

Connecticut River Conservancy Comment Exhibit List*

Exhibit A	Comments of Connecticut River Conservancy in Opposition to certain conditions from the March 31, 2023 Offer of Partial Settlement for the Turners Falls Hydroelectric Project et al. under P-1889 et al., FERC Accession No. 20230525-5090 (filed May 25, 2023)
Exhibit B	Comments of Connecticut River Conservancy on the amended final license application re the Turner Falls Hydroelectric Project, FERC Accession No. 20230525-5090 (filed May 22, 2024)
Exhibit C	Gomez & Sullivan Engineers, Boating Navigability Study: Turners Falls Hydroelectric Project (No. 1889) (2021) (prepared for FirstLight) (“Boating Navigability Study”)
Exhibit D	Notice to Intervene and Comments of The Nolumbeka Project Inc. at 4-5, Project Nos. 1889-000 and 2485-000, FERC Accession No. 20230525-5073 (filed May 25, 2023) (hereinafter The Nolumbeka Project’s Comment)
Exhibit E	FRCOG Comments to DEP on FirstLight’s 401 Water Quality Certificate Application (June 3, 2024)
Exhibit F	Dr. Evan Dethier, Review of Erosion in the Turners Falls Impoundment (May 19, 2024)
Exhibit G	Connecticut River Conservancy letter to Secretary Bethany Card at the Executive Office of Energy and Environmental Affairs, Re: Turners Falls Hydroelectric Project, et al. under P-1889, et.al., FERC Relicensing and Massachusetts Clean Water Act § 401 Certification (June 13, 2022)

* These exhibits are large file sizes and CRC was unable to send them via email. They will be submitted via a Sharepoint folder that DEP will send to Nina Gordon-Kirsch at CRC, ngordonkirsch@ctriver.org. This information was given to Nina over email on 5/31/24 by Elizabeth Stefanik at DEP, who says that Victoria Wu will send the Sharepoint folder to Nina.



**Connecticut River
Conservancy**

Clean water. Healthy habitat. Thriving communities.

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May 25, 2023

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

Re: Offer of Partial Settlement; Turners Falls Hydroelectric Project (FERC No. 1889-081) and
Northfield Mountain Pumped Storage Project (FERC No. 2485-063)

Dear Secretary Bose:

On March 31, 2023, FirstLight MA Hydro LLC, owner and operator of the Turners Falls Hydroelectric Project (“Turners Falls Project”) and Northfield Mountain LLC, owner and operator of the Northfield Mountain Pumped Storage Project (“Northfield Mountain Project”) (collectively, “FirstLight”) submitted an offer of partial settlement for the conditions of relicensing of the Turners Falls Project and Northfield Mountain Project related to flows and fish passage (“Offer”).

Pursuant to Rule 602(f) of the Rules of Practice and Procedure of the Federal Energy Regulatory Commission (“FERC” or “Commission”), the Connecticut River Conservancy (“CRC”) submits the attached comments with accompanying affidavits in opposition to certain license conditions proposed in the Offer.

Thank you for the opportunity to provide these comments. If you have any question regarding this submission, please contact the undersigned at kwentling@ctriver.org or 413-834-9777



Kelsey Wentling (*pronouns: she/her/hers*)
River Steward, MA
Connecticut River Conservancy

**UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION**

FirstLight Hydro MA LLC	)	
	)	Docket No. 1889-000
	)	
Northfield Mountain LLC	)	Docket No. 2485-000
	)	

**COMMENTS OF THE CONNECTICUT RIVER CONSERVANCY
IN OPPOSITION TO OFFER OF SETTLEMENT**

Pursuant to Rule 602(f) of the Commission’s Rules and Regulations,¹ the Connecticut River Conservancy (“CRC”) submits these comments and accompanying attachments in opposition to the offer of settlement (“Offer”) filed in this proceeding on March 31, 2023, by FirstLight Hydro MA, LLC and Northfield Mountain, LLC (“Applicant”). The Offer relates to Flows and Fish Passage at Turners Falls Hydroelectric Project (“Turners Falls Project”) and Northfield Mountain Pumped Storage Project (“Northfield Mountain Project”) (collectively “Relicensing Projects”). For the reasons detailed below and in the attached affidavits, CRC objects to certain proposed license conditions in the Offer, and the Settling Parties have not met their burden to show that those terms are supported by substantial evidence.² Because CRC and many other commenters have raised genuine issues of material fact, the Commission should determine the Offer is contested.³ Rule 602(h)(1)(i) of the Commission’s regulations provides that the Commission may decide the merits of a contested settlement only if “the record contains substantial evidence upon which to base a reasoned decision or the Commission determines that there is no genuine issue of material fact.”⁴ Because the provisions to which CRC objects below are not supported by substantial evidence and CRC (and others) have raised genuine issues of material fact, the Commission should not accept the contested provisions and establish procedures to resolve contested issues.

Since 1952, CRC has been working to protect and restore the Connecticut River and its tributaries. CRC represents thousands of members across four states and, as the only nonprofit organization dedicated to protecting the entire Connecticut River ecosystem, our comments consider not only the localized impact of the Offer, but also the watershed-wide implications of the proposed license articles. CRC has been engaged in the relicensing of Turners Falls Project (FERC No. 1889), and Northfield Mountain Project (FERC No. 2485) for the entirety of the relicensing process. By

¹ 18 C.F.R. § 385.602.

² See *Policy Statement on Hydropower Licensing Settlements*, FERC Docket No. PL06-5-000 (Sept. 21, 2006) at ¶ 5 (“To support a proposed license condition, then, it is necessary for the parties to develop a factual record that provides substantial evidence to support the proposed condition . . .”) (hereinafter “Settlement Policy Statement”)..”).

³ 18 C.F.R. § 385.602(f)(4) (“Rule 602(f)(4)”).

⁴ 18 C.F.R. § 385.602(h)(1)(i) (“Rule 602(h)(1)(i)”).

actively participating in the relicensing process, CRC advocates for the sustainable management of these hydropower facilities, balancing the need for renewable energy generation with the preservation and restoration of the Connecticut River's health and ecological integrity.

4.5.2 Term of New Project License

CRC objects to the issuance of a 50-year license, and the Settling Parties have not provided substantial evidence to support such a long license term. In 2017, FERC adopted a policy stance of defaulting to a 40-year licensee term. FERC noted that comments from resource agencies and environmental groups on this policy indicated opposition to a 50-year term: "Several resource agencies argue that this option would provide little incentive for a license applicant to voluntarily propose or agree to mitigation measures because such measures would no longer factor into the Commission's license term decision. The resource agencies also contended that such policy would result in applicants focusing their license application study efforts on disproving project effects rather than on identifying potential mitigation measures."⁵

In the 2017 policy statement, FERC established three criteria to help guide determination of the length of license terms: (1) coordination with other projects in the same basin; (2) agreed upon timeframes included in a comprehensive settlement agreement; and (3) "significant measures" expected in the new license. This final consideration is contingent upon the first, meaning that the license term must still be coordinated with other projects in the basin. The Settling Parties have not shown that any of these criteria support the imposition of a 50-year license term.

- 1) Coordination: CRC has been an active party to settlement negotiations throughout the Applicant's relicensing process as well as throughout concurrent relicensing of upstream hydropower projects Wilder Dam (P-1892), Bellows Falls Dam (P-1855), and Vernon Dam (P-1904). While CRC supports FERC's policy to issue coordinated license terms among the five facilities undergoing relicensing, such coordination does not support a 50-year license term for the Relicensing Projects or any of the upstream facilities. As described below under bullet 3), Great River Hydro has indicated that they are not seeking a 50-year license term, so a 50-year license term for the Applicant is not supported by FERC's 2017 policy.
- 2) Timeframes: None of the timeframes contemplated in the Offer support the imposition of a 50-year license term. The Applicant failed to submit a comprehensive settlement agreement by the extended deadline of March 31, 2023. Instead, the Applicant filed a settlement offer related to flows and fish but does not include provisions for recreation (other than paddling), erosion or cultural resources. So, while all of the timeframes related to the Relicensing Projects are not yet known, there is no reason to believe that any timeframes established in any future agreements will support a 50-year license term.
- 3) "Significant Measures": FERC is given discretion to determine the meaning of "significant" or "moderate" measures included in a license to determine the appropriate license term. Previously, "moderate" measures have included fish passage facilities, environmental mitigation, recreation flow releases and recreational development, as well as fish monitoring. The Applicant has not demonstrated that measures in the Offer rise above "moderate" so as

⁵ Policy Statement on Establishing License Terms for Hydroelectric Projects, 82 Fed. Reg. 49502 (Oct. 26, 2017).

to justify a 50-year license term. In previous decisions, it has also been determined that, because costs fluctuate substantially over time, “costs can provide some indication of the extent of required measures, [but] costs alone are never entirely dispositive.”⁶ Therefore, while costs may be considered in determining the length of the license term, they cannot be the sole determining factor. In considering the 50-year license term the Applicant has requested, FERC also must consider the commitments made by Great River Hydro for Wilder Dam, Bellows Falls Dam, and Vernon Dam so as to coordinate license terms across the five facilities. In August 2022, Great River Hydro submitted an Offer of Settlement Agreement.⁷ *Table D-1* demonstrates that Great River Hydro anticipates a 40-year period, which is associated with “moderate” measures in FERC’s policy statement. Great River Hydro indicates in this timeline that they believe the measures in their agreement across its three facilities should be considered “moderate” measures. Great River Hydro will be providing improvements for fish passage to three different facilities that affect over 175 miles of river, with comparable measures. The Applicant’s license term request of 50 years is not justified.

In their Explanatory Statement, the Settling Parties provide no justification for the proposed 50-year license term, much less any reference to the substantial evidence required. Instead, the Commission is asked to accept the 50-year license term simply because the Settling Parties have agreed to it among themselves. *See* Explanatory Statement at 27 (“Where settling parties so request, it is the Commission’s policy to defer to the settling parties.”). Not only is this conclusory statement inconsistent with the requirement to support a license condition with substantial evidence, the Settling Parties cite, for their proposition, the Commission’s Settlement Policy Statement “at P 15.” *Id.* at n.15. It is unclear whether the citation to the Settlement Policy Statement is to page or paragraph numbers, but in either case, the citation does not support the Settling Parties’ proposition.⁸

Finally, the Applicant has been operating on a series of annual licenses since the expiration of its current licenses five years ago in April of 2018. The overdue environmental benefits included in the Offer have been long-delayed and the Applicant has been allowed to operate according to archaic standards. In doing so, the Applicant has delayed the implementation of environmental measures and prolonged the stress that outdated license requirements inflict on the Connecticut River. In the current public comment period, members of local communities impacted by the Applicant’s operations have repeatedly and ardently urged FERC not to grant a 50-year license. CRC likewise opposes a 50-year license term and believes that the new license term must reflect the reality of a rapidly changing climate and the uncertainty associated with climate-driven changes over the next several decades.

⁶ *Duke Energy Carolinas, LLC, v. Fed. Energy Regul. Comm’n*, 883 F.3d 923, 927 (D.C. Cir. 2018) (quoting *Duke Carolinas, LLC*, 156 FERC ¶ 61,010 (2016)).

⁷ Offer of Settlement between Great River Hydro, LLC and the U.S. Department of Interior et. al, (P-1892, P-1855, P-1904), *available at* https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20220803-5124&optimized=false.

⁸ Paragraph 15 of the Settlement Policy Statement relates to Dispute Resolution/Enforceability and page 15 deals primarily with establishing project boundaries. *See* Settlement Policy Statement at ¶ 15 & page 15.

Article A110 Minimum Flows Below the Dam

CRC opposes the proposed minimum 500 cubic feet per second (cfs) flow from the dam between July 1 to November 15. This proposed minimum flow fails to protect habitat for fluvial species and macroinvertebrates, does not protect existing and designated uses, and does not adequately address concerns about potential impacts to cultural resources for the approximately one-mile river segment below Turner's Falls Dam (TFD) before the river reaches Station No. 1.

The proposed minimum flow of 500 cfs fails to provide sufficient habitat for fluvial species and macroinvertebrates.

The *Final Massachusetts Integrated List of Waters for the Clean Water Act 2018/2020 Reporting Cycle* lists the Connecticut River below Turners Falls Dam (MA 34-03) as impaired partially due to dewatering and flow regime modification.⁹ As a result of the impairments caused by the Turners Falls Dam, fish habitat and water quality have been degraded in this segment of river. Fish community identification and classification are integral to determining if Aquatic Life Uses are being met. A study of fish communities in New England found that the river segment below the dam had the lowest Index of Biological Integrity (IBI) score of all river segments in the study. *See* Affidavit of Julian Burgoff (hereinafter "Burgoff Affidavit"), ¶ 8. The study found that the addition of increased flows below Station No. 1 increased the IBI score in this reach and that lack of stable fish communities and habitat below the dam are due to dewatering of this segment. ¶ 8,9

The proposed minimum 500 flow severely limits available habitat for species in the reach below the Turners Falls Dam and above Station No. 1, thereby prolonging impairments by preventing the Aquatic Life Uses from being met.

Flows of 500 cfs allow for only 10% of maximum available habitat for macroinvertebrates, see attached Affidavit of Donald Pugh (hereinafter "Pugh Affidavit"), ¶ 7, and less than 27% for several fish species. *Id.* ¶ 6. CRC is particularly concerned with the flows necessary to provide habitat for longnose dace and tessellated darters. These are fluvial species that require constant flow for all stages of their life cycle. *Id.* ¶¶ 5,6. The Massachusetts Consolidated Assessment and Listing Methodology uses the abundance of fluvial species to assess the ecological health of river systems, and so the availability of habitat for these species provides key insights into the restoration of this river segment *Id.* ¶ 6. The proposed flows of 500 cfs will provide only 27% and 18% of available habitat for juvenile and adult longnose dace and only 22% of available habitat for juvenile and adult tessellated darter *Id.* ¶ 6. Similarly, of the available habitat in this reach, only a tenth will be available for macroinvertebrates to fully use; macroinvertebrates are a key component of the food web, providing a source of food for fish species *Id.* ¶ 7.

