	Undetermined
10/16/15	1A	028	dead	1h	LOE	Yes	No	No	No	Major	Undetermined
10/16/15	1A	029	dead	1h	LOE	Yes	No	No	No	Major	Undetermined
10/16/15	1A	035	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	038	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	039	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	047	alive		LOE, Bulging Eyes	Yes	Yes	Yes	No	Minor	Shear
10/16/15	1A	049	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	053	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	055	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	057	dead	1h	Necropsied, no obvious injuries	Yes	Yes	Yes	No	Major	Undetermined
10/16/15	1A	060	dead		LOE	Yes	No	No	No	Minor	Undetermined

10/16/15	1A	061	dead	24h	Missing right Eye	Yes	Yes	Yes	Yes	Major	Shear
10/16/15	1A	062	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	063	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	068	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	072	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	074	dead	1h	Torn Isthmus	Yes	Yes	Yes	Yes	Major	Shear
10/16/15	1A	077	alive		LOE, Hemm. R. pectoral	Yes	Yes	Yes	No	Major	Mechanical
10/16/15	1A	082	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	085	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
					Station 1 Unit 1						
10/17/15	2A	005	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	006	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	008	dead	1h	LOE, Hemm. R. pectoral	Yes	Yes	Yes	Yes	Major	Mechanical
10/17/15	2A	010	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	011	alive		LOE, Hemm. R. eye	Yes	Yes	Yes	No	Minor	Shear
10/17/15	2A	013	dead	48h	LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	020	alive		LOE, bulging eyes, Hemm behind operc.	Yes	Yes	Yes	No	Minor	Shear
10/17/15	2A	021	alive		LOE	Yes	Yes	No	No	Minor	Undetermined
10/17/15	2A	023	dead	1h	LOE	Yes	No	No	No	Major	Undetermined
10/17/15	2A	026	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	032	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	034	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	035	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	036	dead	1h	LOE	Yes	No	No	No	Major	Undetermined
10/17/15	2A	038	dead	1h	R. Eye Missing, R. Operculum, Torn	Yes	Yes	Yes	Yes	Major	Shear
10/17/15	2A	041	dead	1h	Necropsied, no obvious injuries	Yes	Yes	Yes	No	Major	Undetermined
10/17/15	2A	053	dead	24h	Hemm, Snout	Yes	Yes	Yes	Yes	Major	Mechanical
10/17/15	2A	055	dead	1h	Decap.	Yes	Yes	Yes	Yes	Major	Shear
10/17/15	2A	057	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	064	dead	1h	Ruptured r. eye	Yes	Yes	Yes	Yes	Major	Shear
10/17/15	2A	065	alive		Hemm. R. Operculum	Yes	Yes	Yes	No	Minor	Shear
10/17/15	2A	066	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	068	alive	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	069	dead	1h	Bulging r. Eye	Yes	Yes	Yes	Yes	Major	Shear
10/17/15	2A	071	alive		Bleeding r. Operculum	Yes	Yes	Yes	No	Minor	Shear
10/17/15	2A	072	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	076	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/17/15	2A	077	dead	24h	LOE, Ruptured r. Eye, Internal Hemm.	Yes	Yes	Yes	Yes	Major	Shear/Mech.
10/17/15	2A	082	alive		Wounded Snout	Yes	Yes	Yes	No	Minor	Mechanical
10/17/15	2A	085	dead	1h	Ruptured l. Eye	Yes	Yes	Yes	Yes	Major	Shear

					Bascule Gate 1 @ 1,500 cfs						
10/19/15	3	5	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/19/15	3	10	dead	24h	Tear above tag site	Yes	Yes	Yes	No	Major	Mechanical
10/19/15	3	14	dead	48h	Ruptured L. eye, broken back	Yes	Yes	Yes	No	Major	Mechanical
10/19/15	3	17	dead	1h	Hemm. Bruised head, broken back	Yes	Yes	Yes	No	Major	Mechanical
10/19/15	3	21	alive		Hemm. Snout	Yes	Yes	Yes	No	Minor	Mechanical
10/19/15	3	29	alive		cut above caudal peduncle	Yes	Yes	Yes	No	Major	Mechanical
10/19/15	3	32	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/19/15	3	36	dead	1h	bruising and bleeding pectoral fin	Yes	Yes	Yes	No	Major	Mechanical
10/19/15	3	37	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/19/15	3	38	dead	48h	LOE	Yes	No	No	No	Minor	Undetermined
10/19/15	3	42	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/19/15	3	048	dead	24h	LOE, tear at tag site	Yes	No	No	No	Minor	Tag related
10/19/15	3	049	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/19/15	3	052	dead	24h	Bruised, Scraped Head	Yes	Yes	Yes	Yes	Major	Mechanical
10/19/15	3	058	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/19/15	3	059	dead	24h	L. Eye Bleeding, LOE, Gash, L side anal fin	Yes	Yes	Yes	Yes	Major	Mechanical
10/19/15	3	061	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
					Bascule Gate 1 @ 2,500 cfs						
10/20/15	4	002	dead	1h	Bruise, Scrape on Body and Head	Yes	Yes	Yes	Yes	Major	Mechanical
10/20/15	4	005	alive		LOE, Gash L. side	Yes	Yes	Yes	No	Minor	Mechanical
10/20/15	4	010	dead	24h	LOE, Broken Back	Yes	Yes	Yes	Yes	Major	Mechanical
10/20/15	4	012	dead	24h	Tear at Tag Site	Yes	No	No	No	Major	Tag R.
10/20/15	4	016	dead	1h	Decap	Yes	Yes	Yes	Yes	Major	Shear
10/20/15	4	019	dead	24h	Broken Back	Yes	Yes	Yes	Yes	Major	Mechanical
10/20/15	4	022	dead	24h	>20% Descale L. Side	Yes	Yes	Yes	No	Minor	Mechanical
10/20/15	4	028	dead	1h	Necropsied, no obvious injuries	Yes	Yes	Yes	No	major	Undetermined
10/20/15	4	030	dead	1h	Tear at Tag Site	Yes	No	No	No	Major	Tag R.
10/20/15	4	031	dead	24h	LOE, Scrape R. Side	Yes	Yes	Yes	Yes	Minor	Mechanical
10/20/15	4	035	dead	1h	L. Oper., Tear, Head Bruise, Broken Back	Yes	Yes	Yes	Yes	Major	Mech/Shear
10/20/15	4	036	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	041	dead	1h	LOE	Yes	Yes	No	Yes	Major	Mechanical
10/20/15	4	042	dead	24h	LOE, Broken Back	Yes	Yes	Yes	No	Major	Mechanical
10/20/15	4	043	dead	24h	LOE, Broken Back	Yes	Yes	Yes	Yes	Major	Mechanical
10/20/15	4	046	dead	24h		Yes	No	No	No	Minor	Undetermined
10/20/15	4	047	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	051	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	053	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	054	dead	1h	L. Eye Bulge	Yes	Yes	Yes	No	Major	Shear
10/20/15	4	055	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	056	dead	48h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	058	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined

Bascule Gate 1 @ 5,000 cfs

10/21/2015	5	006	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	007	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	008	dead	24h	LOE, Broken Back	Yes	Yes	Yes	No	Major	Mechanical
10/21/2015	5	011	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	013	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	014	dead	1h	Decap.	Yes	Yes	No	Yes	Major	Shear
10/21/2015	5	015	dead	1h	Smashed Face	Yes	Yes	Yes	Yes	Major	Mechanical
10/21/2015	5	016	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	020	alive	24h	Ventral Side Abrasion	Yes	Yes	Yes	No	Minor	Mechanical
10/21/2015	5	021	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	022	dead	24h	LOE, L. Operculum, Hemm,	Yes	Yes	Yes	No	Minor	Shear
10/21/2015	5	024	dead	24h	LOE, Internal Hemm,	Yes	Yes	Yes	No	Major	Mech/Shear
10/21/2015	5	026	alive	1h	LOE, Scraped Nose	Yes	Yes	Yes	No	Minor	Mechanical
10/21/2015	5	027	dead	24h	LOE	Yes	Yes	No	No	Minor	Undetermined
10/21/2015	5	028	dead	24h	LOE, L Scrape on Nose	Yes	Yes	Yes	No	Minor	Mechanical
10/21/2015	5	029	dead	1h	Missing L, Eye, Laceration on Head/Body, R.Operc Tear	Yes	Yes	Yes	Yes	Major	Mech/Shear
10/21/2015	5	030	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	033	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	034	dead	1h	Predation (Chunk out of Caudal)	Yes	No	Yes	Yes	Major	Predation
10/21/2015	5	036	dead	24h	LOE, Broken Back	Yes	Yes	Yes	Yes	Major	Mechanical
10/21/2015	5	038	dead	24h	Damaged (Bent) R/L Operculum	Yes	Yes	Yes	Yes	Major	Undetermined
10/21/2015	5	039	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	040	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	042	dead	24h	LOE, Scrape L. Side, Internal Hemm.	Yes	Yes	Yes	Yes	Major	Mechanical
10/21/2015	5	043	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	044	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	046	dead	24h	LOE, Scale Loss >50%	Yes	Yes	Yes	Yes	Major	Mechanical
10/21/2015	5	047	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	048	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	049	dead	24h	LOE, Scrape on Head	Yes	Yes	Yes	Yes	Minor	Mechanical
10/21/2015	5	050	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	051	dead	24h	Predation	Yes	No	No	Yes	Major	Predation
10/21/2015	5	052	dead	24h	LOE, Bleeding Pec Fin	Yes	Yes	Yes	No	Minor	Mech/Shear
10/21/2015	5	055	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	058	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	059	dead	24h	LOE, Broken Back	Yes	Yes	Yes	No	Minor	Mechanical
10/21/2015	5	060	alive		LOE	Yes	No	No	No	Major	Undetermined
10/21/2015	5	061	dead	24h	LOE, Broken Back	Yes	Yes	Yes	No	Minor	Mechanical
10/21/2015	5	062	dead	24h	LOE	Yes	No	No	No	Major	Undetermined

					Bascule Gate 4 @ 1,500 cfs						
10/22/2015	6	002	dead	1h	LOE, Scale Loss>50%	Yes	Yes	Yes	Yes	Major	Mechanical
10/22/2015	6	004	dead	24h	Bruise behind head (body) Major scale loss	Yes	Yes	Yes	Yes	Minor	Mechanical
10/22/2015	6	007	dead	24h	LOE, Scale Loss>50%	Yes	Yes	Yes	No	Minor	Undetermined
10/22/2015	6	008	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/22/2015	6	010	dead	24h	LOE, Tag Tear, R. side laceration, R. Operc Scrape	Yes	No	No	No	Major	Undetermined
10/22/2015	6	012	dead	1h	No obvious injuries	Yes	Yes	Yes	Yes	Major	Mechanical
10/22/2015	6	014	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/22/2015	6	018	dead	24h	LOE, > 20% descaled both sides, broken back	Yes	Yes	Yes	Yes	Major	Mechanical
10/22/2015	6	019	dead	24h	LOE, Chin Scrape, Int. Hemm.	Yes	Yes	Yes	Yes	Major	Mechanical
10/22/2015	6	020	dead	24h	LOE, Scrape L. Head, Bent R. Pectoral	Yes	Yes	Yes	Yes	Minor	Mechanical
10/22/2015	6	021	dead	24h	LOE, L Torn Operculum	Yes	Yes	Yes	Yes	Minor	Shear
10/22/2015	6	023	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/22/2015	6	025	dead	24h	LOE, Scrape L. Head	Yes	Yes	Yes	Yes	Minor	Mechanical
10/22/2015	6	026	dead	48h	LOE, > 20% descaled both sides	Yes	Yes	Yes	No	Minor	Mechanical
10/22/2015	6	028	dead	48h	LOE, Tag Tear, Broken Back	Yes	Yes	Yes	Yes	Major	Mechanical
10/22/2015	6	031	dead	24h	L. Operc.Tear	Yes	Yes	No	Yes	Minor	Shear
10/22/2015	6	034	alive		LOE, Pelvic and Anal Fin Hemm.	Yes	Yes	Yes	No	Minor	Shear/Press.
10/22/2015	6	037	dead	24h	LOE, Small Puncture L. Side	Yes	Yes	Yes	No	Minor	Mechanical
10/22/2015	6	038	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/22/2015	6	041	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/22/2015	6	043	dead	1h	LOE, L Operculum Tear, Tag Tear	Yes	Yes	Yes	Yes	Major	Shear
10/22/2015	6	044	dead	24h	LOE, R.Operculum Tear,> 20% descaled	Yes	Yes	Yes	Yes	Minor	Shear
10/22/2015	6	045	dead	1h	Necrop. No Obvious Inj.	Yes	No	Yes	No	Major	Undetermined
10/22/2015	6	047	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/22/2015	6	051	dead	24h	Tag Tear, Bent Pelvic Fin	Yes	Yes	Yes	Yes	Major	Shear
10/22/2015	6	052	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/22/2015	6	053	dead	24h	LOE, R.Operculum Flare	Yes	Yes	Yes	Yes	Minor	Shear
10/22/2015	6	054	alive		LOE, Small Puncture L. Side	Yes	Yes	Yes	No	Minor	Mechanical
10/22/2015	6	061	alive		LOE	Yes	No	No	No	Minor	Undetermined
					Bascule Gate 4 @ 2,500 cfs						
10/23/2015	7	001	alive		R. Operc. Tear	Yes	Yes	Yes	No	Minor	Shear
10/23/2015	7	011	dead	1h	R./L. Operc. Tear, Inter Hemm, Ruptured R Eye	Yes	Yes	Yes	Yes	Major	Shear/Mech
10/23/2015	7	012	dead	1h	Severe Tag Tear, Hemm R. Eye	Yes	Yes	Yes	Yes	Major	Shear
10/23/2015	7	013	dead	1h	Torn isthmus, Lacer. Head	Yes	Yes	Yes	Yes	Major	Mechanical
10/23/2015	7	014	alive		LOE, Scrape on body	Yes	Yes	Yes	No	Minor	Mechanical
10/23/2015	7	020	dead	24h	Broken Jaw, Lacer., R. side	Yes	Yes	Yes	No	Major	Mechanical
10/23/2015	7	021	dead	24h	Bruising along R&L body	Yes	Yes	Yes	No	Minor	Mechanical
10/23/2015	7	022	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/23/2015	7	024	dead	24h	Min. Hemm dorsal fin base	Yes	Yes	Yes	No	Minor	Mechanical
10/23/2015	7	026	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/23/2015	7	027	dead	48h	Bruise behind head	Yes	Yes	Yes	No	Minor	Mechanical

10/23/2015	7	031	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/23/2015	7	032	dead	24h	LOE, >20% R. Scale loss, R. Operc. Flare	Yes	Yes	Yes	No	Minor	Shear
10/23/2015	7	034	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/23/2015	7	035	dead	1h	Broken Jaw	Yes	Yes	Yes	Yes	Major	Mechanical
10/23/2015	7	036	dead	24h	LOE, R Operc. Flare	Yes	Yes	Yes	Yes	Minor	Shear
10/23/2015	7	039	dead	24h	LOE, R Operc. Flare and Scraped	Yes	Yes	Yes	No	Minor	Shear/Mech
10/23/2015	7	044	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/23/2015	7	046	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/23/2015	7	049	dead	24h	Tag Tear, L. Operc. Flare	Yes	Yes	Yes	Yes	Minor	Shear
10/23/2015	7	050	dead	1h	L. Operc flare, bruise head	Yes	Yes	Yes	Yes	Major	Shear/Mech
10/23/2015	7	051	dead	24h	LOE, min bruise body	Yes	Yes	Yes	No	Minor	Mechanical
10/23/2015	7	052	dead	24h	LOE>20% R. Scale loss both sides, hemm dorsal	Yes	Yes	Yes	Yes	Minor	Mechanical
10/23/2015	7	053	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/23/2015	7	054	dead	24h	LOE>20% R. Scale loss both sides,	Yes	Yes	Yes	No	Minor	Mechanical
10/23/2015	7	055	dead	24h	LOE, bruise on head	Yes	Yes	Yes	No	Minor	Mechanical
10/23/2015	7	056	alive		LOE	Yes	No	No	No	Minor	Undetermined
					Bascule Gate 4 @ 5,000 cfs						
10/24/2015	8	003	dead	24h	LOE> 20% descaled both sides	Yes	Yes	Yes	No	Minor	Mechanical
10/24/2015	8	004	dead	24h	LOE, L. Operc. Flare, inter hemm	Yes	Yes	Yes	No	Major	Shear/Mech
10/24/2015	8	007	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	009	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	010	dead	24h	LOE, Scrape L&R operc.	Yes	Yes	Yes	No	Minor	Mechanical
10/24/2015	8	014	dead	24h	LOE, Tear tear, broken back	Yes	Yes	Yes	No	Major	Mechanical
10/24/2015	8	015	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	022	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	023	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	027	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	031	dead	24h	LOE> 20% descaled both sides, tag tear	Yes	Yes	Yes	No	Major	Mechanical
10/24/2015	8	033	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	034	dead	24h	Internal Hemm.	Yes	Yes	Yes	No	Major	Shear/Press.
10/24/2015	8	035	dead	24h	LOE, Scrape R. operc. (sm)	Yes	Yes	Yes	No	Minor	Mechanical
10/24/2015	8	039	dead	24h	LOE, min. hemm, L. eye	Yes	Yes	Yes	No	Minor	Shear
10/24/2015	8	046	dead	24h	LOE, L. Operc.hemm	Yes	Yes	Yes	No	Minor	Shear
10/24/2015	8	048	alive		Hemm. L. Eye	Yes	Yes	Yes	No	Minor	Shear
10/24/2015	8	049	dead	24h	Tear Tear, Scrape L. operc	Yes	Yes	Yes	No	Minor	Mechanical
10/24/2015	8	051	dead	24h	LOE, Broken back	Yes	Yes	Yes	No	Major	Mechanical
10/24/2015	8	052	dead	24h	LOE, L. side body punctures	Yes	Yes	Yes	No	Minor	Mechanical
10/24/2015	8	053	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	055	dead	24h	Broken back	Yes	No	Yes	No	Major	Mechanical
10/24/2015	8	056	alive		LOE, missing part of dorsal fin	Yes	Yes	Yes	No	Minor	Mechanical
10/24/2015	8	057	dead	24h	LOE, min L. operc tear	Yes	Yes	Yes	No	Minor	Shear

10/24/2015	8	060	dead	24h	LOE, broken back	Yes	Yes	Yes	No	Major	Mechanical
10/24/2015	8	062	dead	48h	L. Scrape operc.	Yes	Yes	Yes	No	Minor	Mechanical
					Cabot Unit 2 Control						
10/15/15	2	C07	dead	24h	Bruise on Head	Yes	Yes	Yes	No	Major	Mechanical
10/15/15	2	C10	alive		LOE	Yes	No	No	No	Minor	Undetermined
					Station 1 Units 2/3 Control						
10/16/15	1A	C03	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	C05	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	C12	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/16/15	1A	C15	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
					Bascule Gate 1 @ 1,500 cfs Control						
10/19/15	3	C05	dead	1h	Necropsied, no obvious injuries	Yes	Yes	Yes	No	Major	Undetermined
10/19/15	3	C18	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/19/15	3	C20	alive		LOE	Yes	No	No	No	Minor	Undetermined
					Bascule Gate 1 @ 2,500 cfs Control						
10/20/15	4	C11	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	C13	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	C15	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	C16	alive		LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	C17	dead	1h	LOE	Yes	Yes	No	No	Major	Undetermined
10/20/15	4	C18	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/20/15	4	C20	dead	24h	Hemm. L. Eye, Bruise on Head	Yes	Yes	Yes	Yes	Major	Mech/Shear
					Bascule Gate 1 @ 5,000 cfs Control						
10/21/2015	5	C08	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/21/2015	5	C09	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
					Bascule Gate 4 @ 1,500 cfs Control						
10/22/2015	6	C04	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
					Bascule Gate 4 @ 2,500 cfs Control						
10/23/2015	7	C16	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
					Bascule Gate 4 @ 5,000 cfs Control						
10/24/2015	8	C03	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	C05	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined
10/24/2015	8	C06	dead	24h	LOE	Yes	No	No	No	Minor	Undetermined

Attachment I to Study 3.3.3.
NFM Operations and Release Times

See Excel file Attachment_I_Study_3_3_3

STUDY NO. 3.3.7 ATTACHMENTS

Attachment A to Study 3.3.7.
Table Study results from hydroelectric projects equipped with Francis type turbines similar to Cabot as summarized by Franke, et al. (1997)

					Avg. Fish		%	
	Sampling		Sample Size		Length		Survival	
Station	**Method**	**Species Tested**	**Test**	**Control**	**(mm)**	**Control**	**1 hr**	**Source**
White Rapids, WI	Balloon tag	Bluegill	56		90	98.4	95.0	Dilip.xls
Five Channels, MI	Full discharge netting	Bluegill	95		118		93.6	LMS 1991
Five Channels, MI	Full discharge netting	Bluegill	91		170		89.2	LMS 1991
Stevens Creek, SC	Balloon tag	Bluegill	110	110	122	99.1	95.4	RMC 1991
White Rapids, WI	Balloon tag	Bluegill	44		155	97.4	100.0	Dilip.xls
E. J. West, NY	Full discharge netting	Centrarchid			< 100		72.0	KA
E. J. West, NY	Full discharge netting	Centrarchid			100-250		85.0	KA
E. J. West, NY	Full discharge netting	Centrarchid			> 250		60.0	KA
Minetto, NY	Full discharge netting	Centrarchid			< 100		62.0	KA
Minetto, NY	Full discharge netting	Centrarchid			100-250		83.0	KA
Minetto, NY	Full discharge netting	Centrarchid			> 250		84.0	KA
Caldron Falls, WI (Unit 1)	Full discharge netting	centrarchiforms			76	82 fish	100.0	Harza
Caldron Falls, WI (Unit 1)	Full discharge netting	centrarchiforms			127	83 fish	98.9	Harza
Caldron Falls, WI (Unit 1)	Full discharge netting	centrarchiforms			178	35 fish	86.8	Harza
Sandstone Rapids,WI	Full discharge netting	centrarchiforms			76	94 fish	97.0	Harza
Sandstone Rapids,WI	Full discharge netting	centrarchiforms			127	90 fish	80.7	Harza
Sandstone Rapids,WI	Full discharge netting	centrarchiforms			178	52 fish	79.9	Harza
Holtwood, PA(U10/single runner)	Balloon tag	American Shad	100	100	125	90.0	89.4	RMC 1992b
Holtwood, PA (U3/double runner)	Balloon tag	American Shad	100	80	125	93.8	83.5	RMC 1992b
Vernon, VT/NH	Balloon tag	American Shad			95		94.7	D
Stevens Creek, SC	Balloon tag	Blueback Herring	131	120	203	89.2	95.3	RMC 1991
Minetto, NY	Full discharge netting	Clupeid			juvenile?		80.0	KA
Five Channels, MI	Full discharge netting	Gold./Common Shiner	59		114		81.8	LMS 1991
Five Channels, MI	Full discharge netting	Gold./Common Shiner	60		154		85.5	LMS 1991

					Avg. Fish		%	
	Sampling		**Sample Size**		**Length**		**Survival**	
Station	**Method**	**Species Tested**	**Test**	**Control**	**(mm)**	**Control**	**1 hr**	**Source**
E. J. West, NY	Full discharge netting	Soft Ray			< 100		32.0	KA
E. J. West, NY	Full discharge netting	Soft Ray			100-250		71.0	KA
E. J. West, NY	Full discharge netting	Soft Ray			> 250		68.0	KA
Minetto, NY	Full discharge netting	Soft Ray			< 100		82.0	KA
Minetto, NY	Full discharge netting	Soft Ray			100-250		94.0	KA
Minetto, NY	Full discharge netting	Soft Ray			> 250		84.0	KA
Five Channels, MI	Full discharge netting	Spottail Shiner	30		116		36.4	LMS 1991
Caldron Falls, WI (Unit 1)	Full discharge netting	fusiforms			76	82 fish	80.3	Harza
Caldron Falls, WI (Unit 1)	Full discharge netting	fusiforms			127	84 fish	84.8	Harza
Caldron Falls, WI (Unit 1)	Full discharge netting	fusiforms			178	58 fish	70.3	Harza
Caldron Falls, WI (Unit 1)	Full discharge netting	fusiforms			229	62 fish	64.3	Harza
Caldron Falls, WI (Unit 1)	Full discharge netting	fusiforms			292	80 fish	59.5	Harza
Caldron Falls, WI (Unit 1)	Full discharge netting	fusiforms			>292	62 fish	35.5	Harza
Sandstone Rapids,WI	Full discharge netting	fusiforms			76	94 fish	64.9	Harza
Sandstone Rapids,WI	Full discharge netting	fusiforms			127	95 fish	75.0	Harza
Sandstone Rapids,WI	Full discharge netting	fusiforms			178	97 fish	76.0	Harza
Sandstone Rapids,WI	Full discharge netting	fusiforms			229	71 fish	69.8	Harza
Sandstone Rapids,WI	Full discharge netting	fusiforms			292	70 fish	58.4	Harza
Sandstone Rapids,WI	Full discharge netting	fusiforms			>292	82 fish	47.1	Harza
Five Channels, MI	Full discharge netting	Northern Pike	31		352		91.3	LMS 1991
E. J. West, NY	Full discharge netting	Percid			< 100		51.0	KA
E. J. West, NY	Full discharge netting	Percid			100-250		71.0	KA
E. J. West, NY	Full discharge netting	Percid			> 250		68.0	KA
Minetto, NY	Full discharge netting	Percid			< 100		80.0	KA
Minetto, NY	Full discharge netting	Percid			100-250		86.0	KA