Increases in the proposed flows from Turners Falls Dam will provide more habitat for the fluvial species and work to partially restore the dewatered and impaired river segment below the dam and above Station No. 1. CRC reviewed the Instream Flow Incremental Methodology (IFIM) analysis in Study 3.3.1 for this section of the river, which provides a Weighted Useable Area (WUA) under

⁹ Massachusetts Division of Watershed Management Watershed Planning Program, *Final Massachusetts Integrated List of Waters for the Clean Water Act 2018/2020 Reporting Cycle* at 168 (Nov. 2021), available at <https://www.epa.gov/system/files/documents/2022-02/2018-2020-ma-303d-list-report.pdf>.

various flows. With an increase of flow from 500 cfs to 1,400 cfs, WUA for juvenile and adult longnose dace increases by 54% and 51%, respectively, for a total of 81.7% and 69.4%. *See* Pugh Affidavit, ¶ 13, Table 1. Likewise, for tessellated darter, an increase from 500 cfs to 1,400 cfs provides 84.5% WUA, a 63% increase. *Id.* Finally, for macroinvertebrates, this increase would provide 26% more WUA for a total of 36.1% WUA. *Id.* ¶ 13

In addition to the insufficient aquatic habitat at the proposed flow, 500 cfs does not even fill the river such that water covers the riverbed from bank to bank. Aquatic habitat can also be assessed according to the Wetted-Perimeter method, which measures the availability of habitat in a given cross section. *Id.* ¶ 14. Analysis of Transect 11, a study site in Study 3.3.1 approximately 0.8 miles below Turners Falls Dam, indicates that at flows of 470 cfs roughly 35% of the transect is dry or insufficiently wetted. *Id.* ¶ 15. With an increase of flows to 1,670 cfs, the entire width of the river is wetted and available habitat for fluvial species. *Id.* ¶ 15, Figure 2. This is further supported by a photograph taken at flows of 1,500 cfs depicting flowing waters over nearly the entire river width, while a photo of flows at 400 cfs show areas of exposed bedrock, indicating limited aquatic habitat. *Id.* ¶¶ 16, 17, Figures 3, 4.

The proposed 500 cfs minimum flow between July 1 to November 15 will continue to cause impairments due to dewatering and fails to provide sufficient habitat for fluvial species and macroinvertebrates; these insufficient flows prevent the restoration of habitat for species that would otherwise occupy this stretch of the Connecticut River. *Id.* ¶¶ 8, 18; *see also* Burgoff Affidavit, ¶¶ 4–12.

The proposed minimum flow of 500 cfs does not provide sufficient water levels for recreation.

The proposed minimum flow of 500 cfs fails to support the existing and designated use of primary and secondary contact recreation in this segment because the water level is too low to support recreational boating. According to the Applicant's 2021 Boating Navigability Study, the proposed summer flow of 500 cfs is not considered navigable. The minimum navigable flow required is 545 cfs from Bascule Gate #1, 71 cfs from Fall River, and 560 cfs from Station No. 1 for a total of 616 cfs below Peskeomskut Island (measured) and 1,007 cfs below Station No. 1. There is no justification for the proposed summer flow of 500 cfs and given that the Boating Navigability Study indicated that flows above 500 cfs are the *minimum* for navigating a boat in this river segment, the minimum flows must be considerably higher to protect the existing use of recreation.¹⁰

The proposed minimum flow of 500 cfs does not adequately protect cultural resources.

Finally, CRC supports the comments of the Nolumbeka Project,¹¹ which explain that the proposed summer flow of 500 cfs is insufficient to protect cultural resources in the river below the dam to Rawson Island. In 2008, the Department of Interior determined that the Sacred Ceremonial Hill complex, found within the area of the Turners Fall airport, is a federally recognized ceremonial district, which includes a 16-mile radius around this site, encompassing the Connecticut River below

¹⁰ Boating Navigability Study Report Turners Falls Hydroelectric Project (No. 1889) (December 2021).

¹¹ Comment Filed By: The Nolumbeka Project, Inc on 5/25/2023

the Turners Falls Dam.¹² The 2008 determination¹³ makes reference to the numerous indigenous groups who gathered in this area, and the ceremonial activities that took place in and along the river near Great Falls. These activities contributed to the presence of cultural resources and artifacts in the Connecticut River today. The Chaubunagungamaug Band of Nipmuck Indians, the Elnu Abenaki tribe and the Nolumbeka Project are active participants in the relicensing of these projects and have expressed concern that flows of 500 cfs will expose the riverbeds and so also expose artifacts in the riverbed. Using photos taken from the Boating Navigability Study, it is clear that both Rawson Island and Peskeomskut Island remain accessible by foot at the proposed minimum flow. The following two photos are taken from the Applicant's Boating Navigability Study depicting Flow #3, which released a total of 545 cfs from the dam.¹⁴



¹² Shutesbury Historical Commission, *Introduction to Indigenous Cultural Sites in Shutesbury, Massachusetts* at 19 (Mar. 2021), available at https://www.shutesbury.org/sites/default/files/offices_committees/historical/Introduction%20to%20Indigenous%20Cultural%20Sites%20in%20Shutesbury.pdf.

¹³ United States Department of the Interior. 2008. "National Register of Historic Places Determination of Eligibility Comment Sheet: The Turners Falls Sacred Ceremonial Hill Site (Formerly, the Airport Improvement Project-Turners Falls Municipal Airport) Franklin County, Massachusetts."

¹⁴ Boating Navigability Study Report Turners Falls Hydroelectric Project (No. 1889) (December 2021).

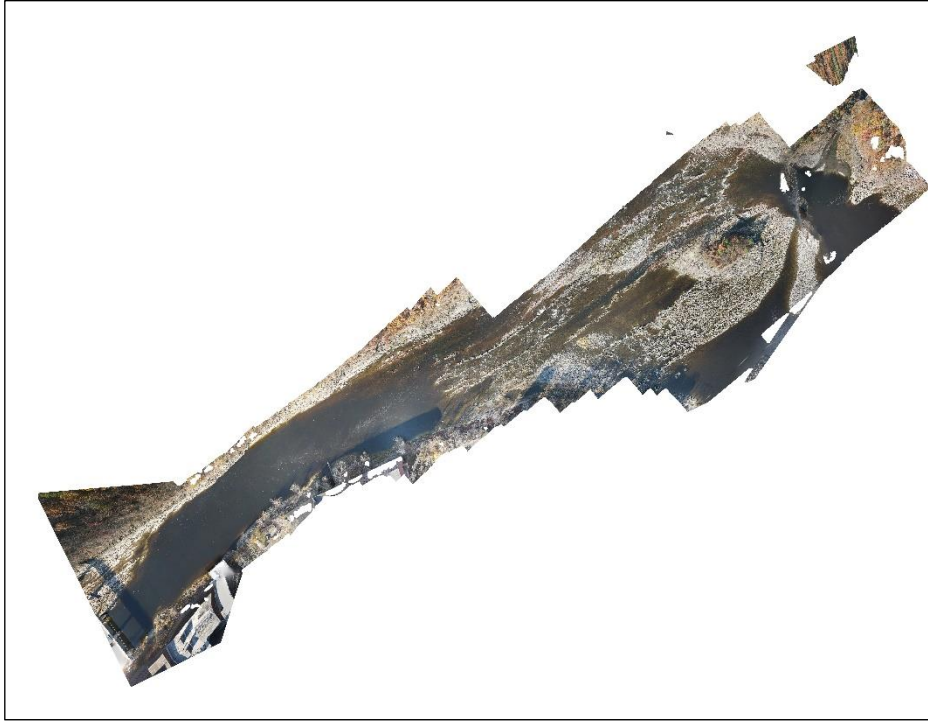


Photo 3-05: Peskeomskut Island – Left Channel – North View

The two photos below, also taken at the flow of 545 cfs, provide an aerial view of the exposed riverbed at this flow. Maintaining water levels in the bypass that impede foot access to the riverbed is critical to protecting these artifacts and cultural resources. Through this comment, CRC would like to support the concerns expressed by Chaubunagungamaug Band of Nipmuck Indians, the Elnu Abenaki tribe and the Nolumbeka Project.¹⁵



¹⁵ Comment Filed By: The Nolumbeka Project, Inc on 5/25/2023



Finally, in consultation with the Nolumbeka Project, it is CRC's understanding that a return to flows of a minimum of 1,600 cfs would allow for flows that would restore some amount of traditional fishing opportunity and ceremony for indigenous groups below the dam. CRC has not participated in negotiations related to culture resources, rather, through this comment, we support the concerns and priorities raised by participants representing cultural interests, who have indicated that a minimum flow of 1,600 cfs below the Turners Falls Dam is necessary to protect cultural resources in this area.¹⁶

CRC Notes a Discrepancy on page A-1 of Article A110

The table under Article A110, Minimum Flows below Turners Falls Dam, proposes minimum flows from April 1 – May 31 as 67% of the naturally routed flow (NRF) if the NRF is equal to or less than 6,500 cfs; this results in proposed flows of 4,355 cfs. When the NRF exceeds 6,500 cfs, the minimum flow is proposed to be 4,290 cfs. There is no explanation as to why there is a decrease in minimum flows when the NRF exceeds 6,500 cfs.

Article A120. Total Minimum Bypass Flows below Station No. 1

If the units used to maintain minimum flows from Station No. 1 become inoperable, the Applicant proposes to maintain the flow below Station No. 1 from the Turners Falls Dam Minimum Flow (dam or canal gate), Fall River, Turners Falls Hydro, LLC or Milton Hilton, LLC. There are three issues with this proposed condition. The first is that Fall River joins with Connecticut River below the Turners Falls Dam and is not a source of flow that the Applicant can justifiably consider in its

¹⁶ Comment Filed By: The Nolumbeka Project, Inc on 5/25/2023

project minimum flow requirements. Second, in the Applicant's May 11, 2023, Response to FERC Additional Information Requests (Response to AIR), the applicant acknowledges that there is no agreement between the applicant and Turners Falls Hydro, LLC or Milton Hilton, LLC to release minimum flows from these sources. Since no agreement exists, this cannot be considered a viable option in a final license article. Third, the Applicant also acknowledges in the Response to AIR that it has no way to quantify flow from Fall River (which does not have a stream gage) nor either entity on the power canal, and so it has no way to know if these sources will meet the requirements for minimum flow below Station No. 1. Therefore, the Turners Falls Dam is the only viable backup to maintain flows below Station No.1. Accordingly, if Station No. 1 becomes inoperable, minimum bypass flows below Station No.1 must be calculated from the discharge from Turners Falls and not from Fall River, Turners Falls Hydro, LLC or Milton Hilton, LLC. The language in the article also states that the flows would come from the "Turners Falls Dam Minimum Flow," and it should simply read "Turners Falls Dam."

This condition is also included in Article A150, and CRC raises the same objects as stated above.

Article A150. Variable Releases from Turners Falls Dam and Variable Flow below Station No. 1

Variable releases described in Article A150 will enhance the experience of recreational boaters visiting the river. Footnote 2 under both *Variable Releases from Turners Falls Dam* and *Variable Flow Below Station No. 1* includes a list of stakeholders to be included in an annual meeting to determine the schedule for variable releases. CRC is the primary advocate for the Connecticut River watershed and the only NGO with a focus on increasing access to and stewarding the entire Connecticut River watershed. CRC regularly hosts public events on and along the river, as well as an annual volunteer day to rescue juvenile lamprey stranded in the power canal when it is dewatered for maintenance. We communicate with thousands of river users each year, relaying important information about river conditions. Therefore, it is critical that CRC be included in these scheduling meetings, and we request Article A150 be amended to include CRC under both footnotes, as well as the notification list for any temporary modifications described in the final paragraphs of this section.

Article A210. Flow Notification and Website

Provisions to report hourly data will increase the ability of boaters and visitors to the river to prepare for various flow conditions. Today, websites are a primary means of disseminating information, but this may not be the case throughout the life of the license. For example, previous documents for public comment have been made available to the public in hard copy at the Northfield Mountain Visitor's Center; such availability of a hard copy may be useful to an extent, but not nearly as accessible as online editions. As the Applicant has transitioned to making documents more easily accessible online, we may also expect that website access may decline in usefulness and accessibility over the life of the license. Language should be altered to reflect this uncertainty and include provisions to provide information on the website or the most used form of communication at the time. Likewise, Article A210 should be modified to require this information,

and other educational and safety information, to be available in languages spoken predominantly in the region. This is in accordance with FEMA *Dam Safety Warning Signs Best Practices*.¹⁷

Article A190. Turners Falls Impoundment Water Level Management and Article B100. Project Operations

In Article A190 the Applicant proposes to maintain the existing Turners Falls Impoundment (“TFI”) elevation range (measured at the dam) while, under Article B100, proposes to expand use of the upper reservoir. As discussed below, under the current TFI range, the Applicant’s operations have resulted in TFI fluctuations which exacerbated erosion. When the Applicant pumps water up Northfield Mountain and lowers the TFI to its lower allowable limit, this also results in stranded boats in Barton Cove. With the proposed expanded use of the upper reservoir, CRC anticipates that the Applicant would be able to increase the volume of water being withdrawn and returned to the TFI and increase the frequency that the Applicant uses the full extent of the TFI elevation range. The proposed operating range for the upper reservoir would induce further erosion along the TFI streambanks and so do not uphold the obligation of the Applicant and of FERC to avoid and minimize impacts on the Connecticut River ecosystem. Therefore, CRC opposes conditions under Article B100, specifically the Applicant’s provision to operate the Northfield Mountain Project between elevation 1004.5 and 920 feet NGVD29.

In the explanatory statement a. Article B100. Project Operations, the Applicant states that it intends to increase usable storage of the Northfield Mountain Project upper reservoir and that this increase will have, “no adverse environmental effects.” This conclusion is predicated on the results of BSTEM erosion modelling conducted in Relicensing Study 3.1.2 (Study 3.2.1) and the 2022 Supplemental BSTEM Modelling Report (the Report). Following the release of Study 3.2.1, CRC contracted with Princeton Hydro to conduct a peer review of this study, which found that the Applicant’s analysis overlooked several critical factors that contribute to streambank erosion. In particular, the peer review found that the study failed to consider the cyclical nature of streambank erosion and the relationship between hydraulic erosion at the toe of the bank and the resulting geotechnical failure, initiating a cycle of erosion along the streambanks of the impoundment. BSTEM analysis also failed to include how geotechnical conditions along the streambank would be altered if permanent vegetation was established on the bank. In addition to flaws with the BSTEM analysis, the peer review found that the analysis included data gaps (failure to include entire reaches of streambank) and that the extrapolation methodology included arbitrary thresholds that potentially bias the study. This peer review is attached to CRC’s comments, see Attachment C.

Since the Relicensing Study 3.1.2, the Applicant has released supplemental BSTEM modelling reports intended to model existing and future operations but carried forward the flaws of the earlier Study 3.1.2; the reports continue to neglect basic principles of the erosion process. The reports also modeled proposed conditions under the Fisheries and Flow Agreement in Principle, which are included in the Offer. The reports use modeled conditions to determine the difference between current and future impacts of expanded upper reservoir use on streambank erosion. However, the

¹⁷ Fed. Emergency Mgmt. Agency P-2188, *Dam Safety Warning Signs Best Practices: Prompting Public Awareness and Preventing Loss of Life* at 14-16 (Sept. 2021), available at [://www.fema.gov/sites/default/files/documents/fema_p-2188-dam-safety-warning-signs-best-practices.pdf](https://www.fema.gov/sites/default/files/documents/fema_p-2188-dam-safety-warning-signs-best-practices.pdf).

reports solely draw on modeled conditions and not actual conditions, meaning that the baseline scenario used in the reports are not representative of real conditions. Finally, the BSTEM report provided by the Applicant in the AIR does not sufficiently describe how proposed operations will impact fluctuation in the TFI. As a result, the collective Reports fail to include any analysis of existing impacts from the Northfield Mountain Project and nullifies comparisons between the report and Study 3.1.2.