Station	Sampling Method	Species Tested	Sample Size Test	Control	Avg. Fish Length (mm)	Control	% Survival 1 hr	Source
Minetto, NY	Full discharge netting	Percid			> 250		84.0	KA
Five Channels, MI	Full discharge netting	Walleye	55		162		71.2	LMS 1991
Five Channels, MI	Full discharge netting	Walleye	60		385		76.7	LMS 1991
Five Channels, MI	Full discharge netting	Yellow Perch	25		107		72.7	LMS 1991
Five Channels, MI	Full discharge netting	Yellow Perch	30		186		77.1	LMS 1991
Five Channels, MI	Full discharge netting	White Sucker	56		180		88.6	LMS 1991
Five Channels, MI	Full discharge netting	White Sucker	60		290		71.4	LMS 1991
White Rapids, WI	Balloon tag	White Sucker	42		204	91.7	93.0	Dilip.xls
White Rapids, WI	Balloon tag	White Sucker	58		112	98.4	100.0	Dilip.xls
Five Channels, MI								Matousek et. al. 1994
Minetto, NY	Full discharge netting	American Eel			500-750		94.0	KA
Vernon, VT/NH	Balloon tag	Atlantic salmon	85	70	180	100.0	94.1	
Five Channels, MI	Full discharge netting	Rainbow Trout	40		108		95.8	LMS 1991
Five Channels, MI	Full discharge netting	Rainbow Trout	46		317		70.0	LMS 1991
E. J. West, NY	Full discharge netting	Salmonid			< 100		73.0	KA
E. J. West, NY	Full discharge netting	Salmonid			100-250		91.0	KA
E. J. West, NY	Full discharge netting	Salmonid			> 250		96.0	KA
Minetto, NY	Full discharge netting	Salmonids			< 100		92.0	KA
Minetto, NY	Full discharge netting	Salmonids			100-250		91.0	KA
Minetto, NY	Full discharge netting	Salmonids			> 250		92.0	KA
Stevens Creek, SC	Balloon tag	Spotted Sucker/Y. Perch	120	120	165	98.3	98.3	RMC 1991

Attachment B to Study 3.3.7.
Revised Table 4.1-1:Summary of Traits Based Assessment in which plus sign indicates an increased risk to entrainment and minus sign indicates a lower likelihood

Species	Location within TFI	Habitat within Channel	Migration and Movement	Reproductive Strategy	Demography	Recolonization	Sources
Yellow Perch	Main channel (+)	Most commonly found in clear water near vegetation; tends to shoal near the shore during spring (-)	Lateral migrations into shallow water, sometimes tributaries (-)	Non-guarders (+)	Medium resilience with minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Cada et al. 2012 Page & Burr 1991
Pumpkinseed	Main channel (+)	Inhabits in or near vegetation cover or brush cover (-)	Lateral migrations into shallow water (-)	Guarders (-)	Medium resilience with minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Page & Burr 1991 Cada et al. 2012
Smallmouth Bass	Main channel (+)	Inhabit shallow rocky areas and flowing pools of rivers, cool flowing streams and reservoirs (+)	Lateral migrations into shallow water (-)	Guarders (-)	Medium resilience with minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Scott & Crossman 1973
Largemouth Bass	Main channel (+)	Inhabits clear, vegetated lakes, ponds, swamps, and backwaters and pools of creeks and rivers; usually found over mud or sand and common in impoundments; prefers quiet, clear water and over-grown banks (+)	Lateral migrations into shallow water (-)	Guarders (-)	Low resilience with minimum population doubling tie 4.5 - 14 years (+)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Page & Burr 1991

Species	Location within TFI	Habitat within Channel	Migration and Movement	Reproductive Strategy	Demography	Recolonization	Sources
Bluegill	Main channel (+)	Found frequently in lakes, ponds, reservoirs, and sluggish streams, and prefers deep weed beds (-)	Lateral migrations into shallow water (-)	Guarders (-)	Medium resilience with minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Page & Burr 1991
Spottail Shiner	Main channel (+)	Found in large rivers or lakes, 3-60 feet dep with sand or gravel bottoms (+)	Lateral migrations into shallow water (-)	Non-guarders (+)	Medium resilience with minimum population doubling time, 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Page & Burr 1991
White sucker	Main channel (+)	Usually occurs in small, clear, cool creeks and small to medium rivers; may be found at a depth greater than 45 meters (-)	Moves to shallow water to feed (-)	Non-guarders (+)	Low resilience with minimum population doubling tie 4.5 - 14 years (+)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Page & Burr 1991
Walleye	Main channel (+)	Preferred habitat are slightly turbid lakes and rivers. (+)	Lateral migrations into tributary streams (-)	Non-guarders (+)	Low resilience with minimum population doubling tie 4.5 - 14 years (+)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Robins et al. 1991 Cada et al. 2012 Page & Burr 1991
Golden Shiner	Main channel (+)	Prefer relatively clear and quiet water with a great deal of aquatic vegetation in lakes, ponds, or large slow-flowing streams and rivers. (-)	Lateral migration towards spawning areas, occurs in ponds and lakes over vegetation, however feeding occurs at the	Non-guarders (+)	Medium resilience with minimum population doubling time, 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Page & Burr 2011

Species	Location within TFI	Habitat within Channel	Migration and Movement	Reproductive Strategy	Demography	Recolonization	Sources
			surface (-)				
Black Crappie	Main channel (+)	Inhabits lakes, ponds, sloughs, and backwaters of pools of streams; usually occurs among vegetation over mud or sand, most common in clear water (-)	Lateral migrations into shallow water (-)	Guarders (-)	Medium resilience with minimum population doubling time, 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Page & Burr 1991 Cada et al. 2012
White Perch	Main channel (+)	Primarily found in brackish water but common in pools and other quiet water areas of medium to large rivers, usually over mud (+)	Travel in schools searching for food and forage over a broad area, broadcast spawning occurs over mud (+)	Non-guarders (+)	Low resilience with minimum population doubling time 4.5 - 14 years (+)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Page & Burr 1991 Cada et al. 2012
Rock Bass	Main channel (+)	Inhabits vegetated brushy stream margins and pools of creeks and small to medium rivers, and rocky and vegetated margins of lakes (+)	Lateral migration to shallow water to spawn, constructs plate-like depression in shallow water (-)	Guarders (-)	Medium resilience with minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Page & Burr 1991
Brown Bullhead	Main channel (+)	Occurs in pools and sluggish runs over soft substrates in creeks and small to large rivers; young often found near surface (-)	Lateral migration into shallow water to spawn, preferring sites with some shelter (-)	Guarders (-)	Medium resilience with minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004Page & Burr 1991

Species	Location within TFI	Habitat within Channel	Migration and Movement	Reproductive Strategy	Demography	Recolonization	Sources
Chain Pickerel	Main channel (+)	Inhabits vegetated lakes, swamps, and backwaters and quiet pools of creeks and small to medium rivers; juveniles lie motionless near shore while larvae hide among vegetation (+)	Lateral migration into marshy areas and shallow bays shortly after ice out; adults migrate (laterally) into deeper water during winter (-)	Non-guarders (+)	Medium resilience with minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Crossman 1996
Fallfish	Main channel (+)	Inhabits gravel-bottomed and rubble bottomed pools and runs of small to medium rivers and also lake margins (+)	Lateral spawning migrations preferring quiet water in streams or around shores of lakes with clean gravel bottom (-)	Nesters (-)	Low resilience with minimum population doubling time 4.5 - 14 years (+)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Hartel et al. 2002 Page & Burr 2011
Common Carp	Main channel (+)	Hardy and tolerant of a wide variety of conditions but generally prefer large water bodies with slow flowing or standing water and soft sediments (+)	Lateral spawning migrations into shallow water (-)	Non-guarders (+)	Medium resilience with minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Kottelat & Freyhof 2007
Banded Killifish	Quiet, shallow margins of lakes, ponds, and sluggish streams (+)	Benthopelagic, usually over sand or mud, often near vegetation (-)	Non-migratory, form schools near surface (-)	Non-guarders (+)	High reproductive rates, relatively short population doubling time of less than 15 months (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Cada et al. 2012 Page & Burr 2011

Species	Location within TFI	Habitat within Channel	Migration and Movement	Reproductive Strategy	Demography	Recolonization	Sources
Channel Catfish	Main channel (+)	Associated with rocky or sandy bottom, but not vegetative areas (+)	Lateral spawning migrations into shallow water (-)	Guarders, nesters (-)	Low resilience with minimum population doubling time 4.5 - 14 years (+)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Cada et al. 2012 Hartel et al. 2002 Page & Burr 1991
Common Shiner	Main channel (+)	Clear, cool, unvegetated areas with swift to moderate current, over gravel to rubble bottom (+)	Non-migratory, but may make upstream movements for spawning (-)	Nesters, guarders (-)	Medium resilience, minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Hartel et al. 2002 Cada et al. 2012 Robins et al. 1991
Longnose Dace	Main channel (+)	Swift-flowing riffles with rubble and gravel (+)	Non-migratory, but lateral spawning movements into shallow water (-)	Non-guarders (+)	Medium resilience with minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Hartel et al. 2002 Cada et al. 2012 Robins et al. 1991
Mimic Shiner	Main channel (+)	Sandly pools of headwaters, creeks and small to large rivers (-)	Non-migratory, but lateral spawning movements into shallow water (-)	Non-guarders (+)	High resilience, minimum population doubling time less than 15 months (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Hartel et al. 2002 Cada et al. 2012 Page & Burr 1991
Northern Pike	Main channel (+)	Occurs in clear vegetated lakes, quiet pools and backwaters of creeks and small to large rivers (-)	Lateral spawning movements inshore or to marsh areas (-)	Non-guarders (+)	Low resilience, minimum population doubling time of 4.5-14 years (+)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Hartel st al. 2002 Cada et al. 2012 Crossman 1996

Species	Location within TFI	Habitat within Channel	Migration and Movement	Reproductive Strategy	Demography	Recolonization	Sources
Rosyface Shiner	Main channel (+)	Prefers clear, swift large creeks and small rivers with gravel or rubble substrate, usually in or around riffles (-)	Non-migratory, but may make lateral spawning movements (-)	Non-guarders (+)	High resilience, minimum population doubling time less than 15 months (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Cada et al. 2012 Page & Burr 1991
Tessellated Darter	Main channel (+)	Prefer fluvial habitat with firm substrates ranging from pebble to cobble (+)	Non-migratory, but may make lateral spawning movements (-)	Nesters, guarders (-)	Medium resilience, minimum population doubling time 1.4 - 4.4 years (-)	Presence of upstream and downstream passage facilities throughout system, population has the ability to recolonize (-)	Werner 2004 Cada et al. 2012 Hartel et al. 2002 Page & Burr 1991

Attachment C to Study 3.3.7.
Table 4.1-2: Resident fish swim speed analysis at Cabot Station, Station No. 1 and Northfield Mountain intakes.

			Swim Speed			Entrainment Susceptibility		
Species Name	**Fork Length (in)**	**Acclimation Temperature (°C)**	**Sustained (fps)**	**Burst (fps)**	**Source**	**Northfield Pumping (3.6 fps)**	**Station No. 1 (1.2 fps)**	**Cabot Station (3.9 fps)**
Yellow Perch	N/A	N/A	1.31	2.43	Leavy & Bonner, 2009	-	+	-
Pumpkinseed	5.00	20	1.25	2.32	Cooke 2009	-	-	-
Smallmouth Bass	0.87	5	0.16	0.29	Cooke 2009	-	-	-
	0.87	10	0.34	0.63		-	-	-
	0.87	15	0.49	0.91		-	-	-
	0.87	20	0.74	1.36		-	-	-
	0.87	25	0.85	1.58		-	-	-
	0.87	30	0.98	1.82		-	-	-
	0.87	35	0.83	1.54		-	-	-
	12.20	17	3.65	6.75		+	+	-
	10.31	15	2.76	5.10		-	+	-
	16.54	20	1.90	3.52		-	+	-
Largemouth Bass	2.28	30	1.54	2.84	Cooke 2009	-	+	-
	3.39	20	2.03	3.76		-	+	-
	4.35	5	0.63	1.16		-	-	-
	4.35	10	0.96	1.78		-	-	-
	3.82	20	1.17	2.17		-	-	-
	3.98	5	0.66	1.21		-	-	-
	4.09	25	1.19	2.21		-	-	-
	4.80	25	1.36	2.53		-	+	-
	6.26	6	0.99	1.83		-	-	-
	6.54	18	1.09	2.03		-	-	-
	6.69	12	1.15	2.13		-	-	-
Bluegill	6.10	13	1.22	2.26	Cooke 2009	-	+	-
	6.10	25	1.53	2.82		-	+	-
	6.10	30	1.42	2.63		-	+	-

			Swim Speed			Entrainment Susceptibility		
Species Name	**Fork Length (in)**	**Acclimation Temperature (°C)**	**Sustained (fps)**	**Burst (fps)**	**Source**	**Northfield Pumping (3.6 fps)**	**Station No. 1 (1.2 fps)**	**Cabot Station (3.9 fps)**
Spottail Shiner	N/A	N/A	1.64	3.03	Leavy & Bonner, 2009	-	+	-
White Sucker	10.83	12	2.02	3.74	Peake 2008	-	+	-
Walleye	21.26	5	1.70	3.14	Bailly 2012; Peake 2000	-	+	-
	21.26	10	1.78	3.30		-	+	-
	21.26	15	1.87	3.45		-	+	-
Golden Shiner	N/A	N/A	1.64	3.03	Leavy & Bonner, 2009	-	+	-
Black Crappie	1.97	6	0.33	0.61	Cooke et al., 2009	-	-	-
	1.97	16.5	0.52	0.97		-	-	-
	1.97	25.5	0.66	1.21		-	-	-
	3.00	15	0.45	0.82		-	-	-
	3.15	25	0.45	0.84		-	-	-
	3.15	5	0.20	0.37		-	-	-
	3.94	6	0.36	0.67		-	-	-
	3.94	16.5	0.66	1.21		-	-	-
	3.94	25.5	0.92	1.70		-	-	-
	5.91	6	0.33	0.61		-	-	-
	5.91	16.5	0.49	0.91		-	-	-
	5.91	25.5	0.98	1.82		-	-	-
	6.50	25	1.14	2.11		-	-	-
	7.87	6	0.49	0.91		-	-	-
	7.87	16.5	0.66	1.21		-	-	-
	7.87	25.5	0.98	1.82		-	-	-
	9.84	6	0.49	0.91		-	-	-
	9.84	16.5	0.66	1.21		-	-	-
	9.84	25.5	0.82	1.52		-	-	-

			Swim Speed			Entrainment Susceptibility		
Species Name	**Fork Length (in)**	**Acclimation Temperature (°C)**	**Sustained (fps)**	**Burst (fps)**	**Source**	**Northfield Pumping (3.6 fps)**	**Station No. 1 (1.2 fps)**	**Cabot Station (3.9 fps)**
White Perch	N/A	N/A	1.31	2.43	Leavy & Bonner, 2009	-	+	-
Rock Bass	N/A	N/A	1.05	1.94	Leavy & Bonner, 2009	-	-	-
Brown Bullhead	N/A	N/A	2.30	4.25	Leavy & Bonner, 2009	-	+	-
Chain Pickerel	11.22	13.5	0.99	1.83	Peake 2008	-	-	-
Fallfish	N/A	N/A	1.64	3.03	Leavy & Bonner, 2009	-	+	-
Common Carp	N/A	N/A	1.64	3.03	Leavy & Bonner, 2009	-	+	-
Banded Killifish	3	N/A	1.10	2.04	Videler, 1993	-	-	-
Channel Catfish	13	N/A	3.09	5.72	Videler, 1993	-	+	-
Common Shiner	5.5	N/A	1.61	2.98	Videler, 1993	-	+	-
Longnose Dace	3	N/A	1.10	2.04	Videler, 1993	-	-	-
Mimic Shiner	2.2	N/A	0.95	1.76	Videler, 1993	-	-	-
Northern Pike	14	N/A	3.28	6.07	Videler, 1993	-	+	-
Rosyface Shiner	2.4	N/A	0.98	1.81	Videler, 1993	-	-	-
Tessellated Darter	2.1	N/A	0.92	1.70	Videler, 1993	-	-	-

Attachment D to Study 3.3.7.
Table Study results from hydroelectric projects equipped with Francis type turbines similar to Station No. 1 as summarized by Franke, et al. (1997).

					Avg. Fish		%	
	Sampling		Sample Size		Length		Survival	
Station	Method	Species Tested	Test	Control	(mm)	Control	1 hr	Source
Five Channels, MI								Matousek et. al. 1994
Hardy, MI (Unit 2)								LMS 1991
Luray, VA	Full discharge netting	American Eel	393	212		76.0	98.6	
Stevens Creek, SC	Balloon tag	Blueback Herring	131	120	203	89.2	95.3	RMC 1991
Alcona, MI	Full discharge netting	Bluegill	97		118		90.2	LMS 1991
Alcona, MI	Full discharge netting	Bluegill	102		170		84.1	LMS 1991
Five Channels, MI	Full discharge netting	Bluegill	95		118		93.6	LMS 1991
Five Channels, MI	Full discharge netting	Bluegill	91		170		89.2	LMS 1991
Grand Rapids, WI (U 1,2,4 comb)	Full discharge netting	Bluegill			76		96.7	LMS
Grand Rapids, WI (U 1,2,4 comb)	Full discharge netting	Bluegill			127		100.0	LMS
Grand Rapids, WI (U 1,2,4 comb)	Full discharge netting	Bluegill			178		94.9	LMS
Hardy, MI (Unit 2)	Full discharge netting	Bluegill	63		118		89.5	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Bluegill	30		170		91.5	LMS 1991
Pricket, MI	Full discharge netting	Bluegill	256	150	52	62.7	97.7	RMC 1991b
Rogers, MI (units 1 & 2)	Full discharge netting	Bluegill	90		118		96.0	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	Bluegill	92		170		85.2	LMS 1991
Stevens Creek, SC	Balloon tag	Bluegill	110	110	122	99.1	95.4	RMC 1991
Pricket, MI	Full discharge netting	Bluegill	131	90	102	80.0	92.5	RMC 1991b
Pricket, MI	Full discharge netting	Bluegill	21	21	> 127	90.5	85.7	RMC 1991b
Higley, NY	Full discharge netting	Centrarchid			< 100		81.0	KA
Higley, NY	Full discharge netting	Centrarchid			100-250		14.0	KA
Higley, NY	Full discharge netting	Centrarchid			> 250		17.0	KA
Peshtigo, WI (Unit 4)	Full discharge netting	centrarchiforms			76	77 fish	100.0	Harza
Peshtigo, WI (Unit 4)	Full discharge netting	centrarchiforms			127	61 fish	98.9	Harza

					Avg. Fish		%	
	Sampling		Sample Size		Length		Survival	
Station	Method	Species Tested	Test	Control	(mm)	Control	1 hr	Source
Peshtigo, WI (Unit 4)	Full discharge netting	centrarchiforms			178	52 fish	100.0	Harza
Potato Rapids, WI (Unit 1)	Full discharge netting	centrarchiforms			76	88 fish	100.0	Harza
Potato Rapids, WI (Unit 1)	Full discharge netting	centrarchiforms			127	90 fish	84.7	Harza
Potato Rapids, WI (Unit 1)	Full discharge netting	centrarchiforms			178	69 fish	83.0	Harza
Potato Rapids, WI (Unit 2)	Full discharge netting	centrarchiforms			76	102 fish	93.4	Harza
Potato Rapids, WI (Unit 2)	Full discharge netting	centrarchiforms			127	102 fish	83.7	Harza
Potato Rapids, WI (Unit 2)	Full discharge netting	centrarchiforms			178	27 fish	91.4	Harza
Peshtigo, WI (Unit 4)	Full discharge netting	fusiforms			76	100 fish	94.0	Harza
Peshtigo, WI (Unit 4)	Full discharge netting	fusiforms			127	86 fish	93.7	Harza
Peshtigo, WI (Unit 4)	Full discharge netting	fusiforms			178	102 fish	96.6	Harza
Peshtigo, WI (Unit 4)	Full discharge netting	fusiforms			229	85 fish	95.4	Harza
Peshtigo, WI (Unit 4)	Full discharge netting	fusiforms			292	89 fish	85.5	Harza
Peshtigo, WI (Unit 4)	Full discharge netting	fusiforms			>292	63 fish	82.8	Harza
Potato Rapids, WI (Unit 1)	Full discharge netting	fusiforms			76	96 fish	89.2	Harza
Potato Rapids, WI (Unit 1)	Full discharge netting	fusiforms			127	68 fish	76.5	Harza
Potato Rapids, WI (Unit 1)	Full discharge netting	fusiforms			178	85 fish	68.4	Harza
Potato Rapids, WI (Unit 1)	Full discharge netting	fusiforms			229	93 fish	61.1	Harza
Potato Rapids, WI (Unit 1)	Full discharge netting	fusiforms			292	83 fish	53.3	Harza
Potato Rapids, WI (Unit 1)	Full discharge netting	fusiforms			>292	106 fish	34.5	Harza
Potato Rapids, WI (Unit 2)	Full discharge netting	fusiforms			76	83 fish	84.5	Harza
Potato Rapids, WI (Unit 2)	Full discharge netting	fusiforms			127	94 fish	61.7	Harza
Potato Rapids, WI (Unit 2)	Full discharge netting	fusiforms			178	91 fish	75.1	Harza
Potato Rapids, WI (Unit 2)	Full discharge netting	fusiforms			229	97 fish	61.0	Harza
Potato Rapids, WI (Unit 2)	Full discharge netting	fusiforms			292	89 fish	57.8	Harza
Potato Rapids, WI (Unit 2)	Full discharge netting	fusiforms			>292	80 fish	48.2	Harza

Station	Sampling Method	Species Tested	Sample Size Test	Sample Size Control	Avg. Fish Length (mm)	Control	% Survival 1 hr	Source
Alcona, MI	Full discharge netting	Gold./Common Shiner	51		114		80.9	LMS 1991
Alcona, MI	Full discharge netting	Gold./Common Shiner	58		154		84.7	LMS 1991
Five Channels, MI	Full discharge netting	Gold./Common Shiner	59		114		81.8	LMS 1991
Five Channels, MI	Full discharge netting	Gold./Common Shiner	60		154		85.5	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Gold./Common Shiner	30		114		85.5	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Gold./Common Shiner	59		154		88.7	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	Gold./Common Shiner	60		114		53.7	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	Gold./Common Shiner	34		154		92.5	LMS 1991
Pricket, MI	Full discharge netting	Golden Shiner	182	120	< 100	70.0	93.9	RMC 1991b
Alcona, MI	Full discharge netting	Grass Pickerel	30		235		86.7	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Largemouth Bass	60		118		76.2	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	Largemouth Bass	60		118		77.4	LMS 1991
Pricket, MI	Full discharge netting	mixed resident					97.8	RMC 1991b
Alcona, MI	Full discharge netting	Northern Pike	44		352		51.2	LMS 1991
Five Channels, MI	Full discharge netting	Northern Pike	31		352		91.3	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Northern Pike	58		352		76.0	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	Northern Pike	47		352		83.4	LMS 1991
Higley, NY	Full discharge netting	Percid			< 100		59.0	KA
Higley, NY	Full discharge netting	Percid			> 250		40.0	KA
Alcona, MI	Full discharge netting	Rainbow Trout	40		108		100	LMS 1991
Alcona, MI	Full discharge netting	Rainbow Trout	40		317		89.4	LMS 1991
Five Channels, MI	Full discharge netting	Rainbow Trout	40		108		95.8	LMS 1991
Five Channels, MI	Full discharge netting	Rainbow Trout	46		317		70.0	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Rainbow Trout	59		108		71.4	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Rainbow Trout	60		317		68.6	LMS 1991

					Avg. Fish		%	
	Sampling		Sample Size		Length		Survival	
Station	Method	Species Tested	Test	Control	(mm)	Control	1 hr	Source
Rogers, MI (units 1 & 2)	Full discharge netting	Rainbow Trout	30		108		89.9	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	Rainbow Trout	30		317		61.2	LMS 1991
Higley, NY	Full discharge netting	Salmonid			< 100		70.0	KA
Higley, NY	Full discharge netting	Salmonid			100-250		44.0	KA
Higley, NY	Full discharge netting	Salmonid			> 250		61.0	KA
Higley, NY	Full discharge netting	Soft Ray			< 100		60.0	KA
Higley, NY	Full discharge netting	Soft Ray			100-250		72.0	KA
Higley, NY	Full discharge netting	Soft Ray			> 250		40.0	KA
Alcona, MI	Full discharge netting	Spottail Shiner	40		116		59.5	LMS 1991
Five Channels, MI	Full discharge netting	Spottail Shiner	30		116		36.4	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	Spottail Shiner	31		116		73.5	LMS 1991
Stevens Creek, SC	Balloon tag	Spotted Sucker/Y. Perch	120	120	165	98.3	98.3	RMC 1991
Alcona, MI	Full discharge netting	Walleye	47		162		16.4	LMS 1991
Alcona, MI	Full discharge netting	Walleye	45		385		38.7	LMS 1991
Five Channels, MI	Full discharge netting	Walleye	55		162		71.2	LMS 1991
Five Channels, MI	Full discharge netting	Walleye	60		385		76.7	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Walleye	60		385		77.3	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	Walleye	40		385		86.2	LMS 1991
Alcona, MI	Full discharge netting	White Sucker	60		180		94.4	LMS 1991
Alcona, MI	Full discharge netting	White Sucker	54		290		90.4	LMS 1991
Five Channels, MI	Full discharge netting	White Sucker	56		180		88.6	LMS 1991
Five Channels, MI	Full discharge netting	White Sucker	60		290		71.4	LMS 1991
Grand Rapids, WI (U 1,2,4 comb)	Full discharge netting	White Sucker			76		100.0	LMS
Grand Rapids, WI (U 1,2,4 comb)	Full discharge netting	White Sucker			127		100.0	LMS
Grand Rapids, WI (U 1,2,4 comb)	Full discharge netting	White Sucker			178		94.9	LMS

					Avg. Fish		%	
	Sampling		**Sample Size**		**Length**		**Survival**	
Station	**Method**	**Species Tested**	**Test**	**Control**	**(mm)**	**Control**	**1 hr**	**Source**
Grand Rapids, WI (U 1,2,4 comb)	Full discharge netting	White Sucker			229		93.7	LMS
Grand Rapids, WI (U 1,2,4 comb)	Full discharge netting	White Sucker			292		90.4	LMS
Grand Rapids, WI (U 1,2,4 comb)	Full discharge netting	White Sucker			>292		80.5	LMS
Hardy, MI (Unit 2)	Full discharge netting	White Sucker	59		180		76.9	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	White Sucker	60		290		64.5	LMS 1991
Pricket, MI	Full discharge netting	White Sucker	201	119	165	80.7	70.8	RMC 1991b
Pricket, MI	Full discharge netting	White Sucker	15	10	> 254	70.0	35.7	RMC 1991b
Rogers, MI (units 1 & 2)	Full discharge netting	White Sucker	55		180		91.2	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	White Sucker	57		290		88.1	LMS 1991
Alcona, MI	Full discharge netting	Yellow Perch	55		107		65.1	LMS 1991
Alcona, MI	Full discharge netting	Yellow Perch	45		186		55.1	LMS 1991
Five Channels, MI	Full discharge netting	Yellow Perch	25		107		72.7	LMS 1991
Five Channels, MI	Full discharge netting	Yellow Perch	30		186		77.1	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Yellow Perch	60		107		83.1	LMS 1991
Hardy, MI (Unit 2)	Full discharge netting	Yellow Perch			186		95.5	LMS 1991
Rogers, MI (units 1 & 2)	Full discharge netting	Yellow Perch	78		107		91.8	LMS 1991

Attachment E to Study 3.3.7.
Revised Table 5.1

Table 5-1

Tag-recapture data and estimated 1 h and 48 h survival for adult American Eels passed through Cabot Station Unit 2, Station No. 1 Unit 1 and Units 2/3, and over the Bascule Gates 1 and 4 at 1,500, 2,500, and 5,000 cfs, November 2015. Controls released into the tailrace downstream of the three stations. Proportions are given in parentheses.

				Bascule Gates 1				Bascule Gates 4				
	Cabot Sation Unit 2	Station No. 1 Unit 2/3	Station No. 1 Unit 1	1,500 cfs	2,500 cfs	5,000 cfs	BG 1 Combined	1,500 cfs	2,500 cfs	5,000 cfs	BG 4 Combined	Combined Controls
Number released	50	30	30	35	30	30	95	35	30	30	95	25
Number recaptured alive	49 (0.980)	18 (0.600)	27 (0.900)	30 (0.857)	24 (0.800)	25 (0.833)	79 (0.832)	31 (0.886)	27 (0.900)	28 (0.933)	86 (0.905)	25 (1.000)
Number recaptured dead	0 (0.000)	1 (0.033)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	1 (0.033)	0 (0.000)	1 (0.011)	0 (0.000)
Number assigned dead*	1 (0.020)	10 (0.333)	3 (0.100)	4 (0.114)	4 (0.133)	4 (0.133)	12 (0.126)	4 (0.114)	2 (0.067)	2 (0.067)	8 (0.084)	0 (0.000)
Dislodged tags	0 (0.000)	10 (0.333)	3 (0.100)	0 (0.000)	1 (0.033)	1 (0.033)	2 (0.021)	1 (0.250)	0 (0.000)	0 (0.000)	1 (0.011)	0 (0.000)
Stationary radio signals	1 (0.020)	0 (0.000)	0 (0.000)	4 (0.114)	3 (0.100)	3 (0.100)	10 (0.105)	3 (0.086)	2 (0.067)	2 (0.067)	7 (0.074)	0 (0.000)
Number undetermined	0 (0.000)	1 (0.033)	0 (0.000)	1 (0.029)	2 (0.067)	1 (0.033)	4 (0.042)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)
Number held	49	18	27	30	24	25	79	31	27	28	86	25
1 hour survival rate	(0.980)	(0.621)	(0.900)	(0.882)	(0.857)	(0.862)	(0.868)	(0.886)	(0.900)	(0.933)	(0.905)	
SE	(0.020)	(0.090)	(0.055)	(0.024)	(0.045)	(0.064)	(0.036)	(0.053)	(0.055)	(0.046)	(0.030)	
90% CI (+/-)	(0.033)	(0.148)	(0.091)	(0.040)	(0.074)	(0.105)	(0.059)	(0.087)	(0.091)	(0.076)	(0.049)	
Number alive 48 h	48	18	27	30	24	25	79	29	27	28	84	25
Number Died in holding	1	0	0	0	0	0	0	2	0	0	2	0
48 hour survival rate	(0.960)	(0.621)	(0.900)	(0.882)	(0.857)	(0.862)	(0.868)	(0.829)	(0.900)	(0.933)	(0.884)	
SE	(0.028)	(0.090)	(0.055)	(0.024)	(0.045)	(0.064)	(0.036)	(0.064)	(0.055)	(0.046)	(0.033)	
90% CI (+/-)	(0.046)	(0.148)	(0.091)	(0.040)	(0.074)	(0.105)	(0.059)	(0.105)	(0.091)	(0.076)	(0.054)	

* includes dislodged tags and stationary signals

Attachment F to Study 3.3.7
5.1.3 Controls

The 25 eels released as controls were assigned to all the treatment releases. This procedure has been used in past studies where the number of specimens available for a study is limited; which was the present case. Additionally, this allocation of control fish to different test conditions has proven to be sufficient if control recapture rate are near or is 100%. Twenty-five control eels were released; 25 (100%) control eels were collected, and the fish were held for the 48 h delayed observation. Control fish recapture times ranged from under two minutes to 12 minutes, with an average recapture time at 2 minutes. Control eels ranged in size from 560-920 mm, with an average size of 715 mm.

STUDY NO. 3.3.13 ATTACHMENTS

Attachment A to Study 3.3.13.
Early Spring Datasheets

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/4/15 TIME:________ STATION I.D. 001 FIELD CREW: BHK / JPG

WEATHER: Sunny breezy RIVER FLOW:________ WATER TEMPEATURE: 10.02

TURBIDITY: Low IMPOUNDMENT STAGE (FT MSL) 181.1

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
001	NOT ACTIVE	0.5-1	N/A	COBBLE	LOW	0.18	NONE	NO	WALLEYE *

NOTES

* - POSSIBLE walleye spawning site in Vernon tailrace
photo 1 of shoreline at site 1.

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation
[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/4/15 TIME: 14:40 STATION I.D. 002 FIELD CREW: BHK | JPG

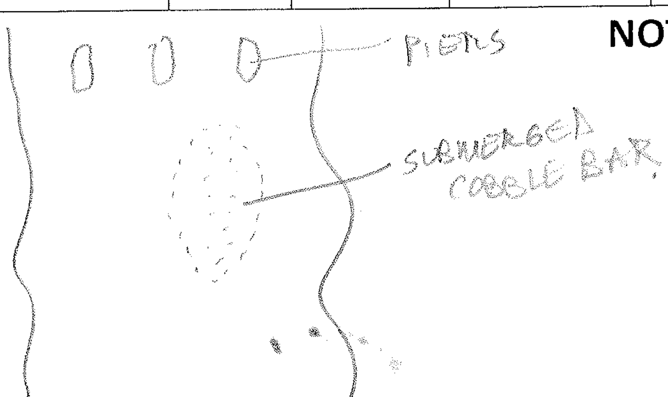
WEATHER: SCATTERED CLOUDS RIVER FLOW: ________ WATER TEMPEATURE: 10.0

TURBIDITY: LOW IMPOUNDMENT STAGE (FT MSL) 181.1

POSSIBLE WALLEYE SPAWNING SITE
COBBLE BAR D.S. OF OLD BRIDGE PIERS – MID CHANNEL SHOAL

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
002	N/A	0.5-3	N/A	COBBLE	CLEAN	3+ ft/sec	N/A	N/A	POSSIBLE WALLEYE

NOTES



[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation
[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 05/04/15 TIME: 15:30 STATION I.D. 003 FIELD CREW: BHK JPG

WEATHER: sunny some clouds RIVER FLOW: ________ WATER TEMPEATURE: 16°

TURBIDITY: ________ IMPOUNDMENT STAGE (FT MSL) 181.1

PACHAUG BROOK - NO EVIDENCE OF SPAWNING

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
—	—	—	—	some emergence	HIGH	0.0-0.3	—	pike	pike

NOTES

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation

[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/5/15 TIME: 10:48 STATION I.D. 004 FIELD CREW: BHK KTPG

WEATHER: Sunny, windy RIVER FLOW: 15,000 WATER TEMPEATURE: 10.58

TURBIDITY: +6 ft IMPOUNDMENT STAGE (FT MSL) 181.1 (RTK)

NO EVIDENCE OF SPAWNING

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
N/A	N/A	3.7'	N/A	BOULDER/COBBLE scattered veg.	LOW	1.0	N/A	—	possible walleye

NOTES

Potential walleye spawning shoal at mouth of Merriam Brook.

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation

[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/5/15 TIME: 11:15 STATION I.D. 005 FIELD CREW: BHK, JPG

WEATHER: partly cloudy breeze RIVER FLOW: 15,000 WATER TEMPEATURE: 10.88

TURBIDITY: +6 IMPOUNDMENT STAGE (FT MSL) 180.9 from RTK

no evidence of spawning

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
005	—	—	—	gravel ✓ rip rap	moderate		—	—	potential walleye

NOTES

River-Left channel near Kidds Island

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[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/5/15 TIME: 12:19 STATION I.D. 006 FIELD CREW: BHK JPG

WEATHER: Partly cloudy lght brz RIVER FLOW: 18,000 WATER TEMPEATURE: 11.36

TURBIDITY: +6 secchi IMPOUNDMENT STAGE (FT MSL) 181.2 RTK

mouth OF 4 MILE BROOK

no evidence of spawning

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
/	/	/	/	cobble	low	0.3-0.6	/	/	potential walleye

NOTES

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation

[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 05/05/15 TIME: 13:15 STATION I.D. 007 FIELD CREW: BHK · GPB

WEATHER: sunny ptly cloudy RIVER FLOW: N/A WATER TEMPEATURE: 16.7

TURBIDITY: Low/CLEAR to secchi IMPOUNDMENT STAGE (FT MSL) 180.1 WSL = 180.9 (RTK)

1st RIFFLE ON MILLERS RIVER

POSSIBLE WALLEYE SPAWNING SITE - no spawning evident

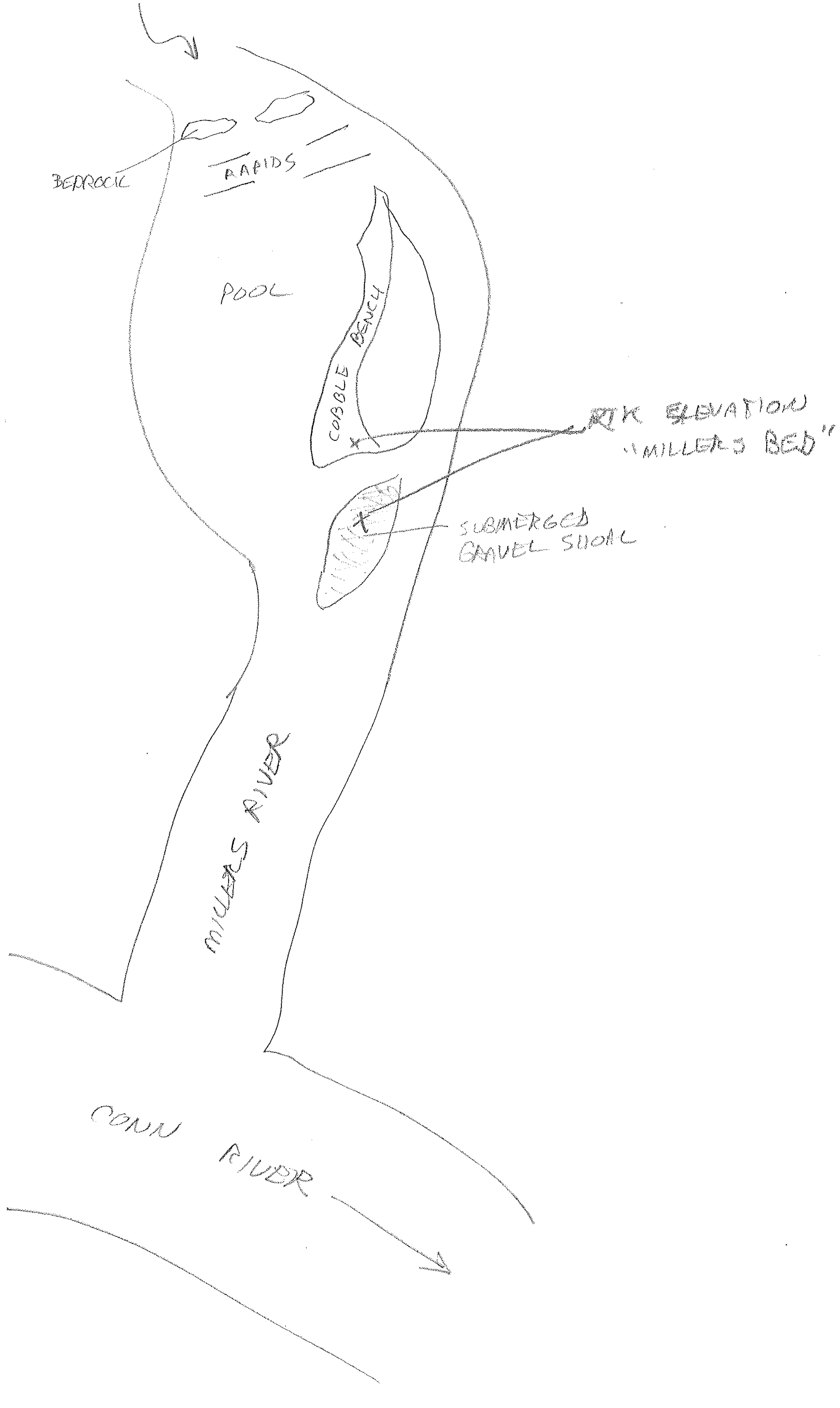
NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
/	/	/	/	COBBLE	LOW	0.2	/	/	/
		0.45	TYPICAL	GRAVEL					

NOTES

Gravel bar complex at toe of BEDROCK Rips, SEE SKETCH on reverse side

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation

[2] High, Moderate, Low, Undetermined


BEDROCK
RAPIDS
POOL
COBBLE BENCH
RTK ELEVATION "MILLERS BED"
SUBMERGED GRAVEL SHOAL
MILLERS RIVER
CONN RIVER

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/5/15 TIME: 14:55 STATION I.D. 008 FIELD CREW: BHK JPG

WEATHER: HAZY SUNN BREEZE RIVER FLOW: 14,500 WATER TEMPEATURE: 11.3

TURBIDITY: SECCHI = 6+ ft IMPOUNDMENT STAGE (FT MSL)________

WSL 181.55 (RTK) no - spawning evident

POSSIBLE YELLOW PERCH & ESOCID SPAWNING

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
/	/	/	/	CATTAIL & SAV ROOTWADS	HIGH	<0.5	/	NO	/

NOTES

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation

[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 05/05/15 TIME: 15:20 STATION I.D. 009 FIELD CREW: BHK JPG

WEATHER: HAZY SUN RIVER FLOW: 14,500 WATER TEMPEATURE: 11.3

TURBIDITY: +6 SECCHI IMPOUNDMENT STAGE (FT MSL) 181.8

no - spawning evident

POTENTIAL YELLOW perch & esocid spawning site

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
—	—	—	—	CATTAIL	HIGH	<0.1	—	—	—

NOTES

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation

[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/5/15 TIME: 16:35 STATION I.D. 6/0 FIELD CREW: BHK/JPG

WEATHER: BRIGHT OVERCAST RIVER FLOW: 14,500 WATER TEMPEATURE: 11.2

TURBIDITY: SECCHI 6f IMPOUNDMENT STAGE (FT MSL) 182.6 (RTK)

FRAGMITIES BENCH upstream of PACHAUG BROOK ~~182.6~~
POTENTIAL YELLOW PERCH & ESOCIDE SPAWNING SITE AT HIGHER WATER

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
/	/	/	/	FINES ~~[illegible]~~ FRAGMITIES	HIGH	<0.1	/	/	/

NOTES

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation
[2] High, Moderate, Low, Undetermined

182.3 12,036

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 05/06/15 TIME: 10:37 STATION I.D. 011 FIELD CREW: BHK JPG

WEATHER: sunny calm RIVER FLOW: 12,036 WATER TEMPEATURE: 11.5

TURBIDITY: 7.5 secch IMPOUNDMENT STAGE (FT MSL) 182.3 (control room RAT.) 182.0 RTK 179.9

potential yellow perch - submerged SAV bed near Fish + Game club cove

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
—	—	—	—	SAV stubble	HIGH	0.0	—	SUNFISH	—

NOTES

observed numerous sunfish schooling in sunny shallows
Big SAV bed during summer - stubble remnants of last season's growth may provide spawning material for some esocids and percids

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation
[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 05/06/15 TIME: 11:57 STATION I.D. 012 FIELD CREW: BHK, JPG

WEATHER: Sunny calm RIVER FLOW: ________ WATER TEMPEATURE: 11.4

TURBIDITY: +7.5 secchi IMPOUNDMENT STAGE (FT MSL) ________

FRAGMITIES Bed + CATTAIL Bed, NE Corner of BARTON Cove

179.8 Bed
182.0 wsl RTK

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
/	/	2.2	NA	FRAG + CATTAIL STUBS	MOD	0.0		SUNFISH	

NOTES

Found large egg mass floating nearby. Took in-situ photos

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation
[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/6/2015 TIME: 12:12 STATION I.D. 0013 FIELD CREW: BHK JRB

WEATHER: Sunny Calm RIVER FLOW: 12,034 WATER TEMPEATURE: 11.3

TURBIDITY: 7.5+ SECCHI IMPOUNDMENT STAGE (FT MSL) ~~[illegible]~~ 182.0 RTK

POSSIBLE YP + ESOCIDE SPAWNING SITE 180.5 ~~BEBEL~~
CATTAIL BENCH along BARTON Cove causeway egg masses nearby

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
—	—	1.5	—	CATTAIL STUB	HIGH	0.0	—	—	—

NOTES

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation

[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/6/2015 TIME: 13:40 STATION I.D. 0014 FIELD CREW: BHK JPG

WEATHER: Sunny light breeze RIVER FLOW: ____ WATER TEMPEATURE: 14.1

TURBIDITY: 7.5+ SECCHI IMPOUNDMENT STAGE (FT MSL) 182.0

SAV stubble in sand flat
POTENTIAL for YP

182.0 - WSEL
180.3 BED EL
} RTK

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
—	—	1.7	—	SAND/SAV	MOD	0.0	—	—	—

NOTES

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation

[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/5/2015 TIME: 13:54 STATION I.D. 0015 FIELD CREW: RHK JPG

WEATHER: SUNNY CALM RIVER FLOW: 12,034 WATER TEMPEATURE: 14.1

TURBIDITY: 7.5 SECCHI IMPOUNDMENT STAGE (FT MSL) 182.0

CATTAIL BENCH NEAR GUN CLUB BED EL 180.5
POTENTIAL YP site. egg masses nearby

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
/	/	1.5	NA	CATTAIL STUBBLE	HIGH	0.0	—	—	/

NOTES

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation
[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/6/2015 TIME: 14:15 STATION I.D. 016 FIELD CREW: BHK JPG

WEATHER: Sunny light breeze RIVER FLOW: ~12,000 WATER TEMPEATURE: 11.3

TURBIDITY: 7.5+ SECCHI IMPOUNDMENT STAGE (FT MSL) ~~182.2~~ 182.0 RTK

BED. EL. 180.1

CATTAIL BENCH - POTENTIAL YP or ESOCID SPAWNING SITE

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
/	/	1.9	/	CATTAIL STUBS	MOD	0.0	/	/	/

NOTES

Narrow wetland strip downstream from sharp bend below FK Gorge
Northern shoreline

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation
[2] High, Moderate, Low, Undetermined

3.3.13 FIRST LIGHT TURNERS FALLS IMPOUNDMENT LITTORAL ZONE SPAWNING SURVEY

DATE 5/6/2015 TIME: 14:33 STATION I.D. 017 FIELD CREW: BHK JPG

WEATHER: Sunny breezy RIVER FLOW: ~12,000 WATER TEMPEATURE: 11.7

TURBIDITY: +7.5 secchi IMPOUNDMENT STAGE (FT MSL) 182.0
182.2 - BENCH EL.

CATTAIL BENCH

POTENTIAL FOR YP or ESOCID spawning

NEST I.D.	Active/ abandoned	DEPTH (ft)	Diameter (inches)	SUBSTRATE/ vegetation[1]	SILTATION[2]	VELOCITY (ft/sec)	EGGS	Fish presence	SPECIES
/	/	/	/	CATTAIL STUBS	MOD	/	/	/	/

NOTES

[1] BR =bedrock BL =boulder CB = cobble GR =Gravel SD=sand FS=fines/sediment AV = Aquatic vegetation

[2] High, Moderate, Low, Undetermined

STUDY NO. 3.3.15 ATTACHMENTS

Attachment A to Study 3.3.15.
Operations Data (Excel)

See Excel file Attachment_A_3_3_15

STUDY NO. 3.3.16 ATTACHMENTS

Attachment A to Study 3.3.16.
Delphi Panel Correspondence

Jason George

From: Jason George
Sent: Thursday, November 19, 2015 2:50 PM
To: 'hgalbraith@usgs.gov'
Subject: Mussel Habitat Delphi Exercise - Round 1
Attachments: Delphi Questionnaire.xlsx

Dear Heather Galbraith,

Thank you for agreeing to serve as a panelist for the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*). The purpose of the exercise is to develop Habitat Suitability Criteria (HSC) for use with habitat modeling to assess the influence of hydropower operations on these species and their habitat in the Connecticut River in Massachusetts. The Delphi technique is being used to supplement field data from the project area (and comparable habitats) and published information on the three target species (and closely related species); resultant HSC will be based on these three sources of information.

Instructions and the tables for completing the first round of the exercise are attached as a single Excel file with six worksheets. A few hours of your time may be required to complete the first and subsequent rounds of the Delphi. We hope to complete this exercise in 1.5 months, and hope that panelists can respond within 10 days of each round. You may wish to recommend a qualified colleague to serve as a panelist if you are unable to serve, or if you think they may provide additional insight.

I will serve as monitor of the exercise; I am working with Ethan Nedeau to prepare materials for each round, summarize responses, and prepare a final report including rationale for final HSC.