Further, a 1991 Army Corps of Engineers Study found that while shear stress contributes to erosion in the TFI, “the larger [Turners Falls] pool fluctuations and flow reversals caused by the present hydropower operation all contribute to the documented bank instabilities. It was noted that pool fluctuations, on the order of 5 feet, as experienced in the Turners Falls pool, are at least twice as destructive to banks as 1 to 3 foot fluctuations in other hydropower pools studied.”¹⁸ As a result of this study and the ongoing erosions issues in the TFI, the previous owners of the Northfield Mountain Project, as well as the Applicant, undertook streambank restoration efforts, most of which did not successfully withstand the continued erosive forces in the TFI; please see the comments of Michael Bathory and Maryanne Gallagher for further details on these efforts.¹⁹ FERC has previously required the licensee to monitor, mitigate and repair areas of substantial erosion. At a minimum, these provisions must be carried forward into a new license.

The Applicant concludes in the Explanatory Statement (page 16) that, “the dominant causes of erosion would continue to be natural high flows at most locations and boat waves in the Barton Cove area.” This conclusion, based on the results of Study 3.1.2 and the Report, is conditioned upon incomplete analysis and flawed methodology. The Applicant’s assertion that boat wake is responsible for erosion speaks to its further culpability in intensifying the cycle of erosion, as it is the Turners Falls Dam and the increase in the TFI elevation for Northfield Mountain that create the conditions for motorboating in Barton Cove.

As CRC has noted on several occasions, the sections of the Connecticut River that make up the TFI are impaired Class B waters under CWA § 303(d), in part due to flow regime modification and streambank modification. Given the role the Northfield Mountain Project plays in eroding streambanks in the TFI, the proposed conditions for the expanding operating range are not justified. The operating regime of the last 50 years has allowed time for the streambank along TFI and Connecticut River to adjust, to some extent, to current operating conditions. An increase in this range to 1004.5 and 920 feet NGVD29 would instigate a new round of erosion along streambanks, bringing with it disastrous impacts for the ecosystem and local landowners along the river.

Under existing license conditions, the elevation range in which the Applicant manages the TFI leads to drawdowns that dewater Barton Cove and prevent boaters and anglers from accessing the river.

¹⁸ U.S. Army Corps of Engineers, New England Division (Corps). 1991. General Investigation Study, Connecticut River Streambank Erosion: Connecticut River - Turners Falls Dam to State Line, MA. July 1991.

¹⁹ Comments of Michael Bathory, et al. re FirstLight Hydro Generating Company's Relicensing Application for the Northfield Mountain Pumped Storage Project under P-2485. Filing Description for Accession Number 20230504-5022. https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20230504-5022&optimized=false

On several occasions between June 1, and August 31, 2007, Barton Cove was drained “down to mud” and the public boat ramp was inaccessible due to low water levels. CRC received numerous public concerns about the low water levels and contacted FERC and the Applicant about the TFI conditions leading to this lower water elevation in the cove. In response, the Applicant confirmed that they were operating in compliance with the license obligations to maintain water surface elevation between 176.0 - 185.0 feet and that the TFI never went below 177.5 NVGD.²⁰ Again, in June of 2021, the Applicant drew down the TFI within its licensed range, stranding boats in Barton Cove and inhibiting recreation on the river.^{21,22} With the proposed expanded use of the upper reservoir, CRC anticipates that fluctuations in TFI elevation could become more frequent and use the allowable elevation range more fully than the Applicant has in the past; CRC is concerned that this would lead to a decrease in public access and recreation in the TFI.

CRC opposes the Applicant’s proposed expansion of the upper reservoir due to the impact these increases will have in instigating further erosion and reducing public access to the Connecticut River due to excessive drawdowns in the TFI.

Article A300. Fish Passage Facilities and Consultation

CRC opposes the unnecessarily long timeframes proposed for the installation of upstream and downstream fish passage under Articles A300. Both upstream and downstream facilities will enhance the ability of migratory species to migrate throughout this portion of the Connecticut River, replacing the outdated and ineffective technologies that have created long-standing issues for migratory fish.²³ However, the Applicant has not sufficiently justified the timeframes proposed to construct these facilities nor the sequencing of prioritization of downstream facility construction before upstream facility construction. The Applicant’s explanatory statement indicates that prioritizations of downstream facilities is aligned with the Connecticut River American Shad Management Plan; however, the plan does not include a stated preference for downstream prioritization and so cannot be used as justification for the proposed sequencing. *See* attached Affidavit of Edwin T. Zapel (hereinafter “Zapel Affidavit”), ¶ 4, Attachment D.

Additionally, the Applicant fails to justify why construction of both upstream and downstream fish passage cannot happen simultaneously. *See* Zapel Affidavit, ¶ 6.

The Offer acknowledges that improved fish passage is necessary to enhance shad passage and that, for the last 50 years, migratory fish populations have been prevented from reaching spawning

²⁰ FirstLight Hydro Generating Co. Response to Letter of Sept. 6, 2007 from FERC Staff Regarding “Complaint on the Operation of the Northfield Mountain PS Project” (P-2485) at 1, (filed Sept. 27, 2007) *available at* https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20071001-0084&optimized=false.

²¹ FERC Alleged Noncompliance Response (P-1889-094) – Massachusetts/New Hampshire/Vermont Turners Falls Hydroelectric Project June 13, 2021 Low Impoundment Levels at 1 (filed June 23, 2021), *available at* https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20210623-5086&optimized=false.

²² Low water levels for parts of Connecticut River in Franklin County, WWLP (June 15, 2021) <https://www.wwlp.com/news/local-news/franklin-county/low-water-levels-for-parts-of-connecticut-river-in-franklin-county/> (last visited May 23, 2023).

²³ Connecticut River Atlantic Salmon Commission, *Connecticut River American Shad Management Plan, Addendum – Fish Passage Performance* at 1–2 (Feb. 28, 2020), *available at* https://www.fws.gov/sites/default/files/documents/CRASC-Shad-Plan-and-Addendum-3_2_2020.pdf

habitat above the Turners Falls Dam due to the deficiencies of existing infrastructure. The inadequacy of the existing fish passage not only limits the mobility of migrating species, but also contributes to fish mortalities. Article A300 proposes to continue these conditions for 5-9 years after license issuance, at which point the Applicant will already have been operating under license conditions 5+ years expired. Simultaneous construction of upstream and downstream fish passage facilities is necessary to expeditiously restore shad populations that have been adversely impacted by antiquated infrastructure.

If sequencing were necessary for the fish passage construction, upstream passage would provide far greater benefit to American Shad by at least three orders of magnitude. Passing shad above Turners Falls Dam allows the species to recolonize habitat above the dam, which is not being fully used under current conditions. Shad reproduce readily and can rapidly colonize a new available habitat, meaning that an increase in spawning habitat above Turners Falls Dam will provide greater opportunity for successful reproduction. Upstream survival and spawning will increase the number of shad out-migrating, regardless of downstream survival rates, whereas downstream improvements will only serve to improve survival for the current population able to successfully pass Turners Falls Dam and spawn. *See* Zapel Affidavit, ¶¶ 6–8. The proposed timelines and construction sequencing in Article A300 are not grounded in the biology and behavior patterns of the shad population and the Offer lacks substantial evidence to justify the prioritization of downstream fish passage. *See id.* ¶ 21.

(a) CRC opposes the timeline for the Spillway Lift at Turners Falls Dam, which is proposed to be operational by Year 9. The proposed fish lift is modeled on existing infrastructure and the Applicant is not proposing a novel or emerging technology that will take a burdensome amount of time to design and construct. Design and construction of the Spillway Lift, which is similar to fish lifts in other river systems, could be completed within a much shorter time period, as few as 4 to 6.5 years. *See* Zapel Affidavit, ¶¶ 10–11, 20.

(b) CRC opposes the timeline for rehabilitation of the Gatehouse Trapping Facility, which is proposed to be operational by Year 9. No new structures are proposed to be installed and the Applicant does not provide substantial evidence or otherwise justify the excessive length of time to complete this activity, given that the majority of the work will be to upgrade existing infrastructure. *See* Zapel Affidavit, ¶ 12.

(f)(g) CRC opposes the timeline for rehabilitation of the Cabot Station trashrack structure, which is proposed to be operational by Year 4. In similar projects that include replacing and upgrading an existing trashrack, design and implementation took approximately one year. With additional agency input into design, the process may take longer. However, the applicant fails to justify why the design and installation would take longer than three years. *See* Zapel Affidavit, ¶ 15. Similarly, CRC opposes the timeline for rehabilitation of the Station No. 1 bar rack, which is proposed to be operational by Year 4. As with the Cabot Station trashrack, the Applicant has not provided substantial evidence that design and implementation should take four years. *See* Zapel Affidavit, ¶ 16.

(h) CRC opposes the timeline for the Turners Falls Dam plunge pool, which is proposed to be operational by Year 9. The plunge pool construction is proposed to be done in conjunction with the fish lift. As previously described, the timeline for fish lift is not supported by substantial evidence or

otherwise justified and therefore the plunge pool construction can likewise be completed on a much faster timeline. *See* Zapel Affidavit ¶17.

Article A310. Schedule of Initial Effectiveness Testing, Consultation Process on Effectiveness Testing Study Plans, and Fish Passage Performance Goals and Article A320. Downstream Fish Passage- Initial Effectiveness Studies, Adaptive Management Measures and Subsequent Effectiveness Studies

CRC's comments on Article A310, A320 and A330 refer to the proposed Years for Adaptive Management Measures "(AMM)" as described in the Offer. However, as discussed above, since the proposed timelines for fish passage construction are unnecessarily long, the timelines for AMMs should be adjusted accordingly.

Depending on the quarter in which the final license is issued, the Applicant proposes to conduct a shakedown year for the Station No. 1 rack and Cabot Rack either in Year 4 or Year 5 after License issuance. For all other fish passage construction projects, the Applicant proposes to complete installation and the shakedown year within the same year or season; this should also be the case for the Station No. 1 rack and Cabot Rack.

Initial effectiveness studies to evaluate the Station No. 1 rack and Cabot Rack are proposed to happen in Years 6 and 7 with final reports by February 1 of Years 7 and 8 for adult shad, and juvenile shad and adult eel, respectively. The Applicant does not explain why reporting will take longer for juvenile shad and adult eels and CRC disagrees that downstream passage reporting would reasonably take between 1-2 full years. Additionally, it is unclear why no AMM effectiveness testing is done in Year 9. Effectiveness testing could begin in the same year that the Round 1 AMMs are implemented; this applies to further rounds of effectiveness testing for AMMs in Years 12, 13 and 17.

For the Turners Falls Dam Plunge Pool, initial effectiveness testing is proposed in Year 10 – 11 and Round 1 AMM effectiveness testing is proposed in Years 14 and 15. Round 1 AMMs include modifying the bascule gate setting and resultant spill. Essentially, this includes increasing the minimum flow and the bascule gates from which flow is provided; this AMM can be implemented at any time without significant effort on the part of the Applicant, so it is unclear why this would not happen in Year 12 and 13.

Article A330. Upstream Fish Passage Initial Effectiveness Studies, Adaptive Management Measures and Subsequent Effectiveness Testing

For upstream fish passage, Tier 2 AMMs are proposed to be implemented in Years 15 and 16 with a shakedown year in Year 17. For most of the proposed fish passage measures, the shakedown year takes place within the same year of construction or modification. The Applicant does not justify the need for an additional year to implement Tier 2 AMMs. The Applicant proposes that all AMMs and reporting will be completed by Year 20 and that state and federal agencies may not proposed new AMMs until Year 25, creating a 5-year gap between the end of reporting and the beginning of any new possible AMMs. CRC strongly objects to this condition, as explained at the end of this section.

The Connecticut River Shad Management Plan sets the following upstream Fish Passage Performance Criteria for adult and juvenile shad for hydroelectric projects in the Connecticut River basin:

- Upstream adult passage minimum efficiency rate of 75%, based on the number of shad that approach within 1 kilometer of a project area
- Upstream adult passage time-to-pass (1 kilometer threshold) is 48 hours or less²⁴

The performance goals outlined in Article A310 comply with these objectives. However, under Article A330, the Applicant proposes that after Tier 1 and Tier 2 AMMs have been implemented, if the performance goal of 75% passage within 48 hours is still unmet, but fish passage efficiency is only 65% within 60 hours, the regulatory agencies forfeit any reserved or regulatory authority to require any further fish passage measures or operational changes. This proposed condition disregards the objectives defined in the Connecticut River Shad Management Plan, which are grounded in the most recently available science related to shad migration in the Connecticut River. The management plan is supported by “... advances on shad population status and dynamics, physiology and energetics, reproduction, movement/behavior, fishway use/passage, fishway design/modification, and both fishway and facility operation and flow management.”²⁵ Clearly, the objectives laid out in the management plan are derived from a scientific perspective, yet the Applicant provides no ecological or scientific justification for lowering overall passage efficiency to 65% within 60 hours. If the Applicant cannot meet the performance targets outlined in Article A310, then the Applicant must be required to include additional AMMs that incorporate advances in technology or change its operations to meet the proposed fish passage goals of passage minimum efficiency of 75% within 48 hours.

CRC strongly opposes the condition under Article A320 and A330 that resource agencies are not permitted to exercise their reserved or regulatory authority regarding downstream and upstream passage in the first 25 years of the license. Massachusetts Division of Fisheries and Wildlife (“MDFW”), National Marine Fisheries Service (“NMFS”) and U.S. Fish and Wildlife Service (“USFWS”) have an obligation to protect the natural resources in the Connecticut River. As new technologies evolve and data become available from effectiveness testing, these agencies must have the ability to draw on their regulatory authority to ensure that the Applicant is meeting necessary criteria to enhance and protect species in the Connecticut River.

Article A350. Fish Passage Facilities Operation and Maintenance Plan

Article A350 describes the implementation of a Facilities Operations and Maintenance Plan (FOMP), which will include details of fish operations and maintenance activities. This will include an annual report submitted to resource agencies and will be drafted in consultation with these agencies. CRC is the sole and primary NGO advocating for the continued conservation and restoration of the entire Connecticut River watershed. As a part of this work, we run numerous programs, in coordination with the U.S. Fish and Wildlife Service and state agencies, to collect data on migratory

²⁴ Connecticut River Atlantic Salmon Commission, *Connecticut River American Shad Management Plan, Addendum – Fish Passage Performance* at 1–2 (Feb. 28, 2020), available at https://www.fws.gov/sites/default/files/documents/CRASC-Shad-Plan-and-Addendum-3_2_2020.pdf.

²⁵ Connecticut River Atlantic Salmon Commission, *Connecticut River American Shad Management Plan*, at 3.

fish species in the river. Our programs to monitor fish species and restore their habitat are done in coordination with hydropower operators throughout the watershed, including Holyoke Gas & Electric, where we hold a seat on the cooperative consultation team (CCT). We request that Article A350 be amended to include CRC in these processes and communications.

Article A400. Bald Eagle Protection Plan

CRC supports the measures included in the Bald Eagle Protection Plan, but we do not believe these measures adequately protect the species. The dams create pond-like conditions in the impoundment, which are well suited for the proliferation of invasive aquatic plants.²⁶ In the TFI, a particular concern to the survival of bald eagles is *Hydrilla verticillata* (hydrilla), which is an invasive plant that forms dense stands that crowd out natural vegetation, alter the chemistry of the water²⁷ and are proven to host a cyanobacterial neurotoxin that is deadly to bald eagles. A study of mass mortality of bald eagles in the southeast United States found that hydrilla and treatment of hydrilla are the causes for these mass bald eagle mortalities and that increased awareness and monitoring should be implemented.²⁸ Hydrilla, first found in the lower Connecticut River watershed in 2016, has spread rapidly throughout the lower watershed, now covering well over 700 acres of the Connecticut River watershed.²⁹ While hydrilla has not yet been observed in the Connecticut River north of Agawam, its transport mechanisms (fragmentation, transport via boat/trailers) indicate that it is likely to travel readily throughout the watershed unless more aggressive monitoring and prevention is undertaken. The Applicant, in its operation of Turners Falls Dam, maintains conditions that are extremely conducive to the proliferation of hydrilla in the TFI. Specifically, the pond-like conditions created by the Turners Falls Dam, paired with increased motorboat access because of these conditions, make the TFI a likely location for the introduction of hydrilla. Due to the conditions maintained by Turners Falls Dam and the potential impact of toxins on bald eagles, the proposed bald eagle protection plan does not sufficiently account for the known threats to the health of the population in the Connecticut River corridor.

Article B200. Fish Intake Protection and Consultation

Article B200 indicates that the intake barrier net will be in place from June 1 – November 15. Initially, the Amended Final License Application proposed a shorter installation period of August – November due to concerns about the impact of the Northfield Mountain Project's operation on out-migrating fish species. Article A340 indicates that the Applicant will operate downstream passage from April 4 – November 15; the installation of the barrier net should be expanded to match the stated out-migration period under A340. There is no explanation of why it should be limited to the proposed timeframe.

²⁶ Johnson, P.T., Olden, J.D. and Vander Zanden, M.J. (2008), Dam invaders: impoundments facilitate biological invasions into freshwaters. *Frontiers in Ecology and the Environment*, 6: 357-363. <https://doi.org/10.1890/070156>

²⁷ <https://www.nae.usace.army.mil/Missions/Projects-Topics/Connecticut-River-Hydrilla/>

²⁸ Steffen Breinlinger et al. (2021). Hunting the eagle killer: A cyanobacterial neurotoxin causes vacuolar myelinopathy. *Science*, 371: 1-7. <https://www.science.org/doi/10.1126/science.aax9050>.

²⁹ Hydrilla in the CT River Watershed, .

Additionally, CRC opposes the timeline for the installation of the Northfield Mountain Project intake barrier net, which is proposed to be operational by Year 7. While CRC is concerned about the shortcomings of the barrier net, described in our comments below, it will provide some relief to species out-migrating past the Northfield Mountain Project intake. However, the proposed timeframe is unjustified and far too long, meaning that benefits to the species of concern will not be felt for nearly a decade. At a pumped storage facility in Michigan (P-2680), a recent FERC license required the replacement of part of the barrier net, totaling over 4,000 linear feet of barrier net. The barrier net at Ludington (P-2680) is far larger than the proposed net at the Northfield Mountain Project (roughly 1,000 ft). While the Northfield barrier net will need to undergo design specific to the facility, the installation of the Ludington panels within the first year of the license demonstrates the feasibility of installing the barrier net long before year 7 of the license. Likewise, very large barrier nets at the Shannon-Lower Banker Lake hydropower facility in NW Washington State were designed and installed within three years of license issuance, even though those nets were much deeper and the reservoir experiences much more significant water level variations than at the Northfield Mountain Project. *See* Zapel Affidavit, ¶ 19. If design begins upon license issuance, it can be completed within a year and installed in the following two years, as has been done at facilities with greater water level fluctuation. *See id.* ¶¶ 19, 23.

The results of the 2016 Relicensing Study 3.3.20, which were updated in the 2017 Addendum to reflect the impact of potential expanded operations, indicate that annual operations of the Northfield Mountain Project operations will result in the entrainment of 1,296 juvenile shad, 175 adult shad, 3 million shad eggs and 500,000 shad larvae (the mortality of shad larvae and eggs are not updated from the 2016 study).³⁰ The Applicant acknowledges the premature mortality its facility inflicts on the local shad and fish populations but does little to prevent and mitigate this impact.

The Applicant field tested several 2 x 2 ft. net panels in 2018 to investigate the amount of “debris loading and biofouling,” at three different depths, that may clog up the open spaces in the net.³¹ These nets were deployed between August 1 and November 15, which is the original proposed season; the Applicant now proposes to extend the net installation from June 1 to November 15, which is a duration that has not been tested. Different sets of screens were pulled at different time intervals and lab-tested for drag. The report from Alden Labs (2019)³² indicated that drag increased at the top of the screen the longer the screen had been in the water. Alden also modeled the velocities at the net (a concern for impingement of fish) but used Connecticut River flows of 5,000 cfs called “low” in the study; 30,000 cfs called “medium”; and 50,000 cfs called “high.” The Pre-Application Document (PAD) demonstrated that between the months of June and November, in most of these months, 30,000 cfs and 50,000 cfs are so high that they are not even on the flow duration curves and are not representative of typical conditions. (see Figures 4.3.1.2-19 to -21 in the

³⁰ Ichthyoplankton Entrainment Assessment at the Northfield Mountain Pumped Storage Project Addendum 1 (July 2017).

³¹ Northfield Mountain Generation Station CFD Modeling for Fish Exclusion Net Forces Alden Report No. : 1175QNorthfieldNet (January 2018)

³² Northfield Mountain Generation Station (FERC No. 2485), CFD Modeling for Fish Exclusion Net Forces Alden Report No. : 3184NMPSBN (June 2019)

PAD).³³ Moreover, the water elevation for the 5,000 cfs flow was modeled at 179 ft. and 181.4 ft. at the Northfield Mountain tailrace, an elevation that is exceeded at least 95% of the time according to PAD Figures 4.3.1.3-13 through -18.³⁴ Therefore, the barrier net study never modeled any flow and elevation conditions that actually represent conditions for the time of year the net will be deployed. It is unclear if fish will be impinged against the net during pumping operations, then spit back out during generation operations. It's unclear how long the net will withstand field conditions, and how holes in the net would ever be found and fixed mid-season.

For this reason, it is critical that the barrier net be accompanied by AMMs that include alternatives to the barrier net as the sole mechanism to prevent fish entrainment.

Article B210. Initial Intake Protection Effectiveness Testing and Fish Passage Performance Goals

The Applicant proposes to install the Northfield Mountain Project barrier net in June of Year 7, which would include a shakedown year, with initial effectiveness testing in Year 10 and Year 11. The Applicant does not include an explanation for the two-year gap between the shakedown year and the beginning of effectiveness testing; this testing should begin the season immediately following the shakedown year.

Article B220. Downstream Fish Passage- Initial Effectiveness Studies, Adaptive Management Measures and Subsequent Effectiveness Studies

For Article B220, CRC refers to the Years for AMM implementation as described in the Offer; however, given the unnecessarily long timeframe proposed for fish passage installation, the AMMs should likewise be modified accordingly. Article B210 indicates that reporting on initial effectiveness testing will be complete by April of Year 12, yet Round 1 AMMs are not implemented until Year 14. The proposed AMMs include altering the arrangement and size of the net panels and modifying maintenance practices; these changes do not merit the proposed gap between initial effectiveness testing and Round 1 AMMs.

The AMMs described in license Article B220 propose very little in the case that the performance targets in Article B120 are unmet. The two AMMs noted in the Offer are to alter the arrangement and size of net panels and improve maintenance measures for the net. Barrier nets for pump storage hydropower have been in use for decades, offering examples of operating and maintenance procedures.³⁵ The AMMs defined in the Offer are activities that should be integrated into the Fish Passage Facilities Operation and Maintenance Plan (FOMP) for the barrier net, as described in Article B240 and are not sufficient as stand-alone AMMs.

³³ Pre-Application Document For The Turners Falls Hydroelectric Project (No. 1889) and Northfield Mountain Pumped Storage Project (No. 2485) (October 30, 2012).

³⁴ Pre-Application Document For The Turners Falls Hydroelectric Project (No. 1889) and Northfield Mountain Pumped Storage Project (No. 2485) (October 30, 2012).

³⁵ Ludington Pumped Storage Project Fish and Aquatic Resources Study Phase 2 Report Evaluation of Entrainment Abatement at Sections 4.2 – 4.3. <https://www.consumersenergy.com/-/media/CE/Documents/company/ludington/ludington-pumped-storage-project-initial-study-report-12-02-2015.ashx>

Additional AMMs are necessary in the final license articles. Downstream AMMs proposed in Article A320 include additional behavior barriers and it is not clear why these would not be implemented at the Northfield Mountain Project intake. At other pumped-storage projects, FERC has approved requirements to conduct a periodic study of developing technologies to reduce fish mortality. The recent Ludington Pumped Storage Project (P-2680) Final License Application includes such a requirement: “The Licensees will conduct a review of fish entrainment abatement technologies every 5 years throughout the course of the new license. The first review will be conducted 5 years after the new license is issued. The goal of this review will be to determine if any technologies are technically and economically practicable for use... either in conjunction with or in lieu of the barrier net to substantively reduce fish entrainment relative to the existing barrier net program.”³⁶

A final license should include the addition of AMMs to routinely study alternative technologies to improve fish survival, as well as studies that examine the possible use of multi-technology behavior systems to reduce entrainment and impingement. CRC is particularly concerned about the continued high rate of entrainment for eggs and larvae at the Northfield Mountain Project and AMMs should include a review of aquatic microfiltration barrier systems, or other emergent technologies, which have shown to be effective in specifically protecting eggs and larvae from entrainment.³⁷ The Applicant should also be responsible for the costs of these studies, a requirement FERC has included for other pumped storage facilities.³⁸ Finally, studies to examine technologies should also include a feasibility study of a closed loop system. Such a study was omitted in pre-licensing studies but is the most certain way to prevent not only fish impingement and entrainment, but to also eliminate the erosion caused by NFM’s operations.

Ultimately, if the Applicant cannot meet agreed upon performance target within five years of operating the barrier net, it is necessary and justifiable to require pumping restrictions or operational changes until the Applicant can meet these targets. Such adaptive management precedent exists the case of North Umpqua Hydroelectric Project (FERC No. 1927) 401 water quality certificate which stipulates adaptive measures “... to investigate, and based upon such investigation, propose options for modification to facilities or Pumped Storage Project operations to prevent any violation of water quality standards.”³⁹ Reduced pumping during the season in which fish migrate past the Northfield Mountain Project intake would be expected to reduce entrainment. The Applicant has an obligation to first avoid harmful impacts to the ecosystem and operational changes are the most effective means currently available to the Applicant to meet this obligation.

To mitigate mortalities caused by the Northfield Mountain Project’s operations, the Applicant has proposed an off-license Ichthyoplankton Mitigation Fund of \$1,296,281 over the span of 50 years. This sum, over the proposed span of the license does little to account for the biodiversity loss due to entrainment at the Project site. In P-2680 by contrast, annual funding for mitigation fund for fish loss at Ludington is estimated to be \$2,722,000. The proposed sum of under \$1.3 million total over

³⁶ <https://www.consumersenergy.com/-/media/CE/Documents/company/ludington/ludington-final-license-application.ashx>, at E-4-60–61.

³⁷ See generally <https://www3.epa.gov/region1/npdes/merrimackstation/pdfs/ar/AR-257.pdf>.

³⁸ <https://www.consumersenergy.com/-/media/CE/Documents/company/ludington/ludington-service-agreement.ashx> at Exhibit 1 page 8-9.

³⁹ <https://www.oregon.gov/deq/wq/Documents/NUHPFishCreek401mod.pdf>, at 3.

50 years is not a justifiable cap and should be based on the actual and full costs of specific mitigation activities.

Finally, CRC again strongly opposes the condition under Article B220 that resource agencies are not permitted to exercise their reserved or regulatory authority regarding passage within the first 25 years of the license. We further object to the condition that agencies are not required to request or require pumping restrictions at any time over the life of the license. If the Applicant cannot, under proposed operations, sufficiently reduce fish mortality to achieve the performance targets of Article B120, then the Applicant must modify operations until it can sufficiently satisfy these goals. The federal and state agencies that oversee the protection and restoration of fish species in the Connecticut River must have the freedom to impose further measures to reach these performance targets if necessary to protect that public trust.

Invasive Species

The Offer includes no mention of the Applicant's responsibility to monitor and control invasive species in the Turners Falls Project Boundary. As stated above in our comments, the conditions created by Turners Falls Dam create slow-moving waters that promote the growth and spread of aquatic invasive species.⁴⁰ In turn the presence of these species leads to impairments of the Connecticut River in the TFI. Segment 34-02 (segment between Rout 10 bridge and Turners Falls Dam, excluding Barton Cove) and segment MA34122 (Barton Cove) are both impaired, in part due to aquatic invasive plants including curly-leaf pondweed, Eurasian water milfoil, fanwort and water chestnut. Relicensing Study 3.5.1 includes results of surveys conducted of native and invasive Submerged Aquatic Vegetation (SAV). The report found that, "... 41 of the mapped 107 SAV beds had some level of infestation by exotic species, which accounts for 38% of the SAV beds. The majority of the exotic species occur immediately upstream of the Turners Falls Dam with fewer occurrences upstream of the French King Bridge." Table 4.1-2 from this study lists the aquatic invasive species identified in the survey, making clear the abundance of invasive plants in the TFI. If left unchecked, these invasive plants have the potential to spread rapidly throughout the TFI and greater Connecticut River watershed, limiting recreational opportunity, degrading water quality and supplanting native species and habitat, thereby contributing to biodiversity loss.

⁴⁰ Johnson, P.T., Olden, J.D. and Vander Zanden, M.J. (2008), Dam invaders: impoundments facilitate biological invasions into freshwaters. *Frontiers in Ecology and the Environment*, 6: 357-363. <https://doi.org/10.1890/070156>

Table 4.1-2: Wetland and Aquatic Invasive Plant Species

Scientific Name	Common Name	Lifeform Type	Notes
<i>Cabomba caroliniana</i>	Carolina Fanwort	Aquatic herb	Chokes waterways
<i>Iris pseudacorus</i>	Yellow Iris	Perennial herb	Wetland habitats, primarily in flood plain areas, grows in full sun to full shade
<i>Lysimachia nummularia</i>	Creeping Jenny	Perennial herb	Problematic in flood plains forms dense mats
<i>Lythrum salicaria</i>	Purple Loosestrife	Perennial herb	Overtakes wetlands, high seed production
<i>Myriophyllum heterophyllum</i>	Variable water-milfoil	Aquatic herb	Chokes waterways, spreads by humans, boat traffic, and possibly birds
<i>Myriophyllum spicatum</i>	Eurasian water-milfoil	Aquatic herb	Chokes waterways, spreads by humans, boat traffic, and possibly birds
<i>Phalaris arundinacea</i>	Reed Canary Grass	Perennial grass	Forms dense stands
<i>Potamogeton crispus</i>	Curly Pondweed	Aquatic herb	Forms dense mats in the spring and persists vegetatively
<i>Trapa natans</i>	Water-chestnut	Aquatic herb	Forms dense floating mats on water

In its 2020 Amended Final License Application, the Applicant drafted an Invasive Plant Management Plan for the Turners Falls Project Boundary (Project Boundary), but this plan lacked any concrete monitoring and/or management conditions.