Thank you again for consenting to be a panelist. I look forward to receipt of your input. If you could respond by December 4, 2015, I would greatly appreciate it.

Note that I will be out of the office all next week, so if you have any questions, please contact me via email, and I will respond after November 30, 2015.

Jason George
Environmental Scientist
Gomez and Sullivan Engineers, DPC
PO Box 2179
Henniker, NH 03242
Office: (603) 428-4960
Cell: (603) 340-7666
jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Thursday, November 19, 2015 2:50 PM
To: 'cynthia.loftin@maine.edu'
Subject: Mussel Habitat Delphi Exercise - Round 1
Attachments: Delphi Questionnaire.xlsx

Dear Cynthia Loftin,

Thank you for agreeing to serve as a panelist for the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*). The purpose of the exercise is to develop Habitat Suitability Criteria (HSC) for use with habitat modeling to assess the influence of hydropower operations on these species and their habitat in the Connecticut River in Massachusetts. The Delphi technique is being used to supplement field data from the project area (and comparable habitats) and published information on the three target species (and closely related species); resultant HSC will be based on these three sources of information.

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I will serve as monitor of the exercise; I am working with Ethan Nedeau to prepare materials for each round, summarize responses, and prepare a final report including rationale for final HSC.

Thank you again for consenting to be a panelist. I look forward to receipt of your input. If you could respond by December 4, 2015, I would greatly appreciate it.

Note that I will be out of the office all next week, so if you have any questions, please contact me via email, and I will respond after November 30, 2015.

Jason George
Environmental Scientist
Gomez and Sullivan Engineers, DPC
PO Box 2179
Henniker, NH 03242
Office: (603) 428-4960
Cell: (603) 340-7666
jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Thursday, November 19, 2015 2:50 PM
To: 'Ethan Nedeau'
Subject: Mussel Habitat Delphi Exercise - Round 1
Attachments: Delphi Questionnaire.xlsx

Dear Ethan Nedeau,

Thank you for agreeing to serve as a panelist for the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*). The purpose of the exercise is to develop Habitat Suitability Criteria (HSC) for use with habitat modeling to assess the influence of hydropower operations on these species and their habitat in the Connecticut River in Massachusetts. The Delphi technique is being used to supplement field data from the project area (and comparable habitats) and published information on the three target species (and closely related species); resultant HSC will be based on these three sources of information.

Instructions and the tables for completing the first round of the exercise are attached as a single Excel file with six worksheets. A few hours of your time may be required to complete the first and subsequent rounds of the Delphi. We hope to complete this exercise in 1.5 months, and hope that panelists can respond within 10 days of each round. You may wish to recommend a qualified colleague to serve as a panelist if you are unable to serve, or if you think they may provide additional insight.

I will serve as monitor of the exercise; I am working with Ethan Nedeau to prepare materials for each round, summarize responses, and prepare a final report including rationale for final HSC.

Thank you again for consenting to be a panelist. I look forward to receipt of your input. If you could respond by December 4, 2015, I would greatly appreciate it.

Note that I will be out of the office all next week, so if you have any questions, please contact me via email, and I will respond after November 30, 2015.

Jason George
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PO Box 2179
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Office: (603) 428-4960
Cell: (603) 340-7666
jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Thursday, November 19, 2015 2:50 PM
To: 'strayerd@caryinstitute.org'
Subject: Mussel Habitat Delphi Exercise - Round 1
Attachments: Delphi Questionnaire.xlsx

Dear David Strayer,

Thank you for agreeing to serve as a panelist for the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*). The purpose of the exercise is to develop Habitat Suitability Criteria (HSC) for use with habitat modeling to assess the influence of hydropower operations on these species and their habitat in the Connecticut River in Massachusetts. The Delphi technique is being used to supplement field data from the project area (and comparable habitats) and published information on the three target species (and closely related species); resultant HSC will be based on these three sources of information.

Instructions and the tables for completing the first round of the exercise are attached as a single Excel file with six worksheets. A few hours of your time may be required to complete the first and subsequent rounds of the Delphi. We hope to complete this exercise in 1.5 months, and hope that panelists can respond within 10 days of each round. You may wish to recommend a qualified colleague to serve as a panelist if you are unable to serve, or if you think they may provide additional insight.

I will serve as monitor of the exercise; I am working with Ethan Nedeau to prepare materials for each round, summarize responses, and prepare a final report including rationale for final HSC.

Thank you again for consenting to be a panelist. I look forward to receipt of your input. If you could respond by December 4, 2015, I would greatly appreciate it.

Note that I will be out of the office all next week, so if you have any questions, please contact me via email, and I will respond after November 30, 2015.

Jason George
Environmental Scientist
Gomez and Sullivan Engineers, DPC
PO Box 2179
Henniker, NH 03242
Office: (603) 428-4960
Cell: (603) 340-7666
jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Thursday, November 19, 2015 2:50 PM
To: 'BWicklow@Anselm.Edu'
Subject: Mussel Habitat Delphi Exercise - Round 1
Attachments: Delphi Questionnaire.xlsx

Dear Barry Wicklow,

Thank you for agreeing to serve as a panelist for the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*). The purpose of the exercise is to develop Habitat Suitability Criteria (HSC) for use with habitat modeling to assess the influence of hydropower operations on these species and their habitat in the Connecticut River in Massachusetts. The Delphi technique is being used to supplement field data from the project area (and comparable habitats) and published information on the three target species (and closely related species); resultant HSC will be based on these three sources of information.

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jgeorge@gomezandsullivan.com

Jason George

From: Galbraith, Heather <hgalbraith@usgs.gov>
Sent: Friday, December 04, 2015 3:50 PM
To: Jason George
Subject: Re: Mussel Habitat Delphi Exercise - Round 1

Hi Jason,

Yes I would like to participate. I have everything printed out and will try to respond in the next day or so. Thanks!

Heather

On Fri, Dec 4, 2015 at 8:23 AM, Jason George <jgeorge@gomezandsullivan.com> wrote:

Hi Heather,

I am following-up on the email below to see if you are still able to participate in this Delphi exercise for freshwater mussels. Please let me know either way, thank you.

Jason George

From: Jason George
Sent: Thursday, November 19, 2015 2:50 PM
To: 'hgalbraith@usgs.gov' <hgalbraith@usgs.gov>
Subject: Mussel Habitat Delphi Exercise - Round 1

Dear Heather Galbraith,

Thank you for agreeing to serve as a panelist for the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*). The purpose of the exercise is to develop Habitat Suitability Criteria (HSC) for use with habitat modeling to assess the influence of hydropower operations on these species and their habitat in the Connecticut River in Massachusetts. The Delphi technique is being used to supplement field data from the project area (and comparable habitats) and published information on the three target species (and closely related species); resultant HSC will be based on these three sources of information.

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I will serve as monitor of the exercise; I am working with Ethan Nedeau to prepare materials for each round, summarize responses, and prepare a final report including rationale for final HSC.

Thank you again for consenting to be a panelist. I look forward to receipt of your input. If you could respond by December 4, 2015, I would greatly appreciate it.

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Heather S. Galbraith, Ph.D.
Research Biologist
USGS - Leetown Science Center
Northern Appalachian Research Laboratory
176 Straight Run Road
Wellsboro, PA 16901
570-724-3322 x 230
Website: https://profile.usgs.gov/hgalbraith

Jason George

From: Cynthia Loftin <cynthia.loftin@maine.edu>
Sent: Tuesday, December 15, 2015 11:05 AM
To: Jason George
Subject: Re: Mussel Habitat Delphi Exercise - Round 1
Attachments: Delphi Questionnaire Loftin.xlsx

Hi Jason,
Sorry for the delay in getting back to you on this. I filled out the spreadsheet based on my field knowledge for tidewater muckets and yellow lampmussels in Maine. If I had budgeted more time, I would have dug into the literature rather than fill this out based on my recollection of field sites, but unfortunately I've too many other things pulling at me right now. So, hopefully the responses are of some use as they are. Let me know if you have any questions.

Cyndy

On Thu, Nov 19, 2015 at 2:50 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:

> Dear Cynthia Loftin,
>
> Thank you for agreeing to serve as a panelist for the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*). The purpose of the exercise is to develop Habitat Suitability Criteria (HSC) for use with habitat modeling to assess the influence of hydropower operations on these species and their habitat in the Connecticut River in Massachusetts. The Delphi technique is being used to supplement field data from the project area (and comparable habitats) and published information on the three target species (and closely related species); resultant HSC will be based on these three sources of information.
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>
> I will serve as monitor of the exercise; I am working with Ethan Nedeau to prepare materials for each round, summarize responses, and prepare a final report including rationale for final HSC.
>
> Thank you again for consenting to be a panelist. I look forward to receipt of your input. If you could respond by December 4, 2015, I would greatly appreciate it.
>
> Note that I will be out of the office all next week, so if you have any questions, please contact me via email, and I will respond after November 30, 2015.

Jason George

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jgeorge@gomezandsullivan.com

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Unit Leader and
Associate Professor of Wildlife Ecology
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phone: 207-581-2843
fax: 207-581-2858
web page: http://www.coopunits.org/Maine

Jason George

From: Ethan Nedeau <ethan@biodrawversity.com>
Sent: Wednesday, December 09, 2015 11:01 AM
To: Jason George
Subject: Delphi Questionnaire
Attachments: Delphi Questionnaire_Nedeau Response.xlsx

Hey Jason,
Here is my stab at the Delphi questionnaire. Let me know when you want to go over responses from everyone and consider how to structure Round 2.

-Ethan

--
**New Address
Ethan Nedeau, Biodrawversity LLC
206 Pratt Corner Road, Leverett, MA 01054
Cell: (413) 253-6561 / Email: nedeau.ethan@gmail.com
Website: www.biodrawversity.com

Jason George

From: Dave Strayer <strayerd@caryinstitute.org>
Sent: Thursday, November 26, 2015 5:58 AM
To: Jason George
Subject: Re: Mussel Habitat Delphi Exercise - Round 1
Attachments: FWB 1994 hudson clams.pdf; JNABS flow refuges 1999.pdf; Delphi Questionnaire for nasuta cariosa ochracea.xlsx

Jason-

Here are my responses, which I hope are useful to you, along with a couple of papers that contain relevant information. Let me know if you have any questions about my responses, or need additional information from me. Thanks.

Dave Strayer

On Thu, Nov 19, 2015 at 2:49 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:

> Dear David Strayer,
>
> Thank you for agreeing to serve as a panelist for the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*). The purpose of the exercise is to develop Habitat Suitability Criteria (HSC) for use with habitat modeling to assess the influence of hydropower operations on these species and their habitat in the Connecticut River in Massachusetts. The Delphi technique is being used to supplement field data from the project area (and comparable habitats) and published information on the three target species (and closely related species); resultant HSC will be based on these three sources of information.
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> I will serve as monitor of the exercise; I am working with Ethan Nedeau to prepare materials for each round, summarize responses, and prepare a final report including rationale for final HSC.
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> Thank you again for consenting to be a panelist. I look forward to receipt of your input. If you could respond by December 4, 2015, I would greatly appreciate it.
>
> Note that I will be out of the office all next week, so if you have any questions, please contact me via email, and I will respond after November 30, 2015.

Jason George

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jgeorge@gomezandsullivan.com

From: Barry Wicklow <BWicklow@Anselm.Edu>
Sent: Monday, November 30, 2015 11:16 AM
To: Jason George
Subject: Delphi input
Attachments: Delphi Questionnaire (BJW).xlsx

Hi Jason,

I've attached my input for round one of the exercise — let me know if you have questions.

Thanks,

Barry

Barry J. Wicklow, Ph.D.
Professor of Biology
Saint Anselm College
100 Saint Anselm Drive
Manchester, NH 03102-1310
Phone 603-641- 7155
Fax 603-222-4012

Jason George

From: Jason George
Sent: Thursday, February 11, 2016 4:19 PM
To: 'hgalbraith@usgs.gov'
Subject: Mussel Habitat Delphi Exercise - Round 2
Attachments: FL Delphi_Round 2.pdf; FL Delphi_Round 2.xlsx; Shear Stress RSS and Mussels.docx

Hi Heather,

We are still in the process of developing Habitat Suitability Criteria (HSC) for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. We have received four responses from panelists based on an initial questionnaire. We would really appreciate if you participated. I am including the Round 2 information below and attached. If you can participate, feel free to fill in the initial data, we left a placeholder for you under "P5" in the excel sheets for each species.

Based on Round 1 responses, we have developed draft binary HSI curves for water depth, benthic water velocity, substrate, and cover. Please find attached instructions and a summary of the curves and information received. An excel data sheet also includes the same information for your use.

Please note that for the two parameters related to shear, we are seeking additional input from panelists before proposing specific numeric criteria. Please see the attached summary (Word document) on shear stress and relative shear stress to understand the types of challenges we are considering for these parameters.

For Round 2, we ask that you review the individual panelists' scores, proposed binary scores, and the moderator's notes on the proposed HSI curves (at the bottom of the Summary sheet). There is space for you to add additional comments (yellow shaded fields).

We are asking for responses by the end of next week, by February 19, 2016. Please feel free to contact me with questions. If this timeline is not feasible, please let me know. Thank you.

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jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Thursday, February 11, 2016 4:19 PM
To: 'Cynthia Loftin'
Subject: Mussel Habitat Delphi Exercise - Round 2
Attachments: FL Delphi_Round 2.pdf; FL Delphi_Round 2.xlsx; Shear Stress RSS and Mussels.docx

Hi Cyndy,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

Based on Round 1 responses, we have developed draft binary HSI curves for water depth, benthic water velocity, substrate, and cover. Please find attached instructions and a summary of the curves and information received. An excel data sheet also includes the same information for your use.

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jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Thursday, February 11, 2016 4:20 PM
To: 'Ethan Nedeau'
Subject: Mussel Habitat Delphi Exercise - Round 2
Attachments: FL Delphi_Round 2.pdf; FL Delphi_Round 2.xlsx; Shear Stress RSS and Mussels.docx

Hi Ethan,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

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Cell: (603) 340-7666
jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Thursday, February 11, 2016 4:19 PM
To: 'Dave Strayer'
Subject: Mussel Habitat Delphi Exercise - Round 2
Attachments: Shear Stress RSS and Mussels.docx; FL Delphi_Round 2.pdf; FL Delphi_Round 2.xlsx

Hi Dave,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

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jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Thursday, February 11, 2016 4:19 PM
To: 'Barry Wicklow'
Subject: Mussel Habitat Delphi Exercise - Round 2
Attachments: FL Delphi_Round 2.pdf; FL Delphi_Round 2.xlsx; Shear Stress RSS and Mussels.docx

Hi Barry,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

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jgeorge@gomezandsullivan.com

Jason George

From: Cynthia Loftin <cynthia.loftin@maine.edu>
Sent: Sunday, February 28, 2016 8:45 PM
To: Jason George
Subject: Re: Mussel Habitat Delphi Exercise - Round 2
Attachments: FL Delphi_Round 2.xlsx; Shear Stress RSS and Mussels.docx

Hi-
See attached. I inserted a couple of comments/thoughts on the word document regarding SS and RSS and the spreadsheet comments in the substrate section. Generally, I think the curves look OK, with the exception of what I noted on the substrate section. Let me know if you have questions.

I hope this is helpful. Sorry for the delay-
Cyndy

On Fri, Feb 26, 2016 at 1:07 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:

> Any updates you could provide on the status of your review would be greatly appreciated. Thanks!
>
> Jason George
>
> **From:** Cynthia Loftin [mailto:cynthia.loftin@maine.edu]
> **Sent:** Tuesday, February 23, 2016 12:17 PM
>
> **To:** Jason George <jgeorge@gomezandsullivan.com>
> **Subject:** Re: Mussel Habitat Delphi Exercise - Round 2
>
> on the list to work on on Thursday
>
> On Tue, Feb 23, 2016 at 10:54 AM, Jason George <jgeorge@gomezandsullivan.com> wrote:
>
>> Hi Cyndy, I'm just checking in to see if you would be able to comment on the curves this week. If you could let me know, I'd appreciate it. Thanks.
>>
>> Jason George

From: Cynthia Loftin [mailto:cynthia.loftin@maine.edu]
Sent: Friday, February 12, 2016 7:49 AM
To: Jason George <jgeorge@gomezandsullivan.com>
Subject: Re: Mussel Habitat Delphi Exercise - Round 2

Hi Jason,

I'm happy to hep and will do what I can to fit it into your timeline. However, I am in the office only ~1 day next week, so it is going to be difficult to get this done by the 19th.

I can try to get my review back to you early in the week of the 22nd. Would that work?

Cyndy

On Thu, Feb 11, 2016 at 4:19 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:

> Hi Cyndy,
>
> Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.
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Jason George

Environmental Scientist

Gomez and Sullivan Engineers, DPC

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Unit Leader and
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5755 Nutting Hall
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phone: 207-581-2843
fax: 207-581-2858

web page: http://www.coopunits.org/Maine

Jason George

From: Ethan Nedeau <ethan@biodrawversity.com>
Sent: Thursday, February 25, 2016 11:20 PM
To: Jason George
Subject: Delphi
Attachments: FL Delphi_Round 2_Ethan.xlsx; SS, RSS, and Mussels_Ethan.docx

Here you go.
Happy to discuss sometime Friday.

-Ethan

--
**New Address
Ethan Nedeau, Biodrawversity LLC
206 Pratt Corner Road, Leverett, MA 01054
Cell: (413) 253-6561 / Email: nedeau.ethan@gmail.com
Website: www.biodrawversity.com

Jason George

From: Dave Strayer <strayerd@caryinstitute.org>
Sent: Friday, February 12, 2016 1:51 PM
To: Jason George
Subject: RE: Mussel Habitat Delphi Exercise - Round 2
Attachments: Delphi_Round 2 nasuta et al.xlsx

Jason-

Here are a few comments, including a suggestion about how you might consider dealing with SS/RSS. Let me know if you have any questions about my comments and suggestions.

Dave S

From: Jason George [mailto:jgeorge@gomezandsullivan.com]
Sent: Thursday, February 11, 2016 4:19 PM
To: Dave Strayer
Subject: Mussel Habitat Delphi Exercise - Round 2

Hi Dave,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

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We are asking for responses by the end of next week, by February 19, 2016. Please feel free to contact me with questions. If this timeline is not feasible, please let me know. Thank you.

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jgeorge@gomezandsullivan.com

Jason George

From: Barry Wicklow <BWicklow@Anselm.Edu>
Sent: Monday, February 22, 2016 1:23 PM
To: Jason George
Subject: Round two

Hi Jason,

First, I agree with the proposed binary HIS curves for the three mussel species. As to SS and RSS – I don't think it is possible to define ranges at this point especially since RSS in or near mussel beds is >>5 for a 1.5 year flood. In comparison, for example, Allen and Vaughn found species richness was high when RSS was >1 but declined sharply when RSS was >2. (However, they state that they used only D50 to estimate substrate movement and that the presence of embedded mussels may also help stabilize the substrate.)

Let me know if you need further information.

Best regards,

Barry

Barry J. Wicklow, Ph.D.
Professor of Biology
Saint Anselm College
100 Saint Anselm Drive
Manchester, NH 03102-1310
Phone 603-641- 7155

Memo

To: **Turners Falls Hydroelectric Project Mussel Delphi Panel**
From: **Jason George, Gomez and Sullivan Engineers**
Date: **February 11, 2016**
RE: **Shear Stress (SS), Relative Shear Stress (RSS), and Mussel Habitat Suitability**

Mussels are morphologically and behaviorally adapted to living in naturally unstable riverine environments. We are focusing on three species that are generalists in terms of the types of waterbodies they inhabit (lakes and ponds, small to large rivers, freshwater tidal areas) and for the specific habitats that they inhabit within these waterbodies. Generally, all three species appear to prefer fine-grained sediment in lakes and rivers. When considering possible habitat suitability criteria for SS and RSS, its worthwhile to consider some ideas about how mussels can persist in areas that appear to have high SS and RSS based on relatively simple parameters of flow velocity, water depth, and resistance of particle sizes to movement.

In the Connecticut River, yellow lampmussels have been found bank to bank over several miles of river, from the Holyoke Dam up to the Hadley Dike. They are usually found in broad flat sandbars in a range of water depths (1-25 ft), even in areas with fairly high flow velocities and near-constant bedload (such as the area between the Route 9 Bridge and Rainbow Beach), although highest densities are in the broad sandbars upstream and downstream of Mitches Island and also near Brunelle's Marina. Of the three species, yellow lampmussels exist in areas of the Connecticut River where SS and RSS are likely to be important. In contrast, eastern pondmussels are found almost exclusively in shallow water (<3 ft) very close to the riverbank, usually within or near dense beds of *Vallisneria* and *Elodea* that fringe the shoreline, and often within/among woody debris. In these areas, flow velocity is very slow (or zero) at all times: SS and RSS is never likely a concern for eastern pondmussels in this system. Tidewater muckets are extremely rare in the project area; only 3 live mussels have ever been found despite numerous surveys over nearly three decades. Elsewhere in the Connecticut River in Connecticut, this species is numerous from bank to bank, occurring with eastern pondmussels near riverbanks and near yellow lampmussels in sandbars.

Mussel Morphology and Behavior

In the Connecticut River, an average yellow lampmussel has a shell length of 3 inches, and in its natural position in the substrate, its large muscular foot extends at least another 2 inches. Unless it is actively moving somewhere, it orients itself nearly vertical in the substrate with its posterior end nearly flush with the surface of the substrate, and the tip of its foot anchored somewhere 4-5 inches below the surface of the sediment. The center of its mass is about 2-2.5 inches below the surface of the substrate. They use the foot for both horizontal and vertical movement…in a split second, the can close their mantles and completely bury themselves with a quick contraction of their foot. Mussels also nearly always point themselves directly upstream.

Importance? Mussels are deeply anchored and streamlined. Most of a mussel's mass, as well as its strong and responsive foot, are deep within the sediment anchoring it in place. It is actually very difficult to extract a mussel from the streambed until you can grasp its center of mass, which often requires some digging around the posterior end. You can "fan away" sediment from around a mussel with strong/turbulent flows and it remains in position until you get down well below its center of mass, and even then, it may remain in position if it does not retract its foot. This suggests that minor bedload, such as that may affect the top 1-2 inches of sediment, would not displace a mussel. Mussels are also responsive…they can bury themselves, or move horizontally. If displaced, they may only be transported short distances as they use their foot to re-anchor themselves. Mussels exist even in streambeds that are mostly sand and are subject to high flow velocities, often congregating near features that may anchor sediments, such as buried logs, coarse rock, or beds of aquatic vegetation.

Streambed Complexity

There is considerable variation in substrate in rivers, both in terms of ways we often think about it (from bank to bank, or along a rivers length) but also vertically. Vertical sediment profiles in a streambed often reveal coarser and more compact layers at depth, with finer-grained and looser sediment near the surface. This is important because although mussels may appear to be living in the finer-grained, loose sediment visible at the surface, the center of their body mass and their feet may be anchored more deeply in the coarser and more compact underlying sediments. Flow velocities that may set fine-grained sediments at the surface into motion may have little effect on the coarser and more compact underlying sediments. If we are to consider SS or RSS values that are capable of displacing mussels, we need to consider substrate type(s) and substrate cohesiveness in the portion of the streambed where mussels are anchored, rather than the substrate where their posterior edge exists. It is difficult to capture this in traditional hydraulic modeling and substrate mapping.

Many factors contribute to substrate stability and resistance to particle movement.

- **Wood/detritus:** fully buried, partly buried, or unburied logs/branches and other detritus help to stabilize the streambed and keep sediment in place, even during flows that should be high enough to transport those sediments.
- **Vegetation:** the roots, stems, and leaves of aquatic vegetation provide stability. Roots help with sediment cohesion, and stems and leaves greatly slow and dissipate flows, disrupt bedload, and promote more deposition.
- **Biofilms and Aufwuchs:** a variety of bacteria, algae, plants, and animals form complex films and surface growth over streambeds and other submerged surfaces. Psammophilic (sand-loving) algae/bacteria can help to establish a biofilm over fine-grained sediments, and it gets thicker and more robust as it is colonized by more and more algae/bacteria, meiofauna, tube-building and case-making macroinvertebrates. In areas of the lower Holyoke Dam impoundment where yellow lampmussels occur, we have observed a very substantial biofilm (in some cases, 5-10 mm thick) overlying very large areas of the streambed. The underlying sand is not subjected to flows, and the biofilm is much more resistant to flow velocity than the underlying fine-grained mineral substrate. You can almost think of it as “topsoil” in the forest.
- **Macroinvertebrates:** as mentioned before, tube-building and case making invertebrates, clams, mussels all help to stabilize the sediment. Insects bind sand particles together with silk. Mussels actively filter tiny particles and then deposit much larger particles, often encased with mucous (this process is called biodeposition). All of these things help to bind the mineral particles, increase sediment cohesion, and thus increase the resistance of these particles to transport. Mussels themselves effectively serve a similar role as large gravel or small cobbles, perhaps even more effectively because of their streamlining and large foot…thus, mussels can self-stabilize their own beds.

What does it take to displace mussels and scour away a mussel bed?

It is important to note that at any single point in the streambed (such as the location of a mussel or mussel bed), there is both export and import of sediment. Flows may reach a level where fine sediments around a mussel are scoured, but presumably fine sediment is also re-filling from upstream. For most flow events, the net effect is that mussels may be subjected to heavy bedload and scour, but can withstand it without being displaced. For the most part, mussels can “clamp up” or “hunker down” until the flows subside.

Flows necessary to displace mussels and disrupt mussel beds would need to completely scour the top few inches of substrate in a short amount of time. (i.e., export >>>> import at any point in the mussel bed). It would need to be strong enough to overcome any sediment cohesion/compaction, to scour both the fine-grained surface sediments AND the coarser-grained subsurface sediments, and to lift/transport bed-stabilizing elements such as embedded wood, roots, rock, and mussels themselves. This has been referred to as “mass wasting” and would probably require great deal of force. It is likely that a flood of greater than 20 yr recurrence intervals may have this potential, but normal seasonal or 5-yr high-flow events probably do not. Tropical Storm Irene is an example of a flow event that indeed caused “mass wasting” in rivers throughout parts of New England, especially Vermont.

Commented [LU1]: Although in general I agree with this summary of displacement during high flow events, I think there likely are annual normal high flow events that may displace mussels, especially juveniles. We saw this in a stream in Maine (Sandy Stream) in which we had pit-tagged yellow lampmussels and tidewater muckets. We relocated lampmussels >100 m downstream from the tag site where they had been tagged and released the previous summer. Between the late summer tag and release period and the subsequent relocation period the next summer, the stream experienced the normal seasonal flow dynamics. So, it did not take excessive or unusual flows to dislodge the mussels (all adult-sized.

The trouble with SS and RSS

The "onset of particle motion" may be a threshold for instability from a hydraulic modeling perspective, but mussels are very well adapted to some amount of instability. It is a natural component of their habitat, especially for our three target species that occur in fine-grained substrates in rivers. Hydraulic models that fail to account for some of the things described above will probably also fail to account for the persistence/stability of mussel beds. Hydraulic modeling of shear stress and RSS using simple parameters are likely to greatly overpredict:

- The amount of shear at the streambed
- The effects of shear on particle movement
- The effects of shear on mussels (via displacement) or mussel beds

Substrate type, and experimental studies of the resistance of particle sizes to flow velocity, comprises the denominator of the RSS equation. Because fine-grained sediments, such as fine sand, are the easiest particles to move, areas with these sediments will appear to have the highest levels of RSS (with otherwise similar water depths and flow velocities). This may seem counterintuitive if we agree that RSS is an important parameter for mussels and that mussels inhabit areas with low RSS. Lowest RSS values will generally be for areas with bedrock or very coarse-grained materials because these materials strongly resist movement; however, mussels do not prefer these substrates.

Commented [LU2]: This is true, however, tidewater muckets and yellow lampmussels in Maine occur is streams where bedrock ledges are interspersed with pockets of sand, and these species occur in these pockets. So, it's really even more complicated than you describe!

Available flow velocity, bathymetry, and substrate data in the Connecticut River where the state-listed mussel species of interest are located is rather coarse. Bank-to-bank variation in substrate particle size, vertical profiles of grain sizes in the streambed, and longitudinal variation in substrate particle size along the entire project area is not well characterized. In addition, other components of substrate diversity that might influence resistance to particle movement (e.g., clay (increases cohesion), coarse wood, detritus, vegetation, biofilms, macroinvertebrates (including mussels themselves) have not been well characterized. Thus, the RSS calculations based on very coarse-scale hydraulic and substrate data will provide very little insight into mussel habitat suitability. It would be difficult to use these data (or data from other rivers) to develop meaningful numeric habitat suitability criteria. For example, Morales et al. (2006)[1] proposed an HSI for RSS as:

- RSS < 1.0 = Suitable
- RSS 1.0 – 1.25 = Marginal
- RSS >1.25 = Unsuitable

Commented [LU3]: And even if they have, these features are so dynamic that it would be difficult to accurately predict suitability based on them, because they are so transient.

But for the Connecticut River, RSS calculations for transects within or near yellow lampmussel beds were typically >>5, even for a 1.5-yr flood (see chart below). These areas have high densities of adult yellow lampmussels and neither quantitative nor qualitative sampling has suggested a decline in the years they have been studied (2005 to 2015) despite several very high flow events during that period.

Suggestions?

What do we do with SS and RSS? The main problem with RSS is that it does not account for the many other elements that contribute to bed stability, or how mussels may be congregated (or actually create) these areas of bed stability. It only tells you when particles of a certain size begin to move, which is not that meaningful because mussels are adapted to bedload. A case could be made that SS and RSS may not be ideal parameters for our analysis, even though researchers have suggested they are generally important to mussels. It is likely that 2D or even 3D hydraulic modeling, with detailed substrate and bathymetry data, would be necessary to a more insightful analysis of SS and RSS, but these datasets are not available to us.

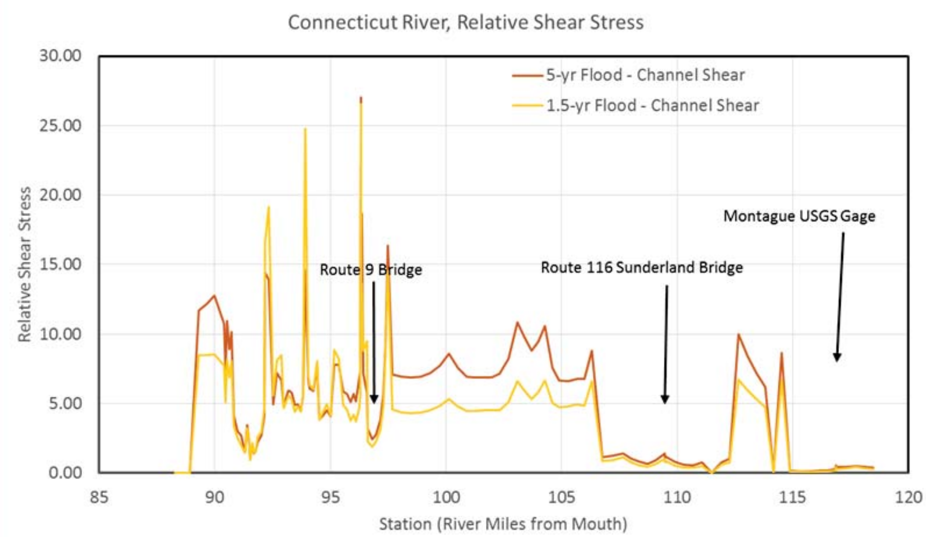
Commented [LU4]: It might be that these are not useful in an initial model application but in a subsequent assessment. That is, evaluate the suitability based on the other parameters, and then if they indicate potentially suitable conditions, then consider RSS and SS.

[1] Effects of substrate and hydrodynamic conditions on the formation of mussel beds in a large river
Y. Morales, L. J. Weber, A. E. Mynett, and T. J. Newton
Journal of the North American Benthological Society 2006 25 (3), 664-676

The Delphi process is being used to develop binary HSI curves for three mussel species that may occur in the project area. Based on what is described in this document, we are uncertain how to proceed with SS and RSS, as we do not know what ranges of values to suggest for the panelists to consider and score. Our proposed next step is to send out the HSI curves developed in Round 1 to the panelists with the information above and ask for a recommendation on the importance of the shear stress parameters to these species.

Commented [LU5]: See previous comment.

One goal of the relicensing study plan is to "…evaluate the potential effects of Project operations on state-listed mussel species." The relicensing study envisioned applying modeling to determine hydraulic parameters such as SS and RSS. Based on the cursory analysis above, RSS calculations for transects within or near yellow lampmussel beds were typically >>5, even for a 1.5-yr flood (approximately 75,000 cfs). It is important to remember that the range of flow fluctuations that can be controlled by the Turners Falls Project is up to approximately 16,000 cfs. Any changes to SS or RSS based on Project operations are of a much smaller magnitude compared to those shear stresses experienced under higher flow conditions.



Commented [LU6]: Can you expand the x-axis and indicate on this figure where the species are currently found in the system?

Jason George

From: Jason George
Sent: Tuesday, April 12, 2016 2:59 PM
To: 'Cynthia Loftin'
Subject: RE: Mussel Habitat Delphi Exercise - Round 3
Attachments: Delphi Round 3 Instructions.pdf; Delphi Round 3 Questionnaire.xlsx; Round 3 Summary_SS and RSS_Sent to Panelists.docx

Hi Cyndy, attached is information for Round 3 of the Delphi exercise for yellow lampmussel, tidewater mucket and eastern pondmussel for the Turners Falls Hydroelectric Project in Massachusetts. Thank you for your responses to Round 2. Based on your and other panelists' responses, there is general agreement on the depth, velocity and substrate curves, although minor changes were made (e.g., substrate codes). Please see attached summary document on SS and RSS for how we plan to incorporate those two challenging parameters.

To answer your specific question on the RSS chart in the previous memo, the three mussel species are found in the CT River downstream of the Route 9 bridge.

We are looking for your final sign-off on these curves. Please see the instructions sheet and the attached files.

If you could respond to me by next Wednesday, April 20, 2016, I would appreciate it. We plan to utilize these curves in our various IFIM models developed for sections of the Connecticut River.

If you have any questions on the attached or need more information, please let me know. Thank you very much.

Jason George

From: Cynthia Loftin [mailto:cynthia.loftin@maine.edu]
Sent: Sunday, February 28, 2016 8:45 PM
To: Jason George <jgeorge@gomezandsullivan.com>
Subject: Re: Mussel Habitat Delphi Exercise - Round 2

Hi-
See attached. I inserted a couple of comments/thoughts on the word document regarding SS and RSS and the spreadsheet comments in the substrate section. Generally, I think the curves look OK, with the exception of what I noted on the substrate section. Let me know if you have questions.

I hope this is helpful. Sorry for the delay-
Cyndy

On Fri, Feb 26, 2016 at 1:07 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:

> Any updates you could provide on the status of your review would be greatly appreciated. Thanks!
>
> Jason George

From: Cynthia Loftin [mailto:cynthia.loftin@maine.edu]
Sent: Tuesday, February 23, 2016 12:17 PM

To: Jason George <jgeorge@gomezandsullivan.com>
Subject: Re: Mussel Habitat Delphi Exercise - Round 2

on the list to work on on Thursday

On Tue, Feb 23, 2016 at 10:54 AM, Jason George <jgeorge@gomezandsullivan.com> wrote:

Hi Cyndy, I'm just checking in to see if you would be able to comment on the curves this week. If you could let me know, I'd appreciate it. Thanks.

Jason George

From: Cynthia Loftin [mailto:cynthia.loftin@maine.edu]
Sent: Friday, February 12, 2016 7:49 AM
To: Jason George <jgeorge@gomezandsullivan.com>
Subject: Re: Mussel Habitat Delphi Exercise - Round 2

Hi Jason,

I'm happy to hep and will do what I can to fit it into your timeline. However, I am in the office only ~1 day next week, so it is going to be difficult to get this done by the 19th.

I can try to get my review back to you early in the week of the 22nd. Would that work?

Cyndy

On Thu, Feb 11, 2016 at 4:19 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:

Hi Cyndy,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

Based on Round 1 responses, we have developed draft binary HSI curves for water depth, benthic water velocity, substrate, and cover. Please find attached instructions and a summary of the curves and information received. An excel data sheet also includes the same information for your use.

Please note that for the two parameters related to shear, we are seeking additional input from panelists before proposing specific numeric criteria. Please see the attached summary (Word document) on shear stress and relative shear stress to understand the types of challenges we are considering for these parameters.

For Round 2, we ask that you review the individual panelists' scores, proposed binary scores, and the moderator's notes on the proposed HSI curves (at the bottom of the Summary sheet). There is space for you to add additional comments (yellow shaded fields).

We are asking for responses by the end of next week, by February 19, 2016. Please feel free to contact me with questions. If this timeline is not feasible, please let me know. Thank you.

Jason George

Environmental Scientist

Gomez and Sullivan Engineers, DPC

PO Box 2179

Henniker, NH 03242

Office: (603) 428-4960

Cell: (603) 340-7666

jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Tuesday, April 12, 2016 2:31 PM
To: 'Ethan Nedeau'
Subject: RE: Mussel Habitat Delphi Exercise - Round 3
Attachments: Round 3 Summary_SS and RSS_Sent to Panelists.docx; Delphi Round 3 Instructions.pdf; Delphi Round 3 Questionnaire.xlsx

Hi Ethan, attached is information for Round 3 of the Delphi exercise for yellow lampmussel, tidewater mucket and eastern pondmussel for the Turners Falls Hydroelectric Project in Massachusetts. Thank you for your responses to Round 2. Based on your and other panelists' responses, there is general agreement on the depth, velocity and substrate curves, although minor changes were made (e.g., substrate codes). Please see attached summary document on SS and RSS for how we plan to incorporate those two challenging parameters.

We are looking for your final sign-off on these curves. Please see the instructions sheet and the attached files.

If you could respond to me by next Wednesday, April 20, 2016, I would appreciate it. We plan to utilize these curves in our various IFIM models developed for sections of the Connecticut River.

If you have any questions on the attached or need more information, please let me know. Thank you very much.

Jason George

From: Jason George
Sent: Thursday, February 11, 2016 4:20 PM
To: 'Ethan Nedeau' <ethan@biodrawversity.com>
Subject: Mussel Habitat Delphi Exercise - Round 2

Hi Ethan,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

Based on Round 1 responses, we have developed draft binary HSI curves for water depth, benthic water velocity, substrate, and cover. Please find attached instructions and a summary of the curves and information received. An excel data sheet also includes the same information for your use.

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For Round 2, we ask that you review the individual panelists' scores, proposed binary scores, and the moderator's notes on the proposed HSI curves (at the bottom of the Summary sheet). There is space for you to add additional comments (yellow shaded fields).

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Jason George
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PO Box 2179
Henniker, NH 03242
Office: (603) 428-4960
Cell: (603) 340-7666
jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Tuesday, April 12, 2016 2:59 PM
To: 'Dave Strayer'
Subject: RE: Mussel Habitat Delphi Exercise - Round 3
Attachments: Delphi Round 3 Instructions.pdf; Delphi Round 3 Questionnaire.xlsx; Round 3 Summary_SS and RSS_Sent to Panelists.docx

Hi Dave, attached is information for Round 3 of the Delphi exercise for yellow lampmussel, tidewater mucket and eastern pondmussel for the Turners Falls Hydroelectric Project in Massachusetts. Thank you for your responses to Round 2. Based on your and other panelists' responses, there is general agreement on the depth, velocity and substrate curves, although minor changes were made (e.g., substrate codes). Please see attached summary document on SS and RSS for how we plan to incorporate those two challenging parameters.

We are looking for your final sign-off on these curves. Please see the instructions sheet and the attached files.

If you could respond to me by next Wednesday, April 20, 2016, I would appreciate it. We plan to utilize these curves in our various IFIM models developed for sections of the Connecticut River.

If you have any questions on the attached or need more information, please let me know. Thank you very much.

Jason George

From: Dave Strayer [mailto:strayerd@caryinstitute.org]
Sent: Friday, February 12, 2016 1:51 PM
To: Jason George <jgeorge@gomezandsullivan.com>
Subject: RE: Mussel Habitat Delphi Exercise - Round 2

Jason-

Here are a few comments, including a suggestion about how you might consider dealing with SS/RSS. Let me know if you have any questions about my comments and suggestions.

Dave S

From: Jason George [mailto:jgeorge@gomezandsullivan.com]
Sent: Thursday, February 11, 2016 4:19 PM
To: Dave Strayer
Subject: Mussel Habitat Delphi Exercise - Round 2

Hi Dave,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

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Jason George
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Office: (603) 428-4960
Cell: (603) 340-7666
jgeorge@gomezandsullivan.com

Jason George

From: Jason George
Sent: Tuesday, April 12, 2016 2:59 PM
To: 'Barry Wicklow'
Subject: RE: Mussel Habitat Delphi Exercise - Round 3
Attachments: Delphi Round 3 Instructions.pdf; Delphi Round 3 Questionnaire.xlsx; Round 3 Summary_SS and RSS_Sent to Panelists.docx

Hi Barry, attached is information for Round 3 of the Delphi exercise for yellow lampmussel, tidewater mucket and eastern pondmussel for the Turners Falls Hydroelectric Project in Massachusetts. Thank you for your responses to Round 2. Based on your and other panelists' responses, there is general agreement on the depth, velocity and substrate curves, although minor changes were made (e.g., substrate codes). Please see attached summary document on SS and RSS for how we plan to incorporate those two challenging parameters.

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Cell: (603) 340-7666
jgeorge@gomezandsullivan.com

-----Original Message-----
From: Barry Wicklow [mailto:BWicklow@Anselm.Edu]
Sent: Monday, February 22, 2016 1:23 PM
To: Jason George <jgeorge@gomezandsullivan.com>
Subject: Round two

Hi Jason,

First, I agree with the proposed binary HIS curves for the three mussel species. As to SS and RSS – I don't think it is possible to define ranges at this point especially since RSS in or near mussel beds is >>5 for a 1.5 year flood. In comparison, for example, Allen and Vaughn found species richness was high when RSS was >1 but declined sharply when RSS was >2. (However, they state that they used only D50 to estimate substrate movement and that the presence of embedded mussels may also help stabilize the substrate.)

Let me know if you need further information.

Best regards,

Barry

Barry J. Wicklow, Ph.D.
Professor of Biology
Saint Anselm College
100 Saint Anselm Drive
Manchester, NH 03102-1310
Phone 603-641- 7155

Jason George

From: Cynthia Loftin <cynthia.loftin@maine.edu>
Sent: Wednesday, May 11, 2016 11:31 AM
To: Jason George
Subject: Re: Mussel Habitat Delphi Exercise - Round 3

Hi-
I have looked at the materials you sent on April 12th, and I have no additional suggestions or comments about the proposed curves and treatment of RSS and SS. I think your approach for the HSC to be based on water depth, flow velocity, and substrate, and considering SS and RSS where they may be a limiting factor is logical.

Again, I apologize for my tardiness in getting back to you about this. My only excuse is that my travel schedule and end of semester craziness in April resulted in an e-mail accumulation that buried the request in my mailbox.

Cyndy

On Wed, Apr 27, 2016 at 11:13 AM, Jason George <jgeorge@gomezandsullivan.com> wrote:

Hi Cyndy, just a reminder on the requested response below. If you could let me know your thoughts either way, I would appreciate it. Thank you.

Jason George

From: Jason George
Sent: Tuesday, April 12, 2016 2:59 PM
To: Cynthia Loftin <cynthia.loftin@maine.edu>
Subject: RE: Mussel Habitat Delphi Exercise - Round 3

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> **Sent:** Tuesday, February 23, 2016 12:17 PM

To: Jason George <jgeorge@gomezandsullivan.com>
Subject: Re: Mussel Habitat Delphi Exercise - Round 2

on the list to work on on Thursday

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Hi Cyndy,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

Based on Round 1 responses, we have developed draft binary HSI curves for water depth, benthic water velocity, substrate, and cover. Please find attached instructions and a summary of the curves and information received. An excel data sheet also includes the same information for your use.

Please note that for the two parameters related to shear, we are seeking additional input from panelists before proposing specific numeric criteria. Please see the attached summary (Word document) on shear stress and relative shear stress to understand the types of challenges we are considering for these parameters.

For Round 2, we ask that you review the individual panelists' scores, proposed binary scores, and the moderator's notes on the proposed HSI curves (at the bottom of the Summary sheet). There is space for you to add additional comments (yellow shaded fields).

We are asking for responses by the end of next week, by February 19, 2016. Please feel free to contact me with questions. If this timeline is not feasible, please let me know. Thank you.

Jason George

Environmental Scientist

Gomez and Sullivan Engineers, DPC

PO Box 2179

Henniker, NH 03242

Office: (603) 428-4960

Cell: (603) 340-7666

jgeorge@gomezandsullivan.com

Jason George

From: Dave Strayer <strayerd@caryinstitute.org>
Sent: Wednesday, June 01, 2016 9:17 AM
To: Jason George
Subject: Re: Mussel Habitat Delphi Exercise - Round 3
Attachments: JNABS flow refuges 1999.pdf

Jason-

Sorry for the very late reply. I was able to read through the latest version, and don't have any changes to suggest for the HSI curves. The basic conclusions of the text that you sent ("Moving forward") seem reasonable, given the limitations of data and understanding of mussel distributions.

Here are a couple of comments on other parts of the memo, which may or may not be of interest to you. The last sentence on p. 1 seems far too pessimistic - it seems likely that the basic conditions for mussel life (hosts, food, water quality, temperature) are met at many sites, including Turners Falls, so that sediment stability may be of primary importance in limiting local distribution of mussels. Certainly this was the case in the 2 rivers that were studied in detail in the attached paper.

In the section on limitations of binary HSC, it is worth noting that the threshold does not have to be set where the probability of occurrence of a species = 0.5 (equal probability of presence and absence). There has been some discussion in the literature on modeling species occurrence about choosing the optimal value for such a threshold, which depends in part on the rarity of the species and the purposes of the model. Thus, I don't see the basis for concluding that the threshold would have to be at high values of SS or RSS. Maybe I'm missing the logic here.

Thanks for involving me in this interesting process, and sorry again for the long, long delay in responding.

Dave S

On Wed, May 18, 2016 at 3:01 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:

> Hi Dave, thanks for the response. Don't worry about it, I hope you feel better soon.
>
> Jason
>
> **From:** Dave Strayer [mailto:strayerd@caryinstitute.org]
> **Sent:** Wednesday, May 18, 2016 2:50 PM
> **To:** Jason George <jgeorge@gomezandsullivan.com>
> **Subject:** Re: Mussel Habitat Delphi Exercise - Round 3
>
> Jason-

Sorry for the silence - the day of my last email to you, I came down with a terrible cold and ended up missing 12 days of work, which is a new experience for me. I'm still catching up. I'm headed out to the SFS meeting in California tomorrow, but will take your material with me and see if I can read it on the plane. Sorry.

Dave S

On Tue, May 10, 2016 at 2:50 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:

> Hi Dave, I am checking in to see if you have some time this month to comment or concur on the HSI curves for the Turners Falls project. Either way, thanks.
>
> Jason George
>
> **From:** Dave Strayer [mailto:strayerd@caryinstitute.org]
> **Sent:** Tuesday, April 12, 2016 3:01 PM
> **To:** Jason George <jgeorge@gomezandsullivan.com>
> **Subject:** Re: Mussel Habitat Delphi Exercise - Round 3
>
> Jason-
>
> Sorry, I simply can't respond by next Weds - I'm flat out until the end of the month, including nights and weekends. You can decide whether to proceed without me or wait until mid-May. Sorry.
>
> Dave S
>
> On Tue, Apr 12, 2016 at 2:59 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:
>
>> Hi Dave, attached is information for Round 3 of the Delphi exercise for yellow lampmussel, tidewater mucket and eastern pondmussel for the Turners Falls Hydroelectric Project in Massachusetts. Thank you for your responses to Round 2. Based on your and other panelists' responses, there is general agreement on the depth, velocity and substrate curves, although minor changes were made (e.g., substrate codes). Please see attached summary document on SS and RSS for how we plan to incorporate those two challenging parameters.
>>
>> We are looking for your final sign-off on these curves. Please see the instructions sheet and the attached files.
>>
>> If you could respond to me by next Wednesday, April 20, 2016, I would appreciate it. We plan to utilize these curves in our various IFIM models developed for sections of the Connecticut River.

If you have any questions on the attached or need more information, please let me know. Thank you very much.

Jason George

From: Dave Strayer [mailto:strayerd@caryinstitute.org]
Sent: Friday, February 12, 2016 1:51 PM
To: Jason George <jgeorge@gomezandsullivan.com>
Subject: RE: Mussel Habitat Delphi Exercise - Round 2

Jason-

Here are a few comments, including a suggestion about how you might consider dealing with SS/RSS. Let me know if you have any questions about my comments and suggestions.

Dave S

From: Jason George [mailto:jgeorge@gomezandsullivan.com]
Sent: Thursday, February 11, 2016 4:19 PM
To: Dave Strayer
Subject: Mussel Habitat Delphi Exercise - Round 2

Hi Dave,

Thank you for providing information to support the Delphi exercise for yellow lampmussel (*Lampsilis cariosa*), tidewater mucket (*Leptodea ochracea*), and eastern pondmussel (*Ligumia nasuta*) for the Turners Falls Hydroelectric Project in Massachusetts. Your responses have been very helpful and we really appreciate your participation.

Based on Round 1 responses, we have developed draft binary HSI curves for water depth, benthic water velocity, substrate, and cover. Please find attached instructions and a summary of the curves and information received. An excel data sheet also includes the same information for your use.