FERC has established that invasive species monitoring and removal as a requirement of hydropower licensing on the Connecticut River. Under Article 417(d) of the Holyoke Gas and Electric (HG&E) Settlement Agreement (P-2004), FERC approved requirements for HG&E to conduct invasive species monitoring; this was further revised in 2019⁴¹. Additionally, FERC required HG&E to contribute to the cost of water chestnut control in the project area in cooperation with state and federal agencies. Monitoring requirements under the license include, “(1) data from the previous two years of monitoring for invasive species; (2) invasive species maps that shall identify found populations of invasive species in relation to the project features as well as all the bordering wetlands and banks within the project boundary; (3) the total quantity of each invasive species found within the surveyed areas each year; (4) any control measures implemented; (5) the total quantity of each invasive species controlled or removed each year; (6) documentation of the annual meeting that occurred with the resource agencies; and (7) agency comments and recommendations on the monitoring results.”

Financial Assurances for Decommissioning and Removal

While this Offer is not a comprehensive settlement agreement and therefore does not include all license terms, CRC would be remiss if we did not mention the absence of any financial assurances for future decommissioning and removal of the Relicensing Projects. The Settling Parties are requesting a 50-year license term. As detailed above, CRC opposes such a lengthy term, and the Settling Parties have not provided substantial evidence to support it. Even if the license is issued for

⁴¹ Report of Holyoke Gas & Electric under P-2004. Revised Invasive Species Plan. Filing Description for Accession Number 20190614-5045. https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20190614-5045&optimized=false

a shorter period, it is likely that both Relicensing Projects will reach the end of their useful lives before the expiration of the licenses. Even a 40-year license term will put the Northfield Mountain Project close to a century old by the time its next license expires.

The presence of these facilities continues, and will continue, the impairments of several segments of the Connecticut River in Massachusetts and, upon the end of their operations, they must be removed to fully restore the Connecticut River to meet designated and existing uses and to comply with the Clean Water Act and Massachusetts water quality standards. Nearly 30 years ago, FERC announced that it had the authority to require financial assurances as part of its license.⁴² As FERC's policy contemplates, imposing financial assurances during relicensing, "would help assure that the funds are available to do the job when the time for decommissioning arrives, thereby avoiding the possibility that State or Federal taxpayers might, by default, be compelled to pay them because the licensee lacks the resources."⁴³

In 2021, FERC issued a Notice of Inquiry regarding Financial Assurance Measures for Hydroelectric Projects and solicited comments.⁴⁴ FERC received several comments from federal resource agencies, including USFWS and NMFS, two of the signatories to the Offer, that supported the idea of FERC requiring financial assurances to address decommissioning costs and removal of hydroelectric projects:

FWS: The Service also recommends that financial assurances address decommissioning costs, including the removal of project infrastructure and the restoration of habitat when a licensee or exemptee surrenders its license or otherwise voluntarily abandons a project. This would ensure projects that are abandoned do not pose a risk to the environment and would reduce the risk that taxpayers and ratepayers would have to pay to remove project infrastructure and restore habitat if a project is abandoned.⁴⁵

NMFS: NMFS supports FERC requiring financial assurances from licensees. Financial assurance from licensees should support mechanisms that promote environmental conservation, forward planning, flexibility in terms of types of hydroelectric projects, and equity for communities affected by or reliant on hydroelectric projects.⁴⁶

Because the Applicant maintains and operates the project and will benefit from these operations, it is the responsibility of the Applicant to take steps to decommission and remove its facilities when they reach the end of their useful life. Accordingly, the final license should include conditions for the Applicant to create a decommissioning plan and require financial assurances to ensure the ability of the Applicant to complete this work. CRC looks forward to future opportunities to comment

⁴² Project Decommissioning at Relicensing; Policy Statement, Federal Energy Regulatory Commission, 60 Fed. Reg. 339 (Jan. 4, 1995).

⁴³ 60 Fed. Reg. at 346.

⁴⁴ Financial Assurance Measures for Hydroelectric Projects, Federal Energy Regulatory Commission, 86 Fed. Reg. 7,081 (Jan. 26, 2021).

⁴⁵ FWS Comments in Response to FERC's Notice of Inquiry, at Answer to Question 1 (attached).

⁴⁶ NMFS Comments in Response to FERC's Notice of Inquiry, at 1–2 (attached) (describing hydroelectric projects that would have benefited from financial assurances: "If financial assurance mechanisms had been required by FERC to address fish passage and dam removals, then the environmental harm caused by these projects and others would have been mitigated").

further on the need and appropriateness of financial assurance conditions for the Relicensing Projects.

Attachments:

Attachment A Burgoff Affidavit

Attachment B Pugh Affidavit

Attachment C Princeton Hydro Peer-Review of Relicensing Study 3.1.2

Attachment D Zapel Affidavit

Attachment E U.S. Fish and Wildlife Service Comments on the Federal Energy Regulatory Commission's Notice of Inquiry on Financial Assurance Measures

Attachment F National Marine Fisheries Service Office Comments on Financial Assurance Mechanisms

Attachment A

**UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION**

FirstLight Hydro MA LLC

Northfield Mountain LLC

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Docket No. 1889-000

Docket No. 2485-000

**AFFIDAVIT OF JULIAN BURGOFF
ON BEHALF OF THE CONNECTICUT RIVER CONSERVANCY**

1. My name is Julian Burgoff. I received a Bachelor of Science degree with honors from UMass-Amherst in Natural Resources Conservation with a concentration in Fisheries Ecology and Conservation in 2021. I worked as a seasonal fisheries technician for the U.S. Fish and Wildlife Service Connecticut River Conservation Office during the spring and summer of 2022, and I am currently a master's student at the University of Massachusetts-Amherst in the Environmental Conservation department with the Massachusetts Cooperative Fish and Wildlife Research Unit. My research investigates juvenile river herring productivity, growth and habitat use in a series of coastal watersheds in eastern Massachusetts.
2. The purpose of my affidavit is to explain the Connecticut River Conservancy's ("CRC") opposition to the offer of settlement ("Offer") as it relates to minimum flows below Turners Falls Dam during the summer and fall months and the effects of those flows on native fluvial fish communities in that segment of the river ("Bypass Reach").
3. To provide this affidavit testimony, I reviewed the Offer and the Settling Parties' Explanatory Statement, Relicensing Studies pertaining to flows and fish assemblages in the Bypass Reach, Massachusetts water quality policy, and various journal articles within the scientific literature that pertain to the effects of hydropower operations on native fish communities. I have listed the literature cited at the end of this affidavit.
4. Alterations to river flow below hydroelectric dams have significant implications for downstream fish communities, where flow diversions and stochastic water releases can reduce the diversity of resident fish populations (Bain et al. 1988). Kinsolving and Bain (1993) found a spatial gradient of fish community composition downstream of a hydroelectric facility in Alabama, where the reaches immediately downstream of the dam were dominated by fish species that tolerate a wide variety of aquatic habitats (macrohabitat generalists) with fewer fish species present that are dependent on flowing-water habitats (fluvial specialists) compared with reaches farther downstream with more stable flow conditions.

5. As a means of quantifying impacts to native riverine fish assemblages, The Massachusetts Executive Office of Energy and Environmental Affairs (Mass EOE) made recommendations to conduct fish community assessments in mainstem rivers as part of their Water Policy in 2004. Mass EOE subsequently funded the development of Target Fish Communities for Massachusetts rivers in conjunction with the Massachusetts Division of Fisheries and Wildlife in 2009. An excerpt from the Target Fish Communities Technical Report summarizes the classification of Massachusetts fish species into various tolerance and habitat use categories:

Species were classified into three habitat-use categories and three tolerance categories. Habitat Use Categories were adopted as in Bain and Meixler (2008) with regional modification: fluvial specialist (FS) species that require flowing water for all of their life-history requirements; fluvial dependent (FD) species that require flow for at least some portion of their life history; and macrohabitat generalist (MG) species that can meet all of their life-history requirements in lentic conditions. Rivers that are dominated by macrohabitat generalist species likely have impairments to stream flow or are dominated by impounded habitat.

Three tolerance categories following Plafkin et al. (1989) (Table 2): intolerant (I), moderately tolerant (M), and tolerant (T), reflect the species observed tolerance to environmental degradation. Water quality concerns should likely be addressed in rivers that are dominated by tolerant individuals or have lost intolerant species entirely.

6. The Target Fish Communities Technical Report assigned habitat use and tolerance classifications to Massachusetts fishes as depicted in the table below.

Table 2. Massachusetts fish species with their Origin (Hartell et al. 2002), habitat-use categories (HUC) based on Bain (1992 – and modified for regional application), and tolerance (Plafkin et al. 1989).

Species	Scientific Name	Origin ^a	Habitat-Use Category ^b	Tolerance ^c
American eel	<i>Anguilla rostrata</i>	N	MG	T
Atlantic salmon	<i>Salmo salar</i>	N	FS	I
Banded killifish	<i>Fundulus diaphanus</i>	N	MG	T
Banded sunfish	<i>Enneacanthus obesus</i>	N	MG	I
Black crappie	<i>Pomoxis nigromaculatus</i>	I	MG	M
Blacknose dace	<i>Rhinichthys atratulus</i>	N	FS	T
Bluegill	<i>Lepomis macrochirus</i>	I	MG	T
Bluntnose Minnow	<i>Pimephales notatus</i>	I	MG	T
Bridle shiner	<i>Notropis bifrenatus</i>	N	MG	I
Brook trout	<i>Salvelinus fontinalis</i>	N	FS	I
Brown bullhead	<i>Ameiurus nebulosus</i>	N	MG	T
Brown trout	<i>Salmo trutta</i>	I	FS	I
Chain pickerel	<i>Esox niger</i>	N	MG	M
Channel catfish	<i>Ictalurus punctatus</i>	I	MG	M
Common carp	<i>Cyprinus carpio</i>	I	MG	T
Common shiner	<i>Notropis cornutus</i>	N	FD	M
Creek chub	<i>Semotilus atromaculatus</i>	N	FS	T
Creek chubsucker	<i>Erimyzon oblongus</i>	N	FS	I
Cutlip Minnow	<i>Exoglossum maxillingua</i>	I	FS	I
Fallfish	<i>Semotilus corporalis</i>	N	FS	M
Golden shiner	<i>Notemigonus crysoleucas</i>	N	MG	T
Green sunfish	<i>Lepomis cyanellus</i>	I	MG	T
Landlocked salmon	<i>Salmo salar</i>	I	FD	
Largemouth bass	<i>Micropterus salmoides</i>	I	MG	M
Longnose dace	<i>Rhinichthys cataractae</i>	N	FS	M
Longnose Sucker	<i>Catostomus commersoni</i>	N	FD	I
Northern pike	<i>Esox lucius</i>	I	MG	I
Pumpkinseed	<i>Lepomis gibbosus</i>	N	MG	M
Rainbow trout	<i>Oncorhynchus mykiss</i>	I	FS	I
Redbreast sunfish	<i>Lepomis auritus</i>	N	MG	M
Redfin pickerel	<i>Esox americanus americanus</i>	N	MG	M

Table 2. (Continued)

Species	Scientific Name	Origin ^a	Habitat-Use Category ^b	Tolerance ^c
Rock bass	<i>Ambloplites rupestris</i>	I	MG	M
Slimy sculpin	<i>Cottus cognatus</i>	N	FS	I
Smallmouth bass	<i>Micropterus dolomieu</i>	I	MG	M
Spottail shiner	<i>Notropis hudsonius</i>	N	MG	M
Swamp Darter	<i>Etheostoma fusiforme</i>	N	MG	I
Tessellated darter	<i>Etheostoma olmsted</i>	N	FS	M
White perch	<i>Morone americana</i>	N	MG	M
White sucker	<i>Catostomus commersoni</i>	N	FD	T
Yellow bullhead	<i>Ameiurus natalis</i>	I	MG	T
Yellow perch	<i>Perca flavescens</i>	N	MG	M

^a - Origin categories: N = Native, I = Introduced

^b - Habitat-use categories: FS = fluvial specialist, FD = fluvial dependent, MG = macrohabitat generalist

^c - Tolerance categories: T = Tolerant, M = Moderately Tolerant, I = Intolerant

7. The Massachusetts Consolidated Listing and Assessment Methodology (CALM) Guidance Manual, updated Fall of 2022, uses fish community classifications as a metric for determining the attainment of Aquatic Life Use. An excerpt from page 19 of the CALM specifies fluvial fish presence as a key metric for determining Aquatic Life Use support:

For waters designated as a Class B Warm Water Fishery, or those waters otherwise undesignated: in moderate to high gradient streams (riffle/run prevalent streams) the fish community should include two or more fluvial specialist/dependent species (see Appendix B) or at least one fluvial specialist/dependent species in moderate abundance to fully support the Aquatic Life Use. The absence of fluvial fish in these streams will result in an impairment decision.

In low gradient streams (glide/pool prevalent streams) the fish community should include at least one fluvial specialist/dependent species or macrohabitat generalist species which are intolerant or moderately tolerant to environmental perturbations to fully support the Aquatic Life Use. If fish are absent in these streams, or if only tolerant macrohabitat generalist species are present, the Aquatic Life Use will be assessed as impaired.

8. A study of fish assemblages in large rivers of New England conducted by the Midwest Biodiversity Institute included fish sampling of multiple reaches downstream of the Turners Falls dam in 2009. 1 Km long electrofishing surveys in the Bypass Reach beginning at river mile 67.9 (directly downstream of the dam, upstream of Station No. 1) and 66.9 (downstream of Station No. 1) revealed the adverse effects of water diversion on the fish assemblages present in the upper Bypass Reach. The study applied a series of 12 Index of Biological Integrity (ME IBI) metrics that were developed to assess the quality of fish communities in moderate-high gradient rivers in Maine (Yoder et al. 2008). Metrics included measures of native species richness, proportional abundance of non-native species such as black bass, proportional abundance of fluvial fishes and other metrics that aim to quantify the integrity of riverine fish assemblages. Scores from the 12 IBI metrics were combined to determine an overall ME IBI score for each survey reach. The ME IBI score for the 1 km reach in the upper bypass was of the lowest of all New England rivers included in this study, but improved in the lower Bypass Reach with the

flows provided by Station No. 1. The improvements in IBI metrics in the lower Bypass Reach were associated with fewer non-native species and more native species, higher proportional abundance of Cyprinid fishes such as Spottail Shiner and Longnose Dace and lower proportional abundance of macrohabitat generalists such as Smallmouth Bass.

9. The table below from Yoder et al. (2015) depicts the IBI scores for reaches downstream of the Turners Dam. The color of the cells corresponds to the Biological Condition Gradient conceptual model (adapted from Davies and Jackson 2006) that ranks the condition of the fish community from 1 (purple, least impaired) through 6 (red, most impaired). The overall ME IBI score for the 1 km reach downstream of the Turners Dam corresponded to a level 6 Biological Condition Gradient, indicating significant impairment of the fish communities in this reach due to lack of consistent flows from the Turners Falls dam.

Biological Condition Gradient Conceptual Model: Maine Rivers

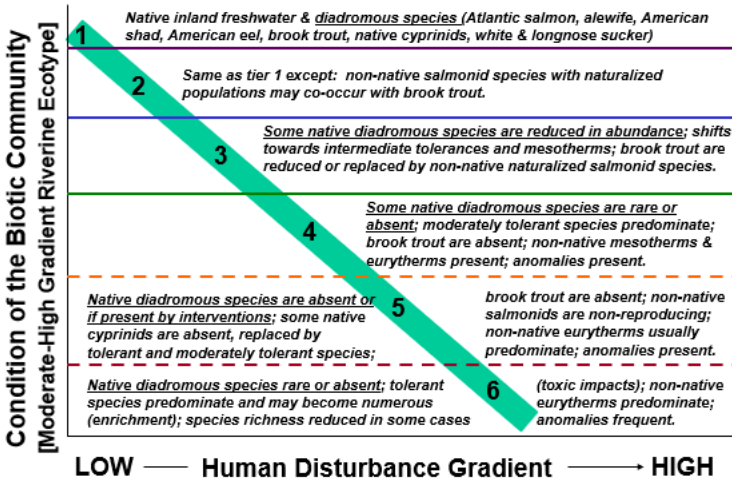


Table 27. Fish sampling results in and downstream from the Turners Falls bypass reach in the Connecticut River and in the vicinity of the Cabot hydropower project in 2009 showing Maine IBI and DIBI scores and Maine IBI metric results. Gray shaded NELR REMAP sites were “embedded” within the preceding NRSA site (site numbers are from NRSA, NELR REMAP, and Connecticut River intensive survey designations). Color shading in the cells corresponds to the BCG level for each result (see Table 24).

River Mile	Site Number	Distance (Km)	Maine IBI (BCG)	Maine DIBI (BCG)	Native Species	Steno-therms	Alien Sp.	Non-guarding Lithophils	%Cyprini-dae	Native Salmon-ids	Benthic Insecti-vores	% Black-bass	Fluvial Special-ist	Macro-habitat General-ists	White/Long-nose Suckers ¹	%DELT
67.9 (NRSA)	FW08MA 021	3.81	34 (5)	39.5 (5)	3	1	6	2	27	0	21	51	29	68	NA	0
67.9 (REMAP)	FW08MA 021	1.0	10 (6)	25.1 (5)	2	0	3	0	0	0	9	44	9	62	0	2.4
66.9	CTR-46	1.0	57 (4)	74.4 (3)	5	1	2	2	18	10	19	13	26	17	22	0
66.1 (NRSA)	FW08MA 020	4.0	29 (6)	36.7 (5)	4	0	3	1	15	0	8	37	33	60	NA	0
66.1	CTR-47A1	1.0	22 (6)	34.3 (6)	6	0	5	2	52	0	4	27	12	85	0	0.4
65.5	CTR-46A	1.0	38 (5)	56.5 (4)	6	1	4	2	7	1	3	48	18	57	9	2.3

¹ This is a biomass based metric and it could not be calculated for the NRSA method.

10. In 2016, First Light released Relicensing Study 3.3.11 Fish Assemblage Assessment which included electrofishing surveys during the summer of 2015 of the same reaches downstream of the Turners Dam sampled in 2009 by the Midwest Biodiversity Institute. Table 4.2.3.1-1 depicts the species abundances at various sites downstream of the Turners Dam. Overall, the fish communities sampled in 2015 are comparable to those sampled in 2009, with high proportional abundance of macrohabitat generalist smallmouth bass and low proportional abundance of native fluvial specialist fishes.

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

FISH ASSEMBLAGE ASSESSMENT

Table 4.2.3.1-1: Species Abundance at Each Boat Electrofishing Station within the Turners Falls Bypass Reach during Late Summer 2015

Species	Plunge Pool	Pool-Run Above Station No. 1	Riffle-Run Below Station No. 1	Pool Above Rock Dam	Total	% of Total
Smallmouth Bass	48	67	30	23	168	62.5%
American Eel	16	1	7	2	26	9.7%
Bluegill Sunfish	12	9		1	22	8.2%
Pumpkinseed	8	8			16	5.9%
White Sucker	10		2	1	13	4.8%
Tessellated Darter	4	2	2	4	12	4.5%
Sea Lamprey	1		1	1	3	1.1%
Largemouth Bass	1				1	0.4%
Yellow Perch				1	1	0.4%
Spottail Shiner				1	1	0.4%
Mimic Shiner				1	1	0.4%
Walleye	1				1	0.4%
Northern Pike				1	1	0.4%
Brown Bullhead				1	1	0.4%
Hybrid Sunfish		1			1	0.4%
Longnose Dace			1		1	0.4%
Total	101	88	43	37	269	

11. According to the fish sampling data from 2009 and 2015, the Bypass Reach is home to fluvial specialist fishes including Longnose Dace, Tessellated Darter, and White Sucker. According to the 2015 survey data, however, only two individuals of a single species of fluvial specialist (Tessellated Darter) were present in the pool-run reach above Station No. 1 (a moderate to high gradient river reach). This fish community does not meet the standards for Aquatic Life Use in moderate to high gradient streams as defined by the Massachusetts CALM, which states that two or more fluvial fish species or one fluvial fish species in moderate abundance must be present. The extremely low proportional abundance of fluvial specialist fishes and the proportional dominance of the fish community by macrohabitat generalist fishes as determined by both the 2009 and 2015 surveys for the upper Bypass Reach fail to meet the criteria for Aquatic Life Use attainment as defined by the Massachusetts CALM.
12. Relicensing Study 3.3.1 Instream Flow Habitat Assessments in the Bypass Reach and below Cabot Station derived Weighted Usable Area (WUA) calculations for fish species in Reach 1 (Table 7.1.1.2-2). Under previous summer minimum flows of 120 cfs from the

Turners Dam, the WUA for Juvenile and Adult Longnose Dace is 13.0% and 9.3% respectively and 12.2% for Juvenile/Adult Tessellated Darter, which explains the extremely low proportional abundance of these fish species documented in the upper Bypass Reach during 2009 and 2015 electrofishing surveys. The proposed summer minimum flows from the Turners Dam of 500 cfs only provide 27.7% and 18.5% WUA for Juvenile and Adult Longnose Dace respectively and 22% WUA for Juvenile/Adult Tessellated Darter, representing a meager increase in usable habitat by 9.2-14.7% for Longnose Dace and 9.8% for Tessellated Darter. Maximum WUA for these species and life stages occurs at flows of 1800-2000 cfs. Thus, significantly higher minimum flows from the Turners Dam would be necessary to provide enough usable habitat for these fluvial specialist fishes in the upper Bypass Reach and to strengthen the integrity of the fish community immediately downstream of the dam to meet Aquatic Life Use standards.

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)
INSTREAM FLOW HABITAT ASSESSMENTS IN THE BYPASS REACH AND BELOW CABOT STATION STUDY REPORT

Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft)	120 (cfs)	150 (cfs)	200 (cfs)	250 (cfs)	400 (cfs)	500 (cfs)	600 (cfs)	700 (cfs)	800 (cfs)	1000 (cfs)	1200 (cfs)	1400 (cfs)	1600 (cfs)	1800 (cfs)	2000 (cfs)	3000 (cfs)	4000 (cfs)	5000 (cfs)
					0.02 (cfsm)	0.02 (cfsm)	0.03 (cfsm)	0.03 (cfsm)	0.06 (cfsm)	0.07 (cfsm)	0.08 (cfsm)	0.1 (cfsm)	0.11 (cfsm)	0.14 (cfsm)	0.17 (cfsm)	0.2 (cfsm)	0.22 (cfsm)	0.25 (cfsm)	0.28 (cfsm)	0.42 (cfsm)	0.56 (cfsm)	0.7 (cfsm)
American Shad	Spawning/Incub	May-June	7,500	898,488	17.6%	18.7%	20.6%	22.5%	27.2%	29.1%	30.6%	32.2%	33.7%	36.6%	40.9%	45.5%	49.8%	54.5%	59.8%	72.4%	81.9%	89.0%
American Shad	Juvenile	June-Oct	2,000	668,444	43.9%	47.7%	53.5%	58.6%	52.9%	55.3%	57.5%	59.2%	61.2%	64.6%	74.4%	83.0%	88.7%	94.4%	100.0%	95.5%	88.1%	80.6%
American Shad	Adult	May-June	7,500	695,459	23.1%	24.0%	25.7%	27.2%	29.1%	30.1%	31.1%	32.2%	33.3%	35.2%	37.7%	40.7%	43.1%	46.3%	50.3%	66.2%	80.2%	90.7%
Shortnose Sturgeon	Spawning	April-May	6,000	893,383	0.5%	1.6%	5.6%	9.7%	23.1%	27.9%	31.0%	32.6%	33.5%	35.0%	39.6%	45.4%	52.3%	60.8%	70.8%	87.7%	96.0%	99.5%
Shortnose Sturgeon	Egg-Larvae	May	3,000	1,360,780	38.9%	43.8%	51.1%	57.5%	42.9%	46.9%	51.0%	55.0%	59.3%	66.6%	77.6%	85.8%	91.5%	95.9%	99.9%	100.0%	100.0%	99.7%
Shortnose Sturgeon	Fry	May	500	64,776	44.5%	54.9%	71.4%	85.1%	99.3%	100.0%	99.9%	99.8%	99.9%	98.3%	94.8%	93.8%	91.8%	91.3%	92.4%	73.1%	56.9%	43.5%
Fallfish	Spawning/Incub	May-June	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fallfish	Fry	May-June	150	25,172	96.3%	100.0%	99.7%	98.5%	87.3%	82.4%	75.3%	61.6%	50.7%	39.0%	32.6%	28.2%	24.3%	20.9%	17.8%	6.1%	1.8%	1.0%
Fallfish	Juvenile	Year Round	1,800	260,011	57.8%	63.6%	71.2%	77.0%	73.3%	74.3%	76.2%	77.6%	79.5%	82.8%	89.5%	93.4%	98.0%	100.0%	99.5%	80.4%	61.6%	44.0%
Fallfish	Adult	Year Round	2,000	549,907	67.5%	70.9%	76.2%	80.6%	75.7%	75.7%	71.2%	67.1%	63.5%	59.8%	70.4%	80.6%	86.7%	93.4%	100.0%	89.6%	74.3%	60.5%
Longnose Dace	Juvenile	Year Round	1,800	155,504	13.0%	16.4%	22.0%	27.6%	23.1%	27.7%	31.3%	34.2%	37.4%	44.0%	64.0%	81.7%	95.7%	100.0%	94.9%	39.8%	12.7%	3.6%
Longnose Dace	Adult	Year Round	2,000	413,608	9.3%	11.7%	15.8%	19.8%	16.1%	18.5%	20.4%	22.8%	25.4%	31.5%	51.4%	69.4%	84.2%	94.0%	100.0%	54.4%	17.0%	4.2%
White Sucker	Spawning/Incub	Apr-May	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
White Sucker	Fry	May-June	120	1,000,248	100.0%	99.6%	97.6%	95.7%	84.7%	79.3%	75.2%	74.9%	76.4%	79.7%	75.7%	66.4%	51.8%	36.6%	20.8%	4.3%	1.0%	0.8%
White Sucker	Adult/Juvenile	Year Round	250	362,803	75.0%	85.5%	95.4%	100.0%	82.0%	71.1%	60.5%	50.9%	43.7%	45.5%	63.6%	77.0%	78.1%	73.4%	63.4%	29.9%	8.2%	2.6%
Walleye	Spawning	April-May	3,000	139,817	14.5%	14.9%	15.5%	16.2%	19.3%	21.4%	25.8%	29.8%	35.2%	45.0%	51.0%	55.9%	59.7%	64.4%	62.8%	100.0%	96.3%	85.7%
Walleye	Fry	April-May	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Walleye	Juvenile	Year Round	120	870	100.0%	82.4%	52.9%	32.4%	26.5%	23.5%	17.6%	14.7%	11.8%	8.8%	4.7%	3.5%	3.5%	2.4%	2.9%	0.0%	0.0%	0.0%
Walleye	Adult	Year Round	120	36,453	100.0%	80.4%	48.8%	24.5%	19.4%	15.8%	13.0%	12.9%	13.1%	13.5%	14.1%	14.6%	14.9%	15.6%	20.0%	14.3%	4.4%	4.4%
Tessellated Darter	Adult/Juvenile	Year Round	1,800	133,736	12.2%	15.4%	20.9%	26.5%	18.0%	22.0%	26.7%	31.9%	36.7%	45.3%	66.1%	84.5%	98.2%	100.0%	96.7%	28.7%	0.9%	0.0%
Sea Lamprey	Spawning/Incub	May-June	1,800	3,870	0.0%	0.0%	0.0%	0.3%	41.4%	56.6%	69.4%	62.8%	59.0%	69.8%	56.4%	74.0%	91.3%	100.0%	94.8%	34.9%	12.3%	2.3%
Macroinvertebrates	Larva	Year Round	4,000	918,412	0.0%	0.1%	0.4%	0.9%	6.0%	10.0%	14.0%	17.7%	21.3%	26.9%	30.4%	36.1%	44.7%	55.2%	67.1%	91.6%	100.0%	97.6%
Shallow Slow	Shallow Slow	Year Round	700	818,354	93.6%	94.1%	95.4%	97.1%	96.6%	97.5%	98.3%	100.0%	100.0%	93.0%	80.8%	78.2%	75.5%	71.7%	68.0%	21.5%	0.0%	0.0%
Shallow Fast	Shallow Fast	Year Round	1,600	535,297	24.8%	30.7%	40.4%	49.7%	26.1%	31.1%	36.2%	41.7%	49.0%	63.3%	83.5%	96.4%	100.0%	97.1%	88.9%	32.3%	9.1%	2.9%
Deep Slow	Deep Slow	Year Round	500	615,160	90.7%	91.4%	93.3%	95.7%	96.1%	100.0%	88.5%	65.6%	59.0%	67.0%	73.3%	78.9%	80.3%	64.2%	54.8%	22.2%	3.6%	1.2%
Deep Fast	Deep Fast	Year Round	3,000	124,411	2.4%	6.7%	15.0%	23.1%	37.8%	53.4%	69.1%	79.4%	82.8%	89.5%	88.3%	89.1%	91.6%	94.4%	99.6%	100.0%	89.8%	52.9%

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**UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION**

FirstLight Hydro MA LLC

Northfield Mountain LLC

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Docket No. 1889-000

Docket No. 2485-000

DECLARATION

JULIAN BURGOFF states that I prepared the affidavit to which this declaration is attached and that the statements contained therein are true and correct to the best of my knowledge and belief.