Please note that for the two parameters related to shear, we are seeking additional input from panelists before proposing specific numeric criteria. Please see the attached summary (Word document) on shear stress and relative shear stress to understand the types of challenges we are considering for these parameters.

For Round 2, we ask that you review the individual panelists' scores, proposed binary scores, and the moderator's notes on the proposed HSI curves (at the bottom of the Summary sheet). There is space for you to add additional comments (yellow shaded fields).

We are asking for responses by the end of next week, by February 19, 2016. Please feel free to contact me with questions. If this timeline is not feasible, please let me know. Thank you.

Jason George

Environmental Scientist

Gomez and Sullivan Engineers, DPC

PO Box 2179

Henniker, NH 03242

Office: (603) 428-4960

Cell: (603) 340-7666

jgeorge@gomezandsullivan.com

Jason George

From: Barry Wicklow <BWicklow@Anselm.Edu>
Sent: Wednesday, April 27, 2016 11:07 AM
To: Jason George
Subject: Re: Mussel Habitat Delphi Exercise - Round 3

HI Jason,

I've reviewed and, based on the information we gathered, agree with the HSI curves presented in round three. I also agree that it will be difficult to integrate SS and RSS into the HSC models.

Best regards,

Barry

On 4/12/16, 2:59 PM, "Jason George" <jgeorge@gomezandsullivan.com> wrote:

>Hi Barry, attached is information for Round 3 of the Delphi exercise
>for yellow lampmussel, tidewater mucket and eastern pondmussel for the
>Turners Falls Hydroelectric Project in Massachusetts. Thank you for
>your responses to Round 2. Based on your and other panelists'
>responses, there is general agreement on the depth, velocity and
>substrate curves, although minor changes were made (e.g., substrate
>codes). Please see attached summary document on SS and RSS for how we
>plan to incorporate those two challenging parameters.
>
>We are looking for your final sign-off on these curves. Please see the
>instructions sheet and the attached files.
>
>If you could respond to me by next Wednesday, April 20, 2016, I would
>appreciate it. We plan to utilize these curves in our various IFIM
>models developed for sections of the Connecticut River.
>
>If you have any questions on the attached or need more information,
>please let me know. Thank you very much.
>
>Jason George
>Environmental Scientist
>Gomez and Sullivan Engineers, DPC
>PO Box 2179
>Henniker, NH 03242
>Office: (603) 428-4960
>Cell: (603) 340-7666
>jgeorge@gomezandsullivan.com
>
>-----Original Message-----
>From: Barry Wicklow [mailto:BWicklow@Anselm.Edu]
>Sent: Monday, February 22, 2016 1:23 PM
>To: Jason George <jgeorge@gomezandsullivan.com>

>Subject: Round two
>
>Hi Jason,
>
>First, I agree with the proposed binary HIS curves for the three mussel
>species. As to SS and RSS - I don't think it is possible to define
>ranges at this point especially since RSS in or near mussel beds is >>5
>for a 1.5 year flood. In comparison, for example, Allen and Vaughn
>found species richness was high when RSS was >1 but declined sharply
>when RSS was >2. (However, they state that they used only D50 to
>estimate substrate movement and that the presence of embedded mussels
>may also help stabilize the substrate.)
>
>Let me know if you need further information.
>
>Best regards,
>
>Barry
>
>Barry J. Wicklow, Ph.D.
>Professor of Biology
>Saint Anselm College
>100 Saint Anselm Drive
>Manchester, NH 03102-1310
>Phone 603-641- 7155
>
>
>
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>
>
>_________________________________
>

>

Jason George

From: Jason George
Sent: Thursday, October 06, 2016 4:19 PM
To: 'BWicklow@Anselm.Edu'; ethan@biodrawversity.com; 'cynthia.loftin@maine.edu'; 'strayerd@caryinstitute.org'
Cc: Mark Wamser
Subject: Connecticut River Mussel Habitat - Delphi Report

Good afternoon,

Thank you for your participation in the Delphi process for habitat criteria for yellow lampmussel, tidewater mucket and eastern pondmussel for the Turners Falls Hydroelectric Project in Massachusetts. The report summarizing the process and results has been prepared and posted to the web, at the link below.

http://www.northfieldrelicensing.com/Lists/Document/Attachments/372/2016_Study_Report_3_3_16.pdf

We are currently applying these curves to evaluate sections of the Connecticut River. Feel free to contact me to discuss this further, if you'd like.

Again, thanks very much for making this a successful process.

Jason George
Environmental Scientist
Gomez and Sullivan Engineers, DPC
PO Box 2179
Henniker, NH 03242
Office: (603) 428-4960
Cell: (603) 340-7666
jgeorge@gomezandsullivan.com
GOMEZ AND SULLIVAN ENGINEERS

Jason George

From: Dave Strayer <strayerd@caryinstitute.org>
Sent: Thursday, October 06, 2016 8:12 PM
To: Jason George
Subject: Re: Connecticut River Mussel Habitat - Delphi Report

Jason-

Thanks for sharing the report with us.

Dave S

On Thu, Oct 6, 2016 at 4:18 PM, Jason George <jgeorge@gomezandsullivan.com> wrote:

> Good afternoon,
>
> Thank you for your participation in the Delphi process for habitat criteria for yellow lampmussel, tidewater mucket and eastern pondmussel for the Turners Falls Hydroelectric Project in Massachusetts. The report summarizing the process and results has been prepared and posted to the web, at the link below.
>
> http://www.northfieldrelicensing.com/Lists/Document/Attachments/372/2016_Study_Report_3_3_16.pdf
>
> We are currently applying these curves to evaluate sections of the Connecticut River. Feel free to contact me to discuss this further, if you'd like.
>
> Again, thanks very much for making this a successful process.
>
> Jason George
>
> Environmental Scientist
>
> Gomez and Sullivan Engineers, DPC
>
> PO Box 2179
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> Henniker, NH 03242
>
> Office: (603) 428-4960

Cell: (603) 340-7666

jgeorge@gomezandsullivan.com

GOMEZ AND SULLIVAN
ENGINEERS

STUDY NO. 3.5.1 ATTACHMENTS

Attachment A to Study 3.5.1.
Montague USGS Gage Rating Curve (Excel)

See Excel file Attachment_A_3_5_1

Attachment B to Study 3.5.1.
Mapped Unoccupied Habitat (Zip file)

See Zip file Attachment_B_3_5_1

Attachment C to Study 3.5.1.
RTE Mapping Polygon Data (Zip file)

See Zip file Attachment_C_3_5_1

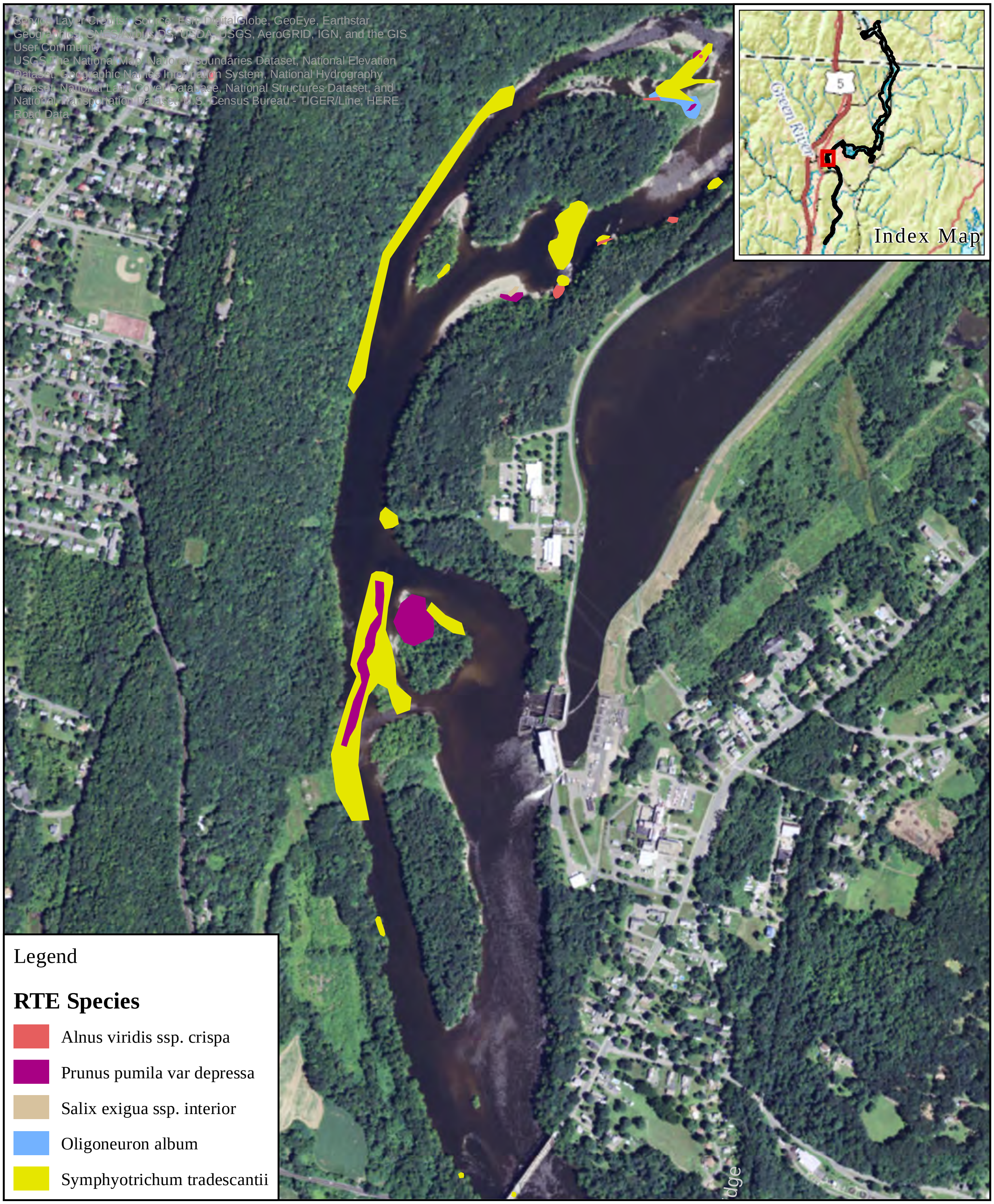
Attachment D to Study 3.5.1.
RTE Elevation Data (Zip file)

See Zip file Attachment_D_3_5_1

Attachment E to Study 3.5.1.
RTE Transect Location Data (Zip file)

See Zip file Attachment_E_3_5_1

Attachment F to Study 3.5.1.
Bypass RTE Maps



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

Study 3.5.1 Baseline Inventory of Wetland, Riparian and Littoral Habitat in the Turners Falls Impoundment and Assessment of Operational Impacts on Special Status Species

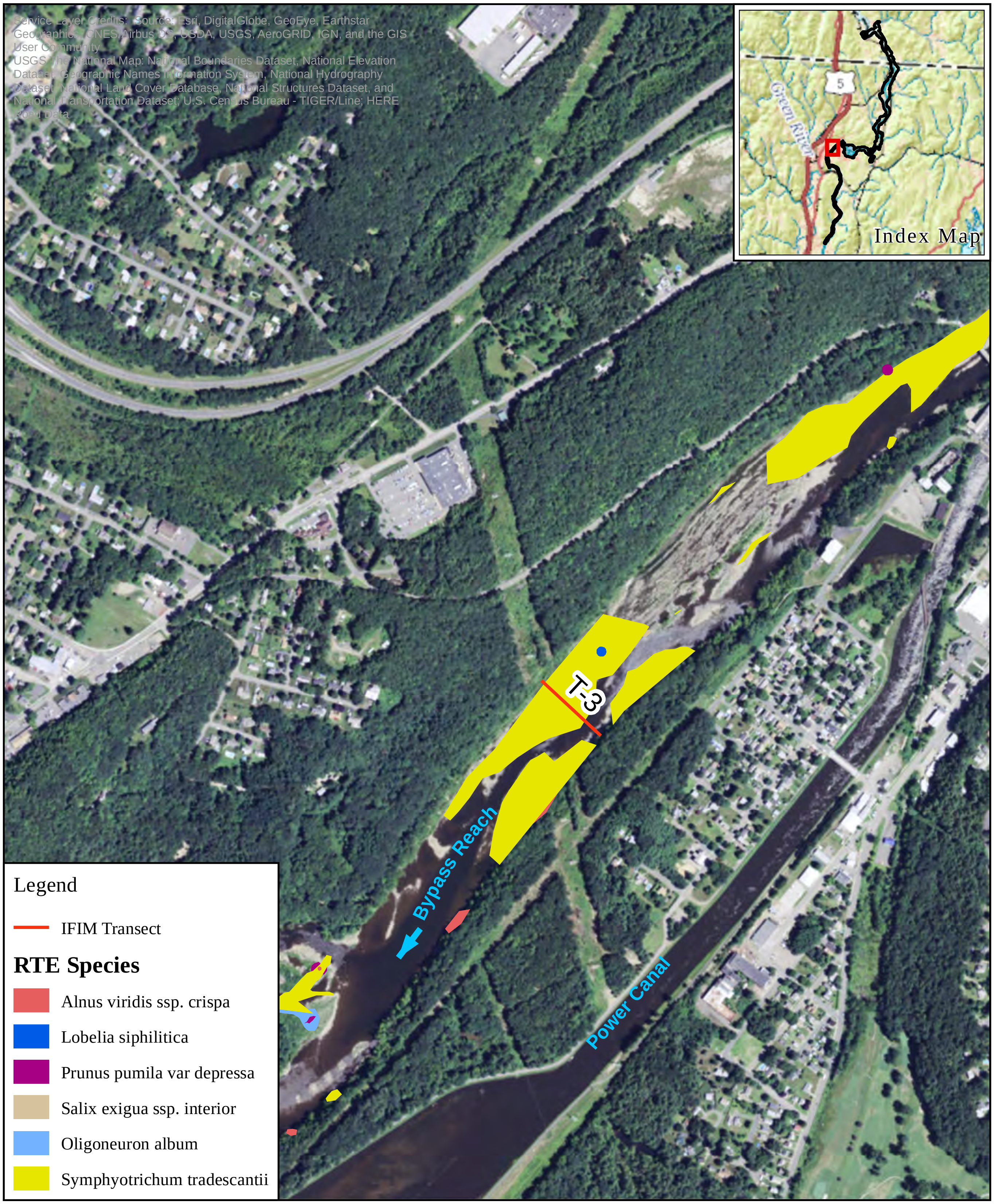
N

0 420 840 1,680 Feet

Attachment F:
Mapping of RTE
Plant Species
In the Bypass Reach
Map 1

FirstLight Power Resources

Path: W:\gis\studies\3_5_1\maps\2016_Agency_Response\Attachment_F_Map1.mxd



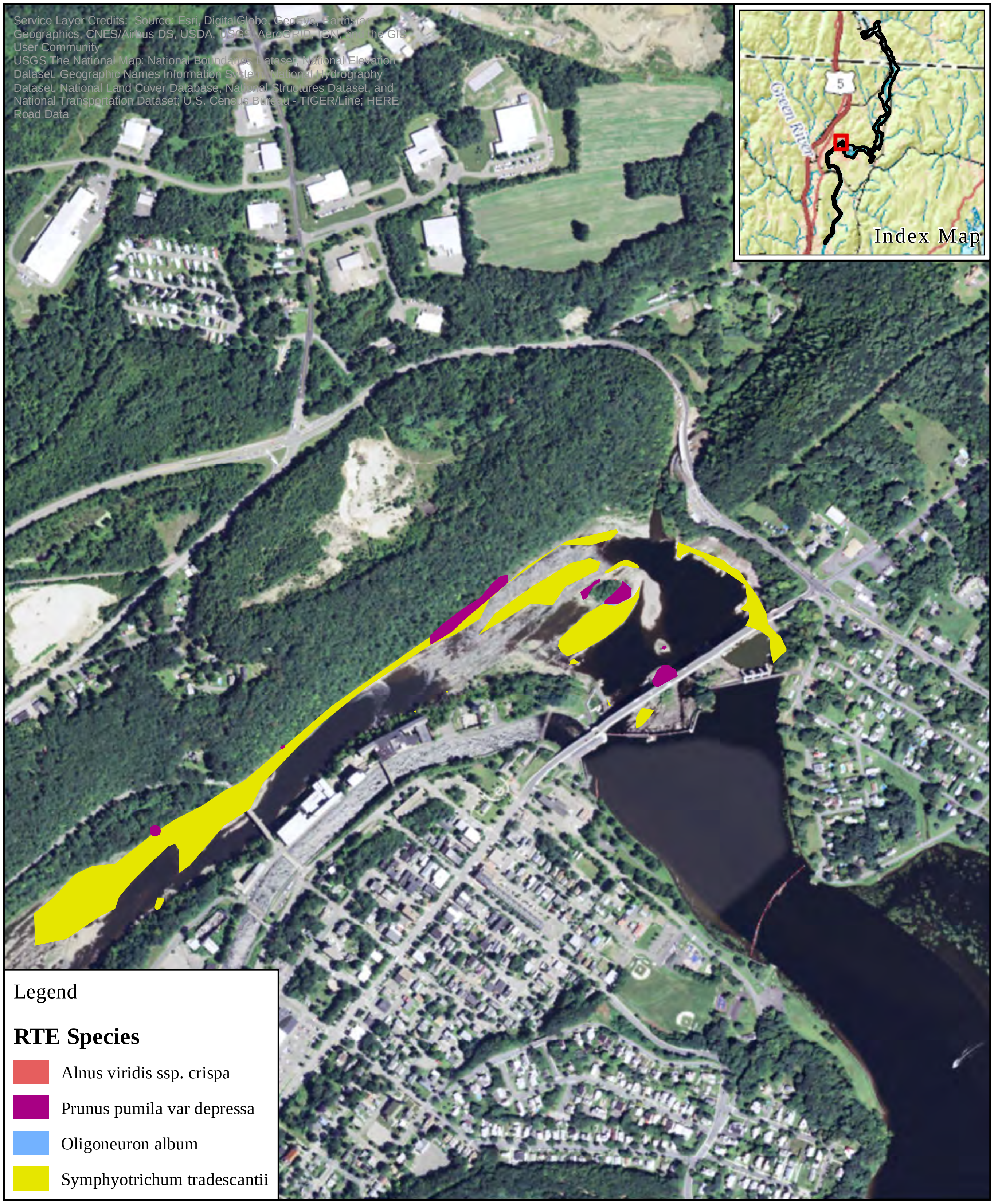
Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study 3.5.1 Baseline Inventory of Wetland, Riparian and Littoral
Habitat in the Turners Falls Impoundment and Assessment
of Operational Impacts on Special Status Species

Attachment F:
Mapping of RTE
Plant Species
In the Bypass Reach
Map 2

N

0 420 840 1,680
Feet

Path: W:\gis\studies\3_5_1\maps\2016_Agency_Response\Attachment_F_Map2.mxd



FirstLight Power Resources

Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)
Study 3.5.1 Baseline Inventory of Wetland, Riparian and Littoral Habitat in the Turners Falls Impoundment and Assessment of Operational Impacts on Special Status Species

N

Attachment F:
Mapping of RTE Plant Species
In the Bypass Reach
Map 3

0 420 840 1,680 Feet

Path: W:\gis\studies\3_5_1\maps\2016_Agency_Response\Attachment_F_Map3.mxd

Attachment G to Study 3.5.1.
Invasive Species Point Data (Zip File)

See Zip file Attachment_G_3_5_1

STUDY NO. 3.6.6 ATTACHMENTS

Attachment A to Study 3.6.6.
Daylight Analysis of Effects of Project Operation on Recreation Sites on the Turners Falls Impoundment

Background

This attachment addresses two particular issues that were raised by stakeholders in their comments on the Study Report for Study 3.6.6 *Assessment of Effects of Project Operation on Recreation and Land Use*. The first, was an issue that was raised during the discussion of the 3.6.6 study report at the November 1, 2016 USR meeting - whether the water surface elevation duration (WSEL) analysis that was applied to Pauchaug Boat Launch (as well as other Turners Falls Impoundment recreation sites) to demonstrate the portion of time that the launch was useable was appropriate, because hourly WSEL data was aggregated over a 24 hour period to produce the WSEL duration curves for the recreation season (May-October), and for each month. The question raised at the meeting and in CRWC's written comments was whether it would be more relevant to look at water surface elevations in the daytime (as opposed to nighttime or over a full 24 hour day) because this is when most boating would occur, and because overnight pumping operations at Northfield Mountain have the potential to affect Turners Falls Impoundment water levels.

The second issue related to whether flow reversals and upstream flow velocities resulting from Northfield Mountain Project operations have the potential to affect the usability of the Turners Falls Impoundment recreation sites closest to the Northfield Mountain Project intake, i.e., Boat Tour and Riverview Picnic Area, Munn's Ferry Boat Camping Recreation Area, and Cabot Camp Access Area. This issue was analyzed in the 3.6.6 study report but additional analysis is presented in this Attachment.

Daylight Analysis of Effects of Project Operation on Recreation Sites on the Turners Falls Impoundment

To address the issue of differences in daytime and nighttime project operation effects, FirstLight re-evaluated the water surface elevation data on a daytime and nighttime basis. To do this, rather than aggregating all hourly data into a single WSEL duration curve for the recreation season (or month), the hours were divided into daylight hours (7AM-7PM) and nighttime hours (8PM-6AM). Separate daytime and nighttime duration WSEL plots were developed for each of the Turners Falls Impoundment water access facilities, including Pauchaug Boat Launch, the boat dock at Munn's Ferry Boat Camping Recreation Area, the boat dock at the Boat Tour and Riverview Picnic Area and the State Boat Launch at Barton Cove (the WSEL curves for the State Boat Launch also serve to evaluate the other Barton Cove facilities – Barton /Cove Canoe/Kayak Launch Area, and the Barton Cove Floating Dock at the Barton Cove Nature Area and Campground). The daylight analysis did not include Governor Hunt because as noted in the original report for Study 3.6.6, a hydraulic control above Stebbins Island prevents the WSEL at the boat launch from falling below the critical elevation of 181 ft.

The resulting daytime (7AM-7PM) and nighttime (8PM-6AM) WSEL duration curves for each of these four sites are shown in Figures 1-4. Generally, when compared to the aggregated elevation duration figures (for all hours of each day), the daytime duration curves do suggest that lower water levels occur more frequently during the daylight hours, as a result of overnight pumping at Northfield Mountain. Other key influences on the WSEL in the Turners Falls Impoundment are releases from the upstream Vernon Project, water level management by FirstLight at the Turners Falls Dam including releases to the Cabot Power Canal, and tributary inflow especially from the Ashuelot and Millers River.

Key metrics from the duration plots are summarized in Table 1, which shows the percentage of time that the water surface elevation of Turners Falls Impoundment is at or above the critical elevation for each of the water-access recreation facilities during daylight hours, during nighttime hours, and during all hours (as provided in the original 3.6.6 study report), for the entire recreation season (May-October). As shown, the frequency that the impoundment is at or above the critical elevation for a particular facility is less during the daylight hours than during the nighttime, or in comparison to all hours, except at the Riverview Boat Dock and the Munn's Ferry Boat Dock, where the elevation exceeds the critical elevations for those facilities 100% of the time, during both night and day. The site where the daytime and nighttime difference in critical water level exceedances is greatest is at Pauchaug Boat Launch, where the critical water surface elevation of 181 ft is exceeded 82% of the time during the daylight hours, as compared to 87% of the time when all hours are combined, for the recreation season (May-October). Smaller differences in the critical water surface elevation exceedances occur between daylight hours and all hours at the Barton Cove facilities, except at the State Boat Launch, where there is no change.

Table 2 shows the percentage of time that the water surface elevation of Turners Falls Impoundment is at or above the critical elevation for each of the water-access recreation facilities during daylight and nighttime hours, for each month of the recreation season (May-October). Again, these numbers indicate that the greatest difference in daytime and nighttime water surface elevations, with respect to the critical elevation of the recreation facility, occurs at the Pauchaug Boat Launch. As shown, at this site water surface elevations exceed the critical elevation for the boat launch of 181 ft between a low of 71% of the time in August to a high of 94% of the time in May. At Riverview and Munn's Ferry, the water surface elevations exceed the critical level for each of those boat docks 100% of the time in all months. At the remaining sites, there are some differences between daytime and nighttime critical elevation exceedance values, but the differences are generally small.

Table 1: Turners Falls Impoundment Recreation Sites/Facilities – Percent of Time that WSEL Meets or Exceeds the Critical Elevation for the Facility for Daylight Hours (7AM-7PM), Nighttime Hours (8PM-6AM), and During All Hours for the May-October period.