Pursuant to Rule 2005(b)(3) (18 CFR § 385.2005(b)(3), citing 28 U.S.C. § 1746), I further state under penalty of perjury that the foregoing is true and correct.

Executed on May 23, 2023.

/s/ Julian Burgoff

Julian Burgoff

Attachment B

**UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION**

FirstLight Hydro MA LLC

Docket No. 1889-000

Northfield Mountain LLC

Docket No. 2485-000

**AFFIDAVIT OF DONALD PUGH
ON BEHALF OF THE CONNECTICUT RIVER CONSERVANCY**

1. My name is Donald Pugh. I am an independent consultant with more than 20 years of experience, study and expertise in analyzing fish passage at hydroelectric projects, including projects going through licensing proceedings before the Federal Energy Regulatory Commission (“FERC”). I formerly worked on both up- and downstream passage at the U.S. Geological Survey’s S.O. Conte Anadromous Fish Research Laboratory, which is located on the Connecticut River just downstream of Turner’s Falls Dam. I have been engaged in numerous fish passage projects or consultations, during which I have examined and analyzed fish passage requirements including aquatic habitat quality and use and minimum flow needs. In 2021, I provided expert testimony in a federal case involving four hydroelectric projects on the Kennebec River in Maine, *Atlantic Salmon Federation U.S., et al. v. Brookfield Renewable Partnerships, L.P., et al.* Case No. 1:21-cv-00257-JDL (D. Me. 2021). The subject matter of my testimony in that case was fish passage, fish mortality caused by the hydroelectric operations, and analysis of measures needed to reduce fish passage mortality. These projects, cases, my publication credits, and presentations are set forth in the attached CV, current as of May 2023. *See Exhibit A.* My business address is 10 Old Stage Rd., Wendell MA 01379.
2. The purpose of my affidavit is to explain the Connecticut River Conservancy’s (“CRC”) opposition to the offer of settlement (“Offer”) as it relates to minimum flows below Turners Falls Dam, during the summer and fall months.
3. To provide this affidavit testimony, I reviewed the Offer and the Settling Parties’ Explanatory Statement, and Relicensing Study 3.3.1 (Study 3.3.1)¹ including individual Habitat Suitability Indices (“HSI”).
4. Based upon my review and analysis of the above documents, my familiarity with the site, and my experience and expertise in analyzing fish passage issues at hydroelectric projects, I have reached an opinion on the sufficiency of proposed minimum flow below Turner’s Falls Dam between July 1 and November 15. The proposed minimum flow of

¹ Instream Flow Habitat Assessments in the Bypass Reach and below Cabot Station, Final Study Report, Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889), October 2016.

500 cfs from the dam provides insufficient habitat for the species and life stages identified as important during consultation between FirstLight, the state and federal agencies and non-government stakeholders. Five hundred cfs is not enough water to even fill the river bank to bank from the dam to Station 1, which is located approximately one mile below the dam.

THE OFFER'S PROPOSED MINIMUM FLOWS OF 500 CFS IN REACH 1 BELOW TURNERS FALLS DAM IS INSUFFICIENT TO PROVIDE A SUITABLE AMOUNT AND QUALITY OF HABITAT FOR MOST AQUATIC SPECIES INHABITING THAT REACH

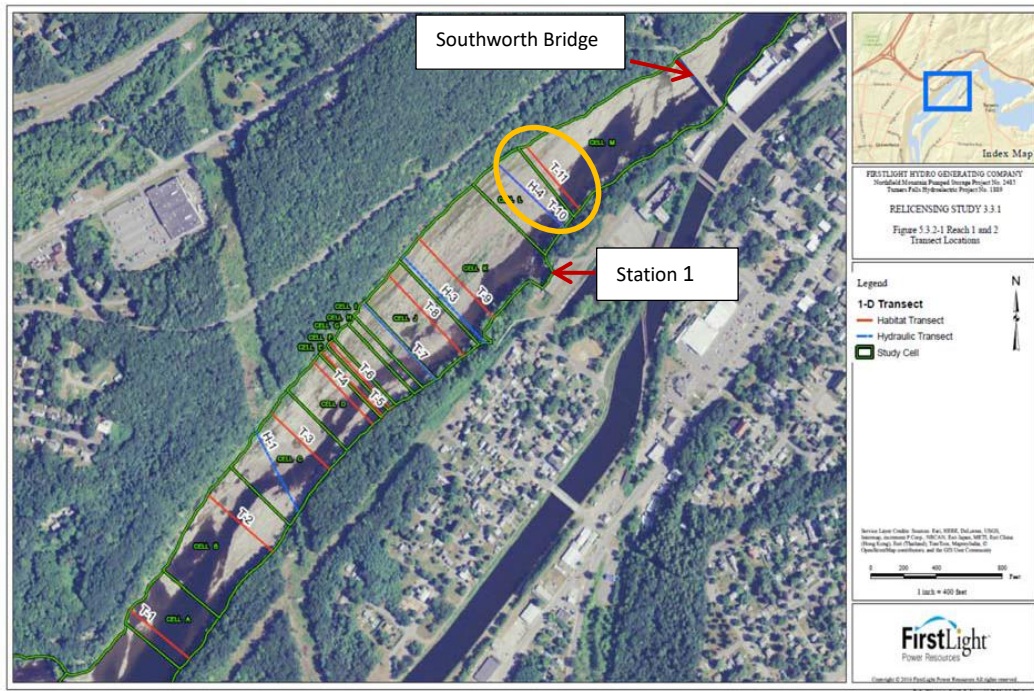
5. The Offer's proposed minimum flow below Turners Falls Dam from July 1 to November 15 are 500 cfs with the qualification that if the Naturally Routed Flow ("NRF") is equal to or less than 500 cfs, flow from the dam will be the NRF. *See* Offer, Appendix A, at A-1 (proposed Article A110). Relicensing Study 3.3.1 identified target species, which were used in the habitat analysis. The proposed minimum flow is insufficient to provide a suitable amount and quality of habitat for most aquatic species inhabiting the reach of the Connecticut River between Turners Falls Dam and Station 1. Fluvial species including longnose dace (*Rhinichthys cataractae*) and tessellated darter (*Etheostoma olmstedii*) are most particularly affected by the proposed minimum flow given the low percentage of weighted usable area available for their habitat. Longnose dace and tessellated darter are fluvial specialist species with a moderate tolerance classification (CALM 2022) and, together with, macroinvertebrates, are provided the least habitat by the proposed flows. While the available habitat to each target species varies depending on flow, an increase in flows to 1,400 cfs provides significantly more habitat for most target fish species and life stages and for macroinvertebrates.
6. The proposed flow of 500 cfs provides limited habitat for longnose dace and tessellated darters, with only 27 and 18% longnose dace juvenile/adult and 22% juvenile and adult tessellated darters available (Table 7.1.1.2-2, Study 3.3.1). Longnose dace and tessellated darter are fluvial specialists, requiring flowing water for all life stages. The relative abundance of fluvial specialist species is used as an indicator of ecological health for rivers in Massachusetts (CALM 2022). The Massachusetts CALM indicates that in high gradient streams (riffle/run prevalent), the fish community should include at least two fluvial specialist/dependent species; fallfish, longnose dace, white sucker and tessellated darter are each classified as fluvial specialist species. The proposed flow of 500 cfs severely limits the habitat for both longnose dace and tessellated darter. Total habitat (square feet) for the four fluvial specialists would increase 47% with a flow of 1,400 cfs versus 500 cfs. When macroinvertebrates are included in the analysis, their habitat is increased 65%. Total habitat for the fluvial species and macroinvertebrates (**Exhibit B**) was calculated from Table 7.1.1.2-2 by multiplying the Maximum WUA for each species and life stage by the percent of Maximum WUA for each species and life stage at each flow.
7. Macroinvertebrate habitat at 500 cfs is only 10% of the maximum available. As shown in Figure 2 below, at 500 cfs much of the river would not provide the flow (velocity and/or

depth) necessary to support fluvial species, the expected fish species in Reach 1, or macroinvertebrates. Macroinvertebrates are an important part of the food web feeding on plant matter and algae and providing food for numerous species and life stages of fish. The Massachusetts CALM relies on aquatic macroinvertebrate communities to determine the biological health of a stream. When data are available from multiple indicators, biological community data carry more weight in decision-making regarding the attainment of Aquatic Life Use; biological community data generated by an Index of Biological Integrity (IBI) are considered the best measure of Aquatic Life Use. Maintaining sufficient flow for macroinvertebrates not only provides for an important part of the food web, but also works towards the attainment of Aquatic Life Use.

8. The Offer provides no evidence that a flow of 500 cfs during summer and fall is sufficient to support a return of the bypass to a riverine state supporting fluvial species and macroinvertebrates. This reach of the river has been degraded for decades by inadequate flows due to the presence and operations of the dam. The presence of the dam and its operation directing virtually all water out of the “bypass” portion of the river has severely compromised the physical and biological integrity of this reach. A higher minimum flow below Turner’s Falls Dam is needed to maintain and restore aquatic life in the one-mile stretch of river below the dam from July 1 to November 15, as demonstrated below.

A MORE SCIENTIFICALLY JUSTIFIABLE MINIMUM FLOW FOR REACH 1 BELOW TURNERS FALLS DAM FROM JULY 1 TO NOVEMBER 15 IS 1,400 CFS

9. Weighted Useable Area (“WUA”) is an output of the Instream Flow Incremental Methodology analysis of available habitat under different flow conditions. It is a commonly used means of habitat analysis in hydroelectric relicensing proceedings. WUA is defined as “...the total surface area having a certain combination of hydraulic conditions, multiplied by the composite probability of use for that combination of conditions. This calculation is applied to each cell within the multidimensional matrix” (Bovee and Cochnauer, 1977). Hydraulic conditions are depth and velocity. These are combined with substrate to determine habitat suitability. HSI curves for each species and life stage were agreed to by FirstLight, state and federal agencies and non-governmental stakeholders.
10. Study 3.3.1 analyzed transects 10 and 11 for habitat (WUA) in Reach 1 of the “bypass channel” below the immediate area of the dam. Figure 1, below, shows the area of the transect analysis.

Figure 1. Relicensing Study 3.3.1, Figure 5.3.2-1

11. Both low and high backwater conditions were evaluated (Station 1 not operating or operating at full capacity, respectively). As Station 1 will be operating during the summer/fall period, Table 7.1.1.2-2 (high backwater) is used in the following analysis. That table is attached as **Exhibit C**.
12. Fallfish, longnose dace, tessellated darter (fluvial specialist) and white sucker (fluvial dependent), were identified during initial stakeholder consultations as important species to analyze as Reach 1 of the river has a higher gradient than the river below the Cabot Station, the preferred habitat for fluvial species. As such it is a unique habitat in Massachusetts. Similarly, a different flow dependent suite of macroinvertebrates will be present in the bypass.
13. A flow of 1,400 cfs provides significantly more habitat for fluvial species and macroinvertebrates than 500 cfs. Using Table 7.1.1.2-2 (attached here as **Exhibit C**) from Study 3.3.1, I calculated the change in percentage of WUA when flows are increased from 500 cfs to 1,400 cfs, which is reflected in Table 1 below. “Delta 500 to 1400” is the difference in percent of WUA between the two flows. In all cases, the increased flow resulted in increased WUA, which in turn resulted in more available habitat for the fluvial species identified as important for the relicensing study and for macroinvertebrates.

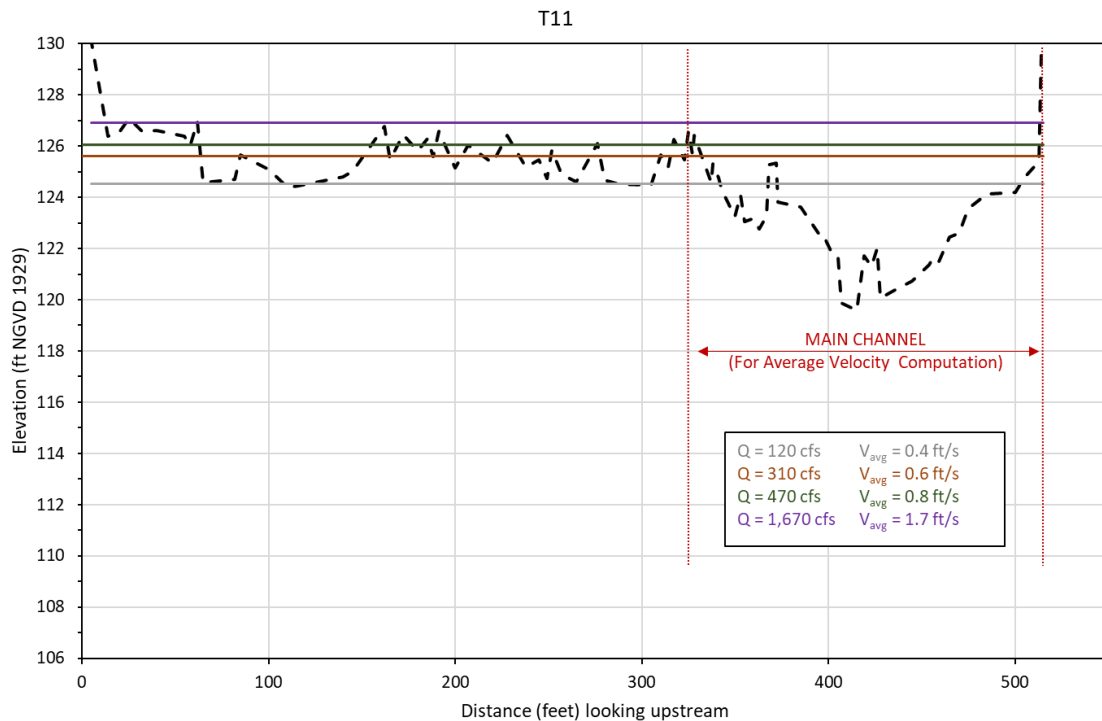
Table 1. Species, life, stage percentage of maximum Weighted Useable Area, and the difference in WUA between 500 cfs and 1,400 cfs, from Table 7.1.1.2-2 Relicensing Study 3.3.1.

Species	Life stage	WUA 1400 (cfs)	Delta 500 to 1400
American Shad	Juvenile	83.0%	28%
Fallfish	Juvenile	93.4%	19%
Fallfish	Adult	80.6%	5%
Longnose Dace	Juvenile	81.7%	54%
Longnose Dace	Adult	69.4%	51%
White Sucker	Adult/Juvenile	77.0%	6%
Walleye	Juvenile	3.5%	-20%
Walleye	Adult	14.1%	-2%
Tessellated Darter	Adult/Juvenile	84.5%	63%
Macroinvertebrates	Larva	36.1%	26%

14. Another recognized method for analyzing the amount of available habitat for aquatic species in a particular stretch of a river is the Wetted Perimeter method. The Wetted-Perimeter method is based on the assumption that there is a direct relation between the wetted perimeter in a riffle and fish habitat in streams (Annear and Conder, 1984; Lohr, 1993). The wetted perimeter of a stream, defined as the width of the streambed and stream banks in contact with water for an individual cross section, is used as a measure of the availability of aquatic habitat over a range of discharges (Annear and Conder, 1984; Nelson, 1984).
15. Water levels at Transect 11 are shown for four flows in Figure 2 below. At 470 cfs (green line) approximately 35% of the transect is either dry or minimally wetted. At 1,670 cfs (purple line) the full river width is wetted increasing habitat for juvenile fish and macroinvertebrates. Based on the slope of the vertical right bank and near vertical left bank, a flow of 1,400 cfs would closely resemble that of 1,670 cfs (purple line).²

² Right and left bank references here refer to the figure whereas all other river references are looking downstream.

Figure 2. CRC letter dated June 13, 2022 to Secretary Bethany Card, Massachusetts Executive Office of Energy and Environmental Affairs.



16. On November 17, 2015, FirstLight provided demonstration flows of 125 cfs, 1,500 cfs, 2,500 cfs and 4,000 cfs. I took the photographs in Figures 3 and 4 below, from the Southworth Bridge, which is 0.6 miles below Turner's Falls Dam (*see* Figure 1 above). In the photographs, transects 10 and 11, as shown in Figure 1, are in the distance before the river bends to the left. I took the photograph in Figure 3 during the 1,500 cfs demonstration flow on November 17, 2015. It shows flowing water over most of the river width. Flows of 1,500 cfs demonstrably increase the wetted area and the available aquatic habitat in this reach. This is further supported in Study 3.3.1 which concluded that in the left channel immediately below the dam, "Bypass flow releases less than 1,500 cfs wet only the right-most 300-ft portion of the channel (looking downstream), whereas higher flow wets the leftmost 150 feet of the transect."³ Increasing the amount of riverbed covered with flowing water will increase habitat for fluvial specialist species and macroinvertebrates.
17. The photograph labeled Figure 4 was taken on May 16, 2023, from the same vantage point (Southworth Bridge), during the upstream fish passage flow of 400 cfs. That photograph shows a narrow area on river left and notable areas of uplifted bedrock on river right. Habitat for both fluvial species and macroinvertebrates at 400 cfs is limited to the channel on river left. Considering the Wetted-Perimeter analysis, the photo further

³ 6.1.1.3 Reach 1-Left Channel

demonstrates that flows of 400 cfs expose a greater width of the streambed and stream banks, thereby limiting the available aquatic habitat.

Figure 3. Reach 1 below the Southworth Bridge at 1,500 cfs (D.Pugh photo).



Figure 4. Reach 1 below the Southworth Bridge at 400 cfs (D.Pugh photo).



18. Both the Weighted Useable Area and the Wetted-Perimeter analysis demonstrate that 500 cfs is inadequate for the species and life stages that would normally inhabit this reach of the river. While 1,400 cfs does not provide for 100 percent of available habitat for fluvial

species and macroinvertebrates, that level of flows increases habitat significantly above flows of 500 cfs. At 1,400 cfs the full width of the river is wetted with flowing water. As recorded downstream at the Montague USGS stream gage (42.5802222, -72.5745) over a 40-year period, a flow of 1,400 cfs is exceeded over 99% of the time from July 1 to November 15.⁴ Accordingly, a flow of 1,400 cfs returns the “bypass reach” to its minimum riverine condition restoring bank to bank habitat and sufficiently maintaining and restoring aquatic life uses there.

References

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Nelson, F.A., 1984, Guidelines for using the wetted perimeter (WETP) computer program of the Montana Department of Fish, Wildlife, and Parks: Bozeman, MT, Montana Department of Fish, Wildlife, and Parks, variously paged.

⁴ USGS Montague Gage #01170500, 1980 to 2020.

**UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION**

FirstLight Hydro MA LLC

Northfield Mountain LLC

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Docket No. 1889-000

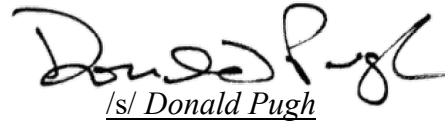
Docket No. 2485-000

DECLARATION

DONALD PUGH states that I prepared the affidavit to which this declaration is attached and that the statements contained therein are true and correct to the best of my knowledge and belief.

Pursuant to Rule 2005(b)(3) (18 CFR § 385.2005(b)(3), citing 28 U.S.C. § 1746), I further state under penalty of perjury that the foregoing is true and correct.

Executed on May 24, 2023.


/s/ Donald Pugh

Donald Pugh

Exhibit A

Donald H. Pugh, Jr.
10 Old Stage Road
Wendell, MA 01379
Telephone 978 544 7438 Office
413 387 9439 Cell

Work History:

Self Employed

Current projects:

Maryland Power Plant Research Project – relicensing of Conowingo Project (FERC # 405) on the Susquehanna River and post-license studies at Holtwood (FERC # 1881) and York Haven (FERC # 1888) upstream of Conowingo. Principle areas of responsibility include: up- and downstream fish passage, telemetry data analysis, fish biology, habitat-flow analysis, American eel passage, fisheries management plans, and fish passage facilities development.

SWCA, Inc. – Shortnose and Atlantic sturgeon habitat and protection plans for sewer line crossing construction on the Connecticut River, Springfield, Massachusetts.

Maine Rivers – relicensing of three projects on the Mousam River (FERC # 14856).

Kennebec Coalition – review and data analysis of downstream smolt radio telemetry studies (2012 – 2015) at four hydroelectric projects and the upstream fish passage plan at the Shawmut project on the Kennebec River (FERC #s 2574, 2611, 2322 & 2325).

Atlantic Salmon Federation – assist ASF with FERC relicensing of hydro projects on the Penobscot River, Maine (FERC #s 4202, 5912 & 2600). Review of study reports FERC filings for all listed projects and ongoing consultation with agencies and Brookfield Renewable Partners L.P.

Natural Resource Council of Maine – review and analysis of Biological Assessments, Species Protection Plans and Biological Opinions for Atlantic salmon on the Kennebec River, Maine.

Geosyntec consultants - Shortnose and Atlantic sturgeon habitat and protection plans for river bank stabilization on the Merrimack River, Haverhill, Massachusetts.

Member of the Holyoke Cooperative Consultation Team for the Holyoke Hydroelectric Project (FERC #2004). Post-licensing downstream fish passage planning including configuration of the downstream passage protection structure, review of CFD analysis, analysis of telemetry data of American shad, shortnose sturgeon, and American eel during post licensing studies.

Connecticut River Conservancy, February 2016 to May 2018

Relicensing of First light hydroelectric projects on the Connecticut River at Turners Falls (FERC # 1889) and the Northfield Mountain Pumped Storage Station (FERC #2485). Reviewed study plans, study reports, IFIM review, shortnose sturgeon spawning flow needs analysis, and shad telemetry analysis. Participated in settlement talks with company, state and federal agencies, and NGOs.

Santo Antônio , January 2010 to June 2011

TIRIS PIT tag installation, data analysis, and fish passage consultation for an experimental fish passage flume on the Rio Maderia, Brazil.

American Rivers, April 2010 to November 2011

Represented American Rivers for the relicensing of three projects on the Susquehanna River – Conowingo Dam, Muddy Run Pumped Storage Project and York Haven Dam. Participated in study plan development, reviewed study reports and prepared comment letters, attended meetings with the project owners, the FERC, state and federal agencies, and NGO's. Developed and independent analysis of American shad telemetry data at York Haven and Conowingo.

University of Massachusetts, Amherst MA January 1997 to January 2009

Research Assistant in the Department of Natural Resource Conservation working at the Silvio O. Conte Anadromous Fish Research Center. Areas of research include the behavior and movement of adult Atlantic salmon in the Westfield River in Massachusetts using radio telemetry, upstream passage of sturgeons and riverine fishes in a spiral fishway, spawning behavior of shortnose sturgeon in an artificial 'stream, and downstream passage of sturgeons at a bar rack and louver system with a low level bypass entrance.

Massachusetts Cooperative Fisheries and Wildlife Research Unit, University of Massachusetts, Amherst MA
March 1991 to January 1997

Project Leader for Anadromous Fish Investigations project. Duties include: hire and supervise technicians staffing the Holyoke, Turners Falls, and Westfield River fish passage facilities; conduct recreational angler creel surveys, Atlantic salmon habitat assessment, and juvenile growth and survival estimates; supervise stocking of Atlantic salmon fry for the Connecticut River basin in Massachusetts; coordinate Unit operations with utility companies and state and federal agencies; and prepare budgets and reports.

Education:

Undergraduate

Trinity College
Hartford, CT 1967-71, B.A.
Major: History
Specialty: American History

Continuing Ed.

Greenfield Community College
Photography I, II & III, Fall 1980-81
Engineering Drawing, Fall 1978
Drafting for Engineers, Spring 1979
Programming Principles and Concepts, Fall 2002
Advanced Basic for Programmers, Spring 2002
Database Programming and Procedures, Spring 2005
Advanced Database Programming, Spring 2006

University of Massachusetts, Amherst
Principles of Management, Fall 1981
Microeconomics, Fall 1980
Macroeconomics, Spring 1981
Social Conflicts and Natural Resources, Spring 1991
Biological Limnology, Fall 1991

Anadromous Fish, Fall 1991
Biostatistics, Fall 1991
Intermediate Biostatistics, Spring 1992
GIS, Spring 1992
Population Dynamics, Fall 1992
Animal Movement and Migration, Fall 1992
Coastal Zone Management, Spring 1993
Ichthyology, Fall 1993
Principles of Fisheries Stock Assessment, Spring 1994
Aquatic Invertebrates, Fall 1994
Freshwater Fisheries Management, 1997
Inland Fisheries Management, Spring 1999
Imaging in Fisheries Science, Fall 2000
Natural Resource Modeling, Spring 2001

American Fisheries Society Workshops
Fish Ageing, 1995
Stream Habitat Assessment, 1996

USFWS - National Education and Training Center
Principles and Techniques of Electrofishing, 1996

DOI-USGS – Motorboat Operator Certification Course, 2000

Certified S.O. Conte Anadromous Research Center dive team member

S.O. Conte Fish Research Projects:

Atlantic salmon behavior and movements in the Westfield River, Massachusetts 1996 to 1998 – wild adult Atlantic salmon returning to the Westfield River were internally radio tagged and released into the upper Westfield River. Fish were tracked with fixed stations and with manual tracking. Movement, habitat choice, spawning, and post-spawning behavior were evaluated. Domestic broodstock Atlantic salmon were also radio tagged and released to assess their spawning potential to contribute to the salmon restoration effort in the Connecticut River basin.

Spiral fishway 2001 to 2007 – evaluation of a spiral, side baffle fishway designed for upstream sturgeon fish passage. Sturgeon, a benthic fish, need a fishway that allows upstream movement while maintaining close proximity to the bottom of the fishway. The spiral uses side baffles to reduce velocity and provide depth allowing fish to move in a sinusoidal curve along the bottom of the channel. Sturgeon movement was evaluated with a PIT tag system detecting fish at the entrance and exit of the fishway and at four points along each of two loops. Riverine fish were also evaluated in the spiral fishway.

Shortnose sturgeon spawning behavior 2002 to 2008 – the spawning behavior of wild Connecticut River shortnose sturgeon was evaluated in an artificial stream. Mating behavior, mate choice, velocity preference, egg to larvae survival, and embryo and larval dispersal timing were evaluated.

Downstream passage and behavior studies of shortnose sturgeon 2004 and 2005 – yearling, juvenile and adult shortnose sturgeon were evaluated for swimming depth, behavior at and movement along a bar rack, entrainment and impingement, and willingness to enter an opening in the bar rack at three different approach velocities. Pressure sensitive (depth) and radio tags were used to assess swimming depth for both upstream and downstream movement in a 20' by 120' flume with a velocity of 1 ft/sec. PIT tags and video were used to assess individual fish movement and behavior at a bar rack oriented 90° to flow at velocities of 1, 2 and 3 ft/sec.

Downstream movement of yearling shortnose sturgeon 2004 and 2006 – yearling shortnose sturgeon (Connecticut River stock in 2004 and Savannah River stock in 2006) were evaluated in a large outdoor oval channel with a river stone substrate to determine the timing, frequency and duration of upstream and downstream movements. Fish were tested for 48 hours on a monthly basis from June through November. PIT tags and five antennas were used to determine movement.

Low level orifice use of sturgeon at an angled bar rack and louver 2006 to 2008 – green, lake, Savannah and Connecticut River shortnose sturgeon of different year classes were tested in a 10' by 120' flume at two bar rack angles (45° and 30°) and one louver angle (26°) with two velocities at the orifice. Approach velocity (2 ft/sec) and water depth (7.5') remained constant for all trials. Fish were tested both day and night. Video and PIT tags were used to determine individual fish movement, behavior at the bar rack and passage through the orifice and pipe which transported fish downstream to a holding area.

Past Relicensing Projects:

Bear Swamp Hydroelectric Project – FERC # 2669

Relicensing of project through the ILP.

Deerfield River Project – FERC # 2323, License issued 1997

Deerfield River Compact – precursor to relicensing, all stakeholders in relicensing, including New England Power Co., met on a regular basis to discuss issues. Final report issued.

Deerfield River Settlement – followed the conclusion of the Deerfield River Compact with similar discussions as to the issues involved in relicensing with the goal of reaching agreement on environmental mitigation prior to issuing or license. Represented Trout Unlimited in meetings with state and federal agencies, New England Power Co. and other NGO's which reached an agreement that was incorporated into and was the basis of relicensing by the FERC.

Holyoke – FERC # 2004, Connecticut River

Relicensing of project – bypass minimum flows, downstream fish passage (salmon smolts, adult Atlantic salmon, American eels, clupeids, and riverine fish), upstream passage (adult Atlantic salmon, clupeids, American eels, and riverine fish) freshwater mussel protection, flow priorities (bypass reach, canal, up- and downstream fish passage, hydrogenation, run of river protection of federally threatened tiger beetle), and disabled angler fishing access.

Comments to both company and the FERC concerning above listed issues.

Participant in CCT meetings representing Trout Unlimited concerning above listed issues. CCT consists of Holyoke Gas & Electric (project owners), state and federal agencies, and NGO's (Trout Unlimited and Connecticut River Watershed Council).

Indian River – FERC # 12462, Westfield River

Licensing of project – bypass minimum flows, freshwater mussel protection, downstream fish passage (salmon smolts, adult Atlantic salmon, American eels, riverine fish), upstream passage for American eels.

Participation in ongoing fish passage discussions regarding both up- and downstream passage issues.

L.S. Starrett Co. – FERC # UL09-01, Millers River

Installation of new turbine initiated local Conservation Commission and Massachusetts Department of Environmental Protection actions presently on hold due to a FERC order of jurisdiction dated October 21, 2009.

Intervened in Massachusetts Department of Environmental Protection appeal by Starrett of a Superseding Order of Conditions.

Commented to the FERC concerning Starrett Motion for Stay of Order of Jurisdiction regarding downstream fish passage.

Muddy