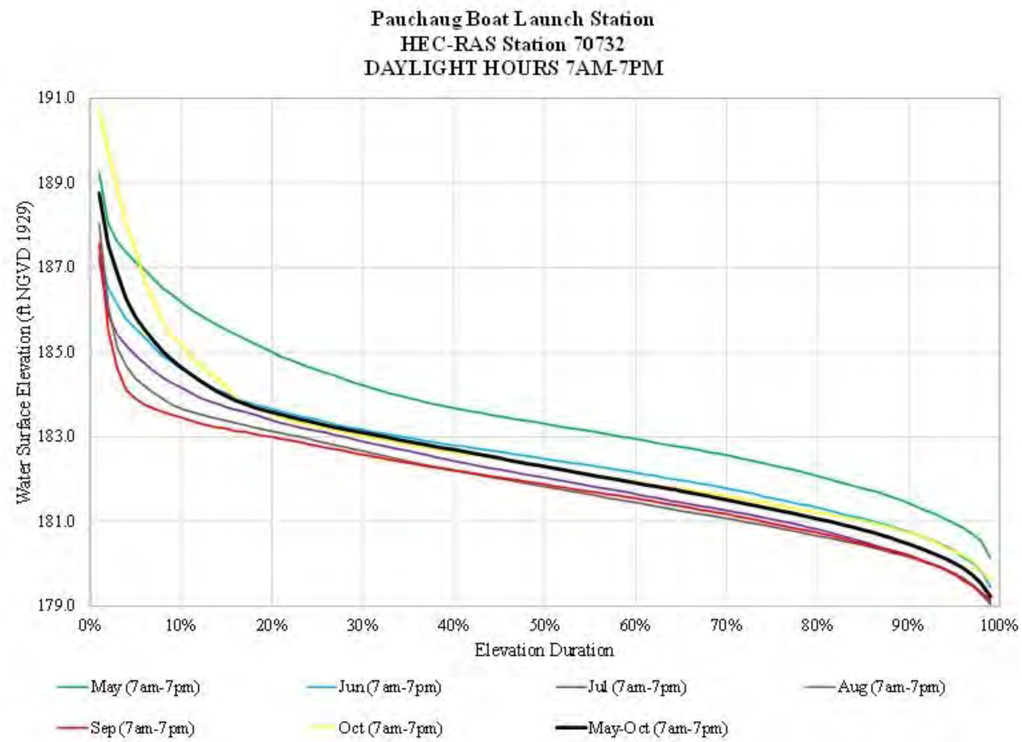
Recreation Site	Water Access Recreation Facilities/ Amenities	Critical Water Surface Elevation (ft)	Percent Exceeded Daylight Hours (7AM-7PM)	Percent Exceeded Nighttime Hours (8PM-6AM)	Percent Exceeded All Hours*
Governor Hunt Boat Launch and Picnic Area	Boat launch	NA	Hydraulic control prevents WSEL from falling below 181 ft.		
Pauchaug Boat Launch	Boat launch	181	82%	93%	87%
Munn's Ferry Boat Camping Recreation Area	Boat dock (floating)	174	100%	100%	100%
Boat Tour and Riverview Picnic Area	Boat dock (floating)	175	100%	100%	100%
Cabot Camp	None	NA	No specific water access facilities at this site. Site remains useable for river access a wide range of water surface elevations.		
Barton Cove Nature Area and Campground	Boat dock (floating)	180	88%	94%	91%
Barton Cove Canoe and Kayak Rental Area	Canoe/Kayak launch	180	88%	94%	91%
State Boat Launch	Boat launch	179	98%	100%	98%

* As originally reported in the 3.6.6 Study Report.

Table 2: Percent Exceedance of WSEL Critical Elevation for Turners Falls Impoundment Recreation Sites – Daytime (7AM-7PM) and Nighttime (7PM-7AM), by Recreation Season Month

			MAY		JUNE		JULY		AUG		SEPT		OCT	
Recreation Site	**Water Access Recreation Facilities/ Amenities**	**Critical Water Surface Elevation (ft)**	**Percent Day Hours**	**Percent Night Hours**	**Percent Day Hours**	**Percent Night Hours**	**Percent Day Hours**	**Percent Night Hours**	**Percent Day Hours**	**Percent Night Hours**	**Percent Day Hours**	**Percent Night Hours**	**Percent Day Hours**	**Percent Night Hours**
Pauchaug Boat Launch	Boat launch	181	94%	97%	86%	94%	76%	90%	71%	91%	74%	90%	85%	92%
Munn's Ferry Boat Camping Recreation Area	Boat dock (floating)	174	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Boat Tour and Riverview Picnic Area	Boat dock (floating)	175	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Barton Cove Nature Area and Campground	Boat dock (floating)	180	87%	92%	87%	94%	88%	96%	86%	96%	89%	97%	88%	91%
Barton Cove Canoe and Kayak Rental Area	Canoe/Kayak launch	180	87%	92%	87%	94%	88%	96%	86%	96%	89%	97%	88%	91%
State Boat Launch	Boat launch	179	97%	98%	97%	99%	98%	100%	98%	100%	98%	100%	97%	98%

Figure 1: Pauchaug Boat Launch WSEL Duration Curves (Daytime and Nighttime)



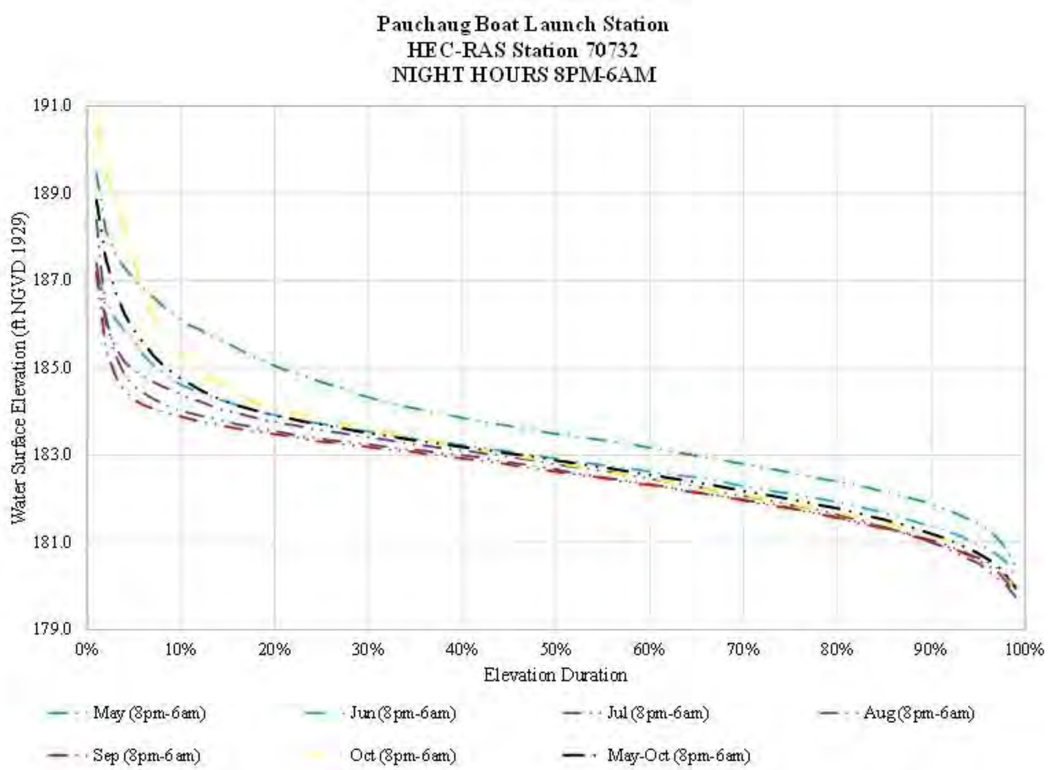
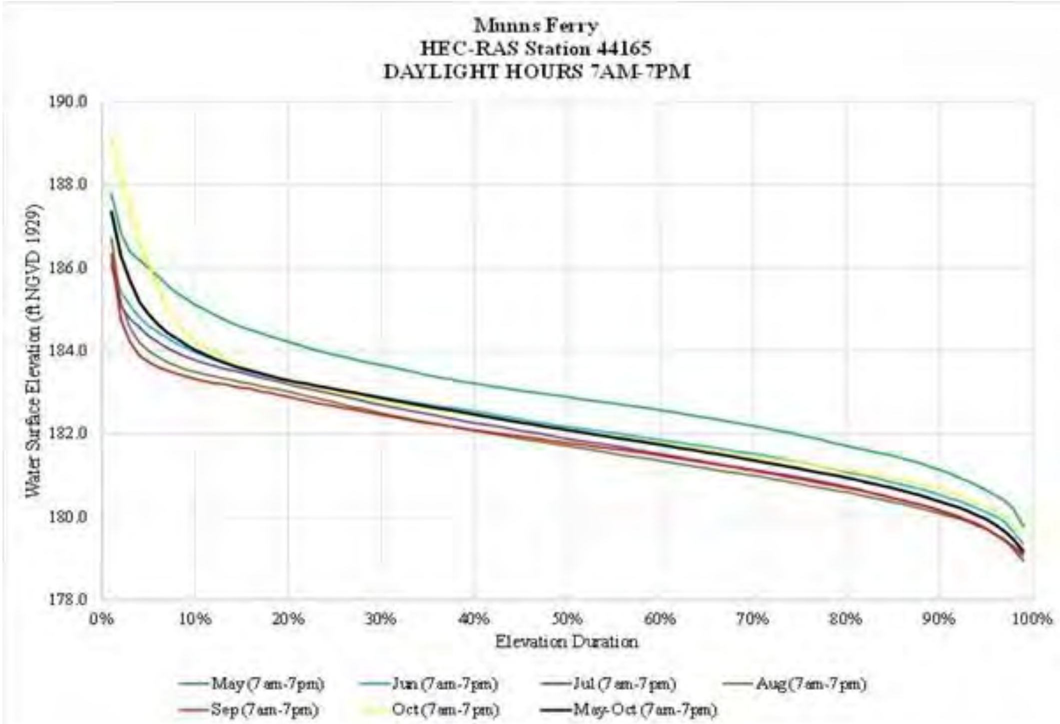


Figure 2: Munn's Ferry Boat Dock WSEL Duration Curves (Daytime and Nighttime)



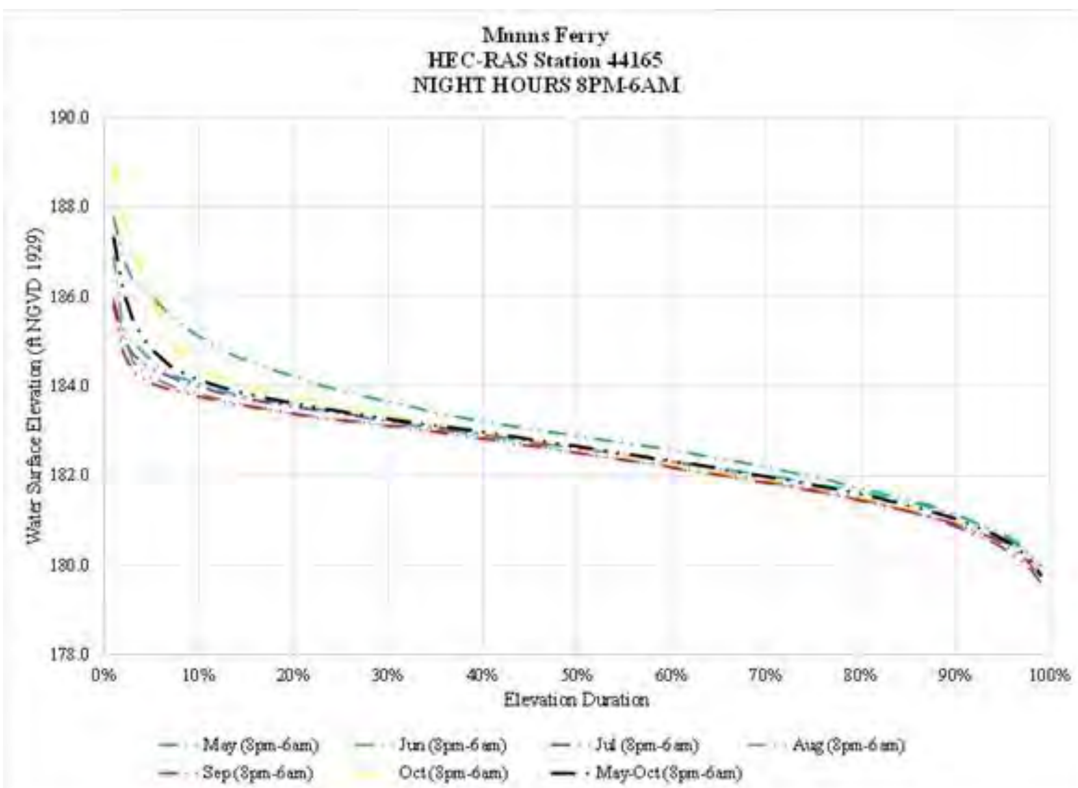
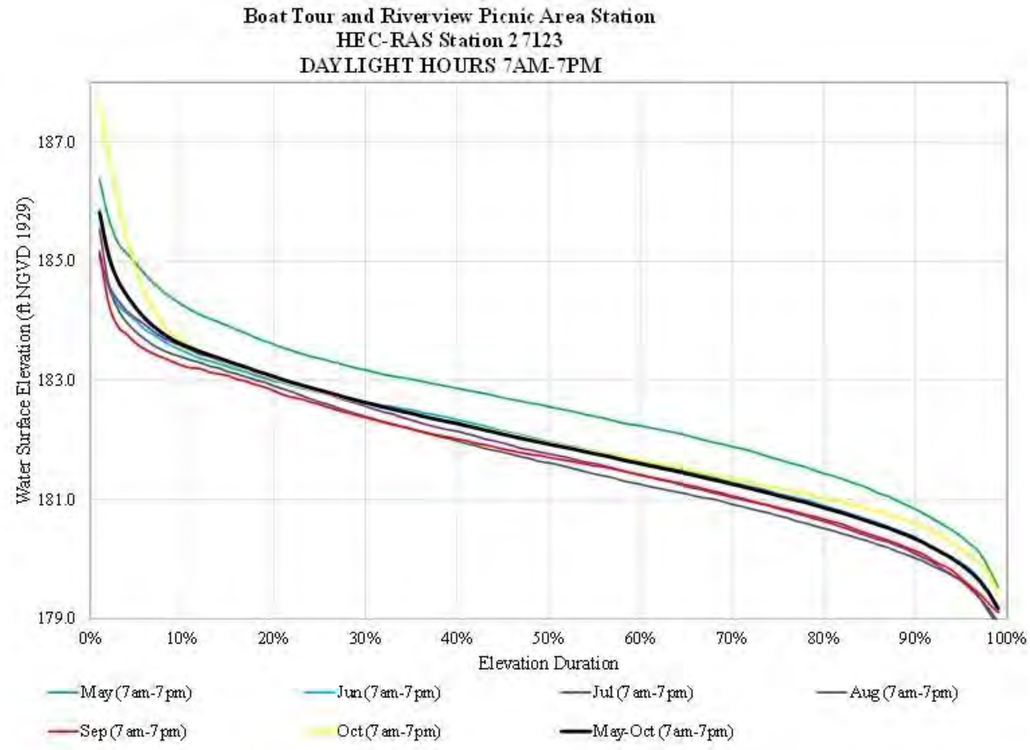


Figure 3: Riverview Boat Dock WSEL Duration Curves (Daytime and Nighttime)



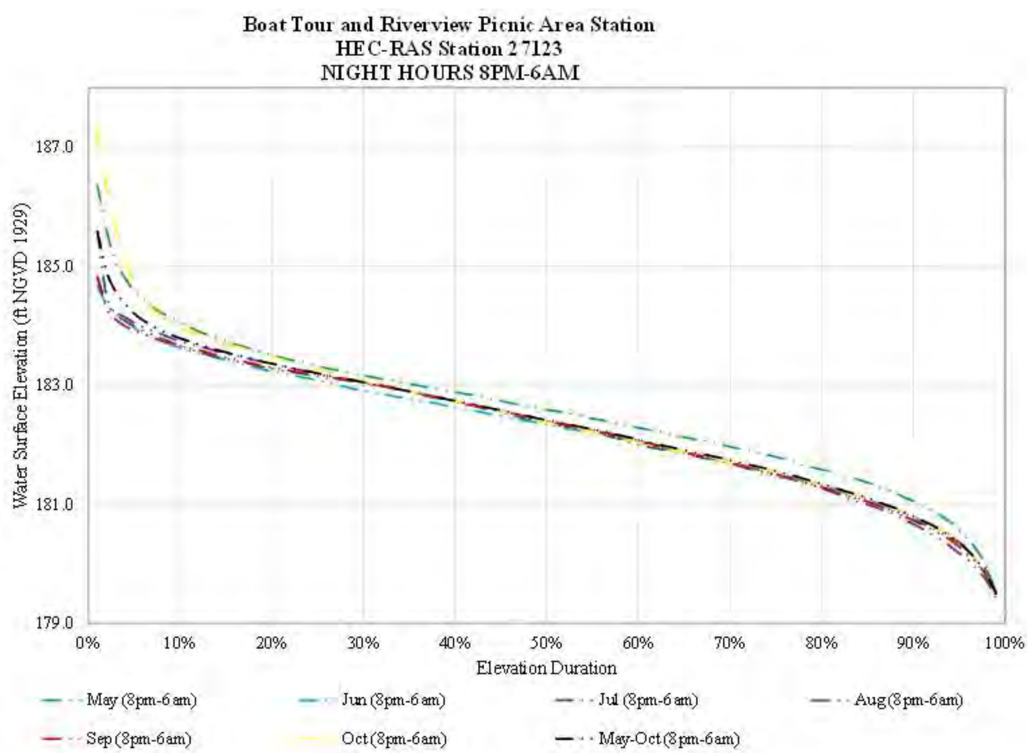
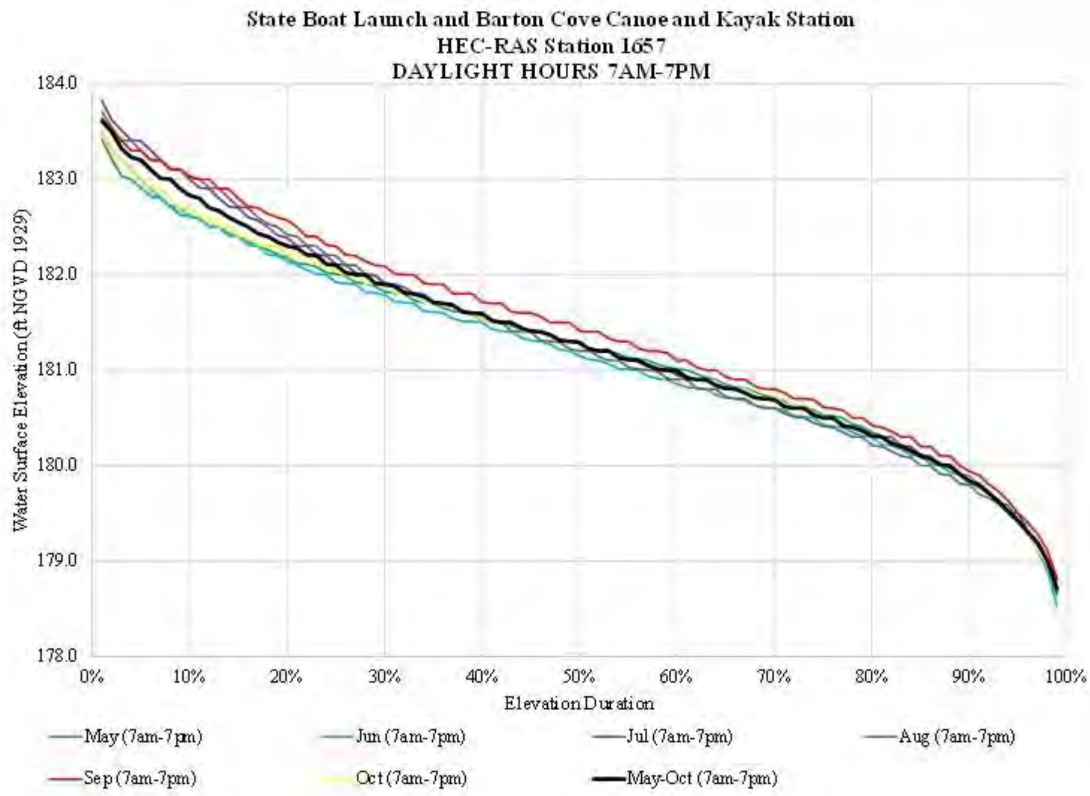
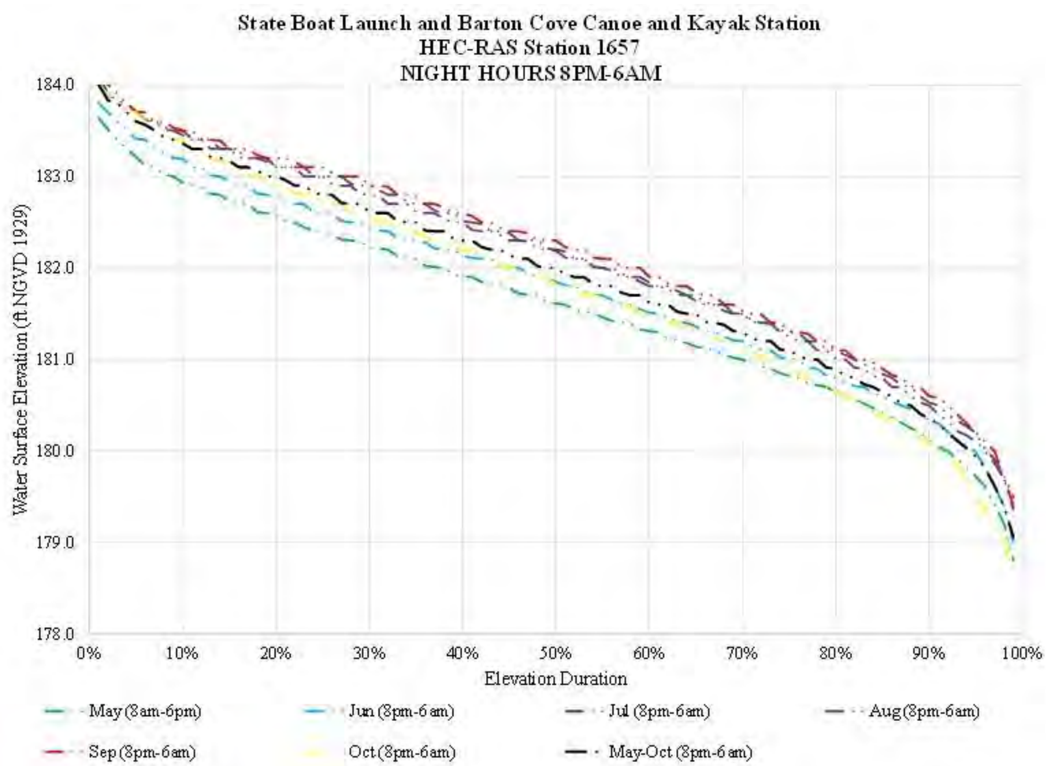


Figure 4: Barton Cove – State Boat Launch WSEL Duration Curves (Daytime and Nighttime)





Additional Analysis regarding Changes in Flow Direction and Upstream Flow Velocities

To address the issue of changes in flow direction and the upstream flow velocities experienced at the Boat Tour and Riverview Picnic Area, Munn's Ferry Boat Camping Recreation Area, and Cabot Camp Access Area, FirstLight utilized output from the HEC-RAS model to develop flow velocity duration plots for each of these sites. The resulting plots are shown in Figures 5-7. In these plots, the velocities plotted are the average velocity across the entire river transect chosen to represent each of the three recreation sites. Positive flow velocity values represent river flows in a downstream direction, while negative flow velocity values represent river flows in an upstream direction.

Boat Tour and Riverview Picnic Area

Figure 5 is a duration plot for average flow velocities during daylight hours (7AM – 7PM) at the model transect located closest to the Riverview recreation site. Because the potential for changes in flow direction due to operation of Northfield Mountain are greatest when river flow (releases from Vernon Dam) are lowest, this figure includes only hours when flow releases from Vernon Dam are less than 18,000[7] cfs on a daily average. Figure 5 confirms the results reported in the 3.6.6 Study Report. As shown, this location does experience some periods of flow reversal, when Northfield Mountain is generating and river flows are less than 18,000 cfs. The frequency of upstream flow events (when velocities are negative) varies by month. For example, in May when river flows are generally higher than later in recreation season, velocities are in a downstream direction 99% of the time, and in August, velocities are in a downstream direction 78% of the time. Table 3 summarizes the frequency of time flows are in a downstream direction, and the frequency of time that flows are in an upstream direction, by month.

The duration plots also show that upstream velocities typically range in magnitude from 0 to -1.0 fps. And there are no hours where the model shows that the average upstream flow velocity across this transect is more than 1.5 fps. This confirms the result described in the 3.6.6 Study Report, which concluded that when upstream velocities occur at Riverview they are low, typically between 0 and -1 fps, and therefore do not interfere with the usability of the Riverview boat dock.

Munn's Ferry Boat Camping Recreation Area

Figure 6 is a duration plot for average flow velocities during daylight hours (7AM-7PM) at the model transect closest to the Munn's Ferry recreation site. This site is located upstream from Northfield Mountain, so the potential to create upstream flows at this site would be as a result of Northfield Mountain generating operations. Figure 6 demonstrates that when river flows are less than 18,000 cfs, generating operations at Northfield Mountain can result in upstream flows at Munn's Ferry. Table 3 summarizes the frequency of time flows are in a downstream (or neutral, velocity=0) direction, and the frequency of time that flows are in an upstream direction at Munn's Ferry. The results of the velocity duration analysis at Munn's Ferry show that there are periods of upstream flow at this site (between 1% and 19% of the time, depending on the month). As at the other two sites, the velocity of upstream flows at this location is also low (0 to only slightly exceeding -1 fps), and therefore would not impact use of the Munn's Ferry Boat Dock or recreational use of the site.

Cabot Camp Access Area

Figure 7 is a duration plot for average flow velocities during daylight hours (7AM-7PM) at the model transect closest to the Cabot Camp site. This site is located downstream from Northfield Mountain and thus any upstream flow occurrences would be the result of Northfield Mountain pumping operations. As the figure shows, the Cabot Camp location does experience some periods of flow reversal when Northfield Mountain is pumping and river flows are less than 18,000 cfs. Table 3 summarizes the frequency of time flows are in a downstream direction, and the frequency of time that flows are in an upstream direction at Cabot Camp. Overall, the results of the velocity duration analysis show that there are periods of upstream flow at Cabot Camp, but that the frequency of such events is low. In addition, the frequency of upstream flow conditions during daytime hours is less than observed at Riverview. In addition, the velocity of upstream flows at this location is also generally lower (0 to only slightly exceeding -1 fps), and therefore would not impact use of the Cabot Camp site for recreation use.

[7] The Vernon Project located at the upstream end of the Turners Falls Impoundment has a generation capacity of 17,130 cfs and often operates at a peaking facility under low flow conditions. FirstLight's Northfield Mountain Project has a maximum generating capacity of 20,000 cfs and a maximum pumping capacity of 15,200 cfs.

Table 3: Percent of Time that Flows at the Riverview, Cabot Camp and Munn's Ferry Recreation Sites are in a Downstream or Upstream Direction, When Daily Average Flows from Vernon Dam are < 18,000 cfs, During the Recreation Season Months (May-October)

Month	Riverview**		Cabot Camp*		Munn's Ferry**	
	Downstream (positive velocity)	Upstream (negative velocity)	Downstream (positive velocity)	Upstream (negative velocity)	Downstream (positive velocity)	Upstream (negative velocity)
May	99%	1%	99%	1%	99%	1%
June	96%	4%	98%	2%	98%	2%
July	86%	14%	96%	4%	91%	9%
August	78%	22%	95%	5%	84%	16%
September	75%	25%	96%	4%	81%	19%
October	85%	15%	98%	2	89%	11%

* Recreation site located downstream of Northfield Mountain where upstream flows result from pumping operations at Northfield Mountain.

** Recreation site located upstream of Northfield Mountain where upstream flows result from generating operations at Northfield Mountain.

Figure 5: Flow Velocity Duration at Riverview During Days when River Flow is < 18,000 cfs, Between the Hours of 7AM-7PM, During the Recreation Season Months (May-October)

(Where Positive Velocities Indicate Flows in a Downstream Direction, and Negative Velocities Indicate Flows in an Upstream Direction)

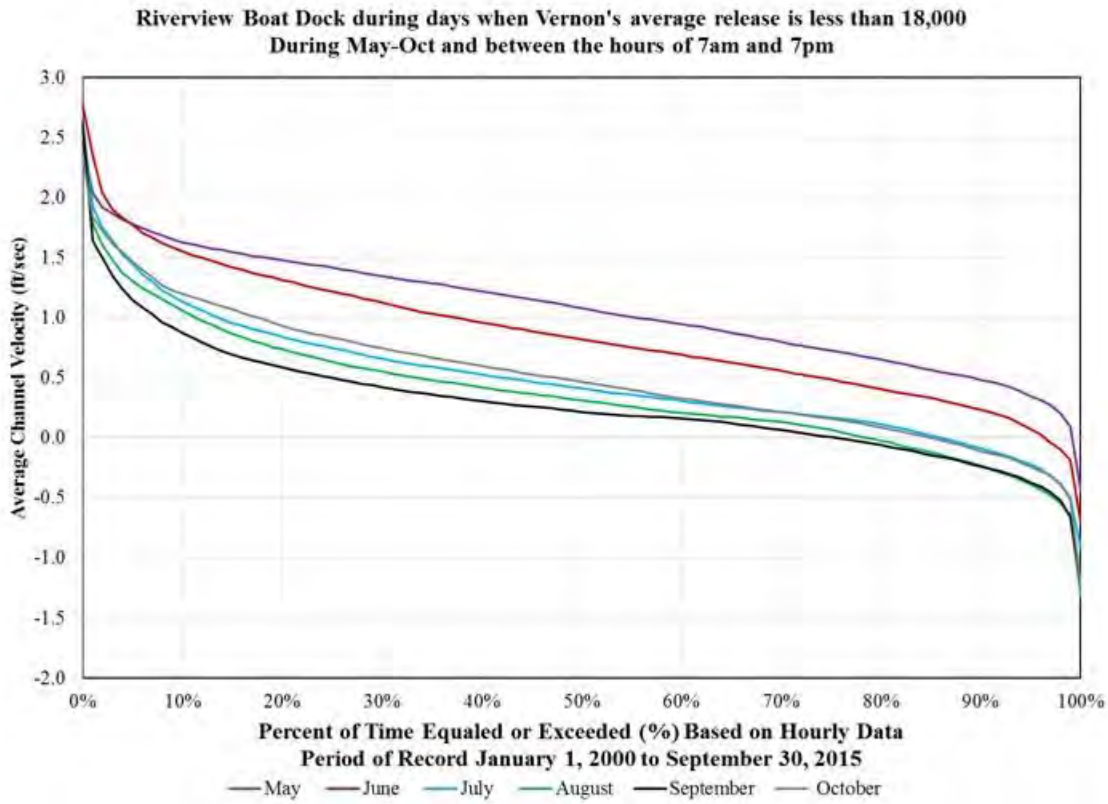


Figure 6: Flow Velocity Duration at Munn's Ferry /During Days when River Flow is < 18,000 cfs, Between the Hours of 7AM-7PM, During the Recreation Season Months (May-October)

(Where Positive Velocities Indicate Flows in a Downstream Direction, and Negative Velocities Indicate Flows in an Upstream Direction)

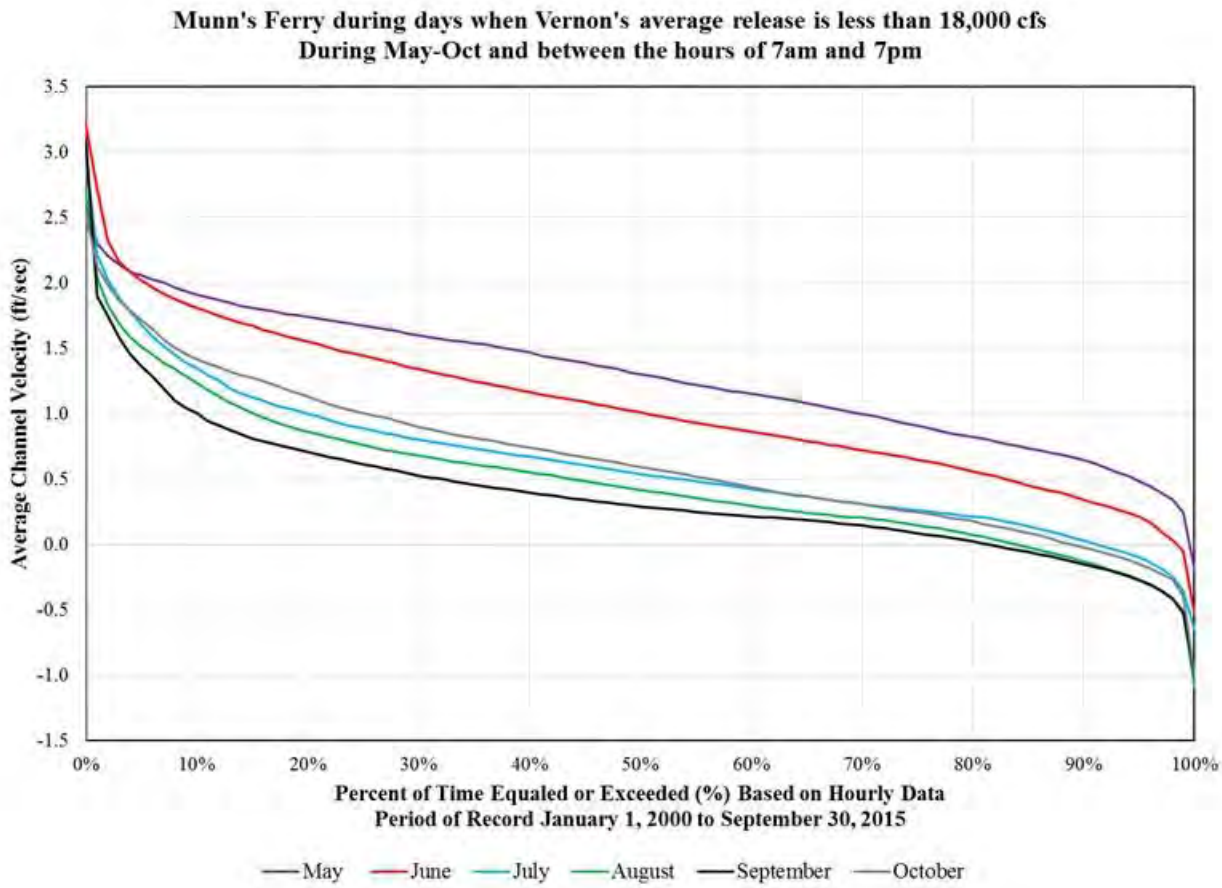
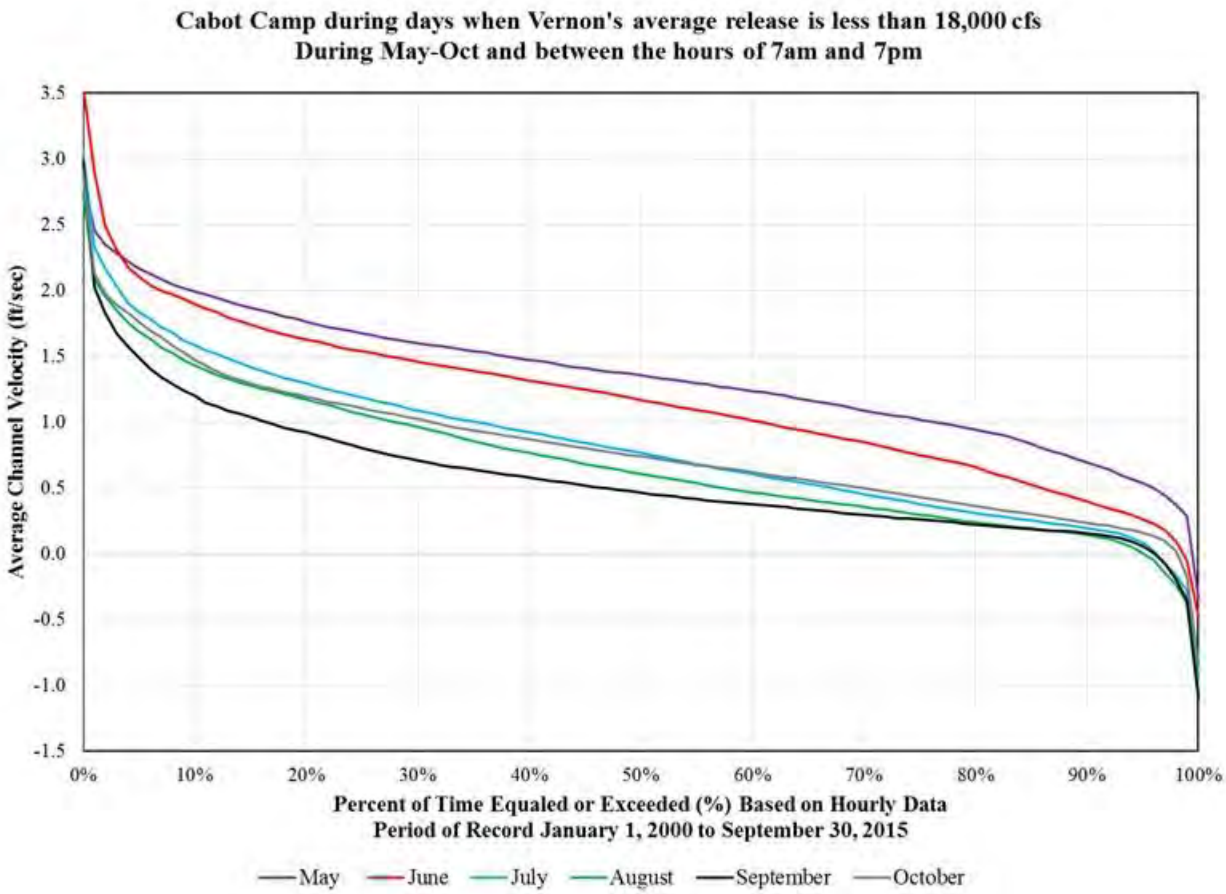


Figure 7: Flow Velocity Duration at Cabot Camp During Days when River Flow is < 18,000 cfs, Between the Hours of 7AM-7PM, During the Recreation Season Months (May-October)

(Where Positive Velocities Indicate Flows in a Downstream Direction, and Negative Velocities Indicate Flows in an Upstream Direction)



Attachment B to Study 3.6.6.
Study Report Corrections

After filing the 3.6.6 Study Report, FirstLight found an error in the critical elevation reported for the floating boat dock associated with the Munn's Ferry Camping Recreation Area. The study report as filed with FERC on October 1, 2016 stated that the critical water surface elevation (WSEL) was 167'. That was an error. The actual critical elevation for the Munn's Ferry Boat Dock is 174'. Below is a revised Section 4.2.3 and Table 5-1 of the study report for Study 3.6.6, which corrects the error. The overall result of the analysis for the Munn's Ferry Boat Dock remains unchanged i.e., the error in critical elevation did not change the outcome of the analysis. HEC-RAS modeling of historic conditions, shows that the elevation of the Turner's Falls Impoundment in the vicinity of the of Munn's Ferry never falls below elevation 174', so there is no impact on the Munn's Ferry Boat Dock associated with fluctuating water levels due to Project operations.

The summary description of Project operational impacts at Pauchaug Boat Launch has also been revised in the revised Table 5-1 to correct the description of the water surface elevation durations. Again, the description in the original Table 5-1 was just in error (less than and greater than were reversed), and there was no change made to the results or impacts analysis as a result of the correction.

4.2.3 Munn's Ferry Boat Camping Recreation Area

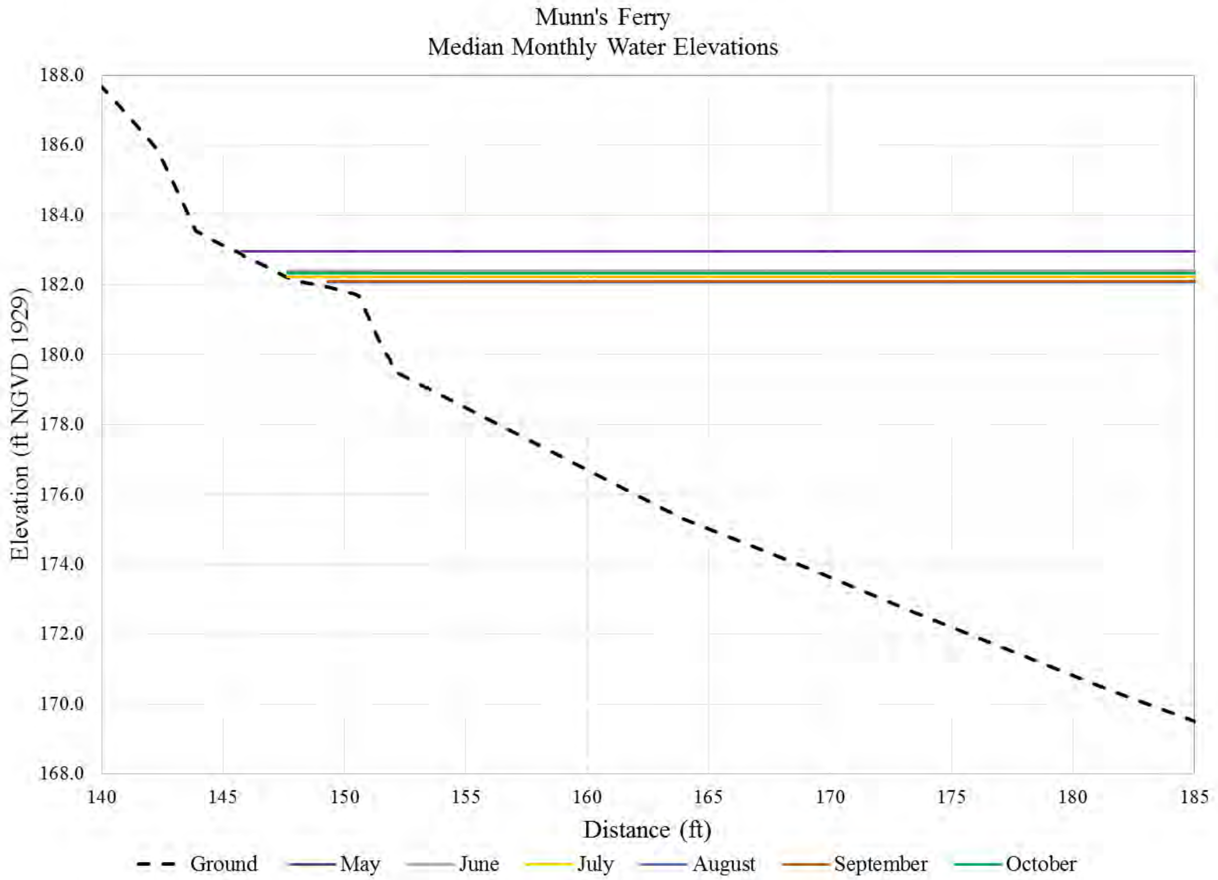
The Munn's Ferry Boat Camping Recreation Area is located on the east side of the TFI in Northfield, MA. The site is owned and managed by FirstLight as a water access-only campground. There is one water access facility at the site, a floating boat dock and associated ramp that is installed seasonally for campers' use (Figure 4.2.3-1). The ramp is approximately 25 feet long, and the floating dock is approximately 20 ft by 8 ft, in size.

The boat dock at Munn's Ferry Boat Camping Recreation Area is designed to accommodate small to moderate sized watercraft, as well as canoes and kayaks. Figure 4.2.3-2 shows the river bed elevation at the Munn's Ferry Boat Camping Recreation Area boat dock at specified distances from the shoreline. Bathymetry data show that the elevation of the river bottom in the area of the boat dock is approximately 171 feet. To allow for a minimum of three (3) feet of water depth for docking power boats, the WSEL would need to be at least 174 feet. The lowest allowable operating range for the TFI is elevation 176 feet. Thus, the WSELs at the boat dock are above 174 feet 100% of the time, including during the recreation season (May through October), and the Munn's Ferry Boat Camping Recreation Area boat dock remains useable all of the time during the recreation season. Figure 4.2.3-2b shows the monthly WSEL duration curves and confirms that water surface elevations at the end of the Munn's Ferry Boat Dock exceed 174' 100% of the time in all months. Results of the Recreation User Survey further confirm this result. Of the six (6) surveys collected from recreation users at the Munn's Ferry Boat Camping Recreation Area, none mentioned water levels as a concern with respect the usability of the boat dock.

Figure 4.2.3-1 Munn's Ferry Boat Camping Recreation Area Floating Boat Dock

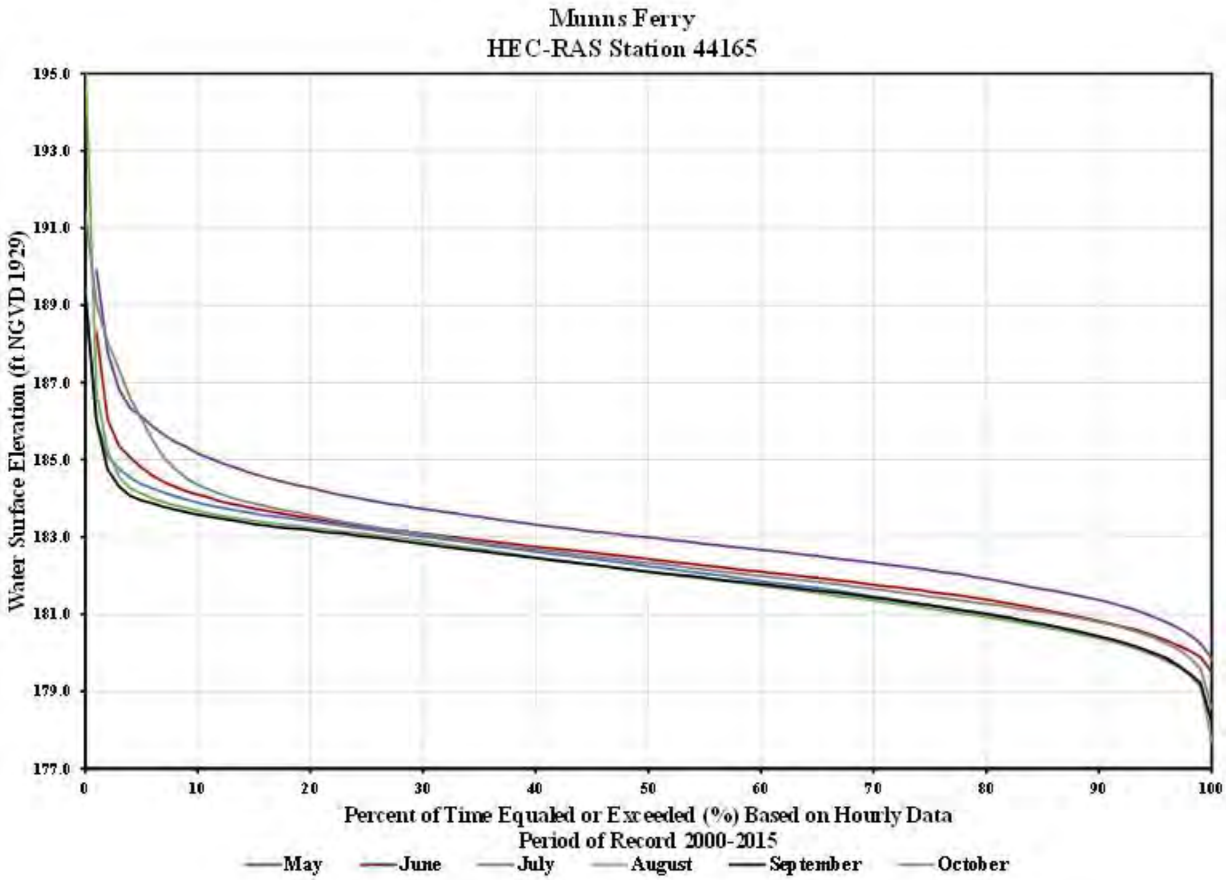
Munn's Ferry Boat Camping Recreation Area Floating Boat Dock – Turners Falls Impoundment elevation at the time of this picture was 180.3 ft.

Figure 4.2.3-2 Munn's Ferry Boat Camping Recreation Area Bottom Contour Elevation and Median Monthly WSEL



(based on hourly model WSEL at the Munn's Ferry Recreation Area for the period January 1, 2000 to September 30, 2015)

Figure 4.2.3-2b Munn's Ferry Boat Dock WSEL Duration Curves, Monthly (May-October)



(based on hourly model WSEL at the Munn's Ferry site for the period January 1, 2000 to September 30, 2015)

Revised Table 5-1 Summary of Project Effects on Water Based Recreation Sites and Facilities

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 water level impacts; launch ramp remains usable at WSELs of > 181 feet, which may occur anywhere from 80% (August) of the time to 95 % (May) of the time during the recreation season (May-October). Launch also has sufficient water depth (elevation 180 feet) 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 to minimal water level impacts; WSEL of 174 feet is needed for docking power boats. Boat dock remains usable at WSELs of ≥ 174 feet, which occur 100% of the time during the recreation season (May-October).
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
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; the 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.

Recreation Site	Water Access Recreation Facilities/ Amenities	Water-based Recreation Uses	Project Operational Impacts
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.
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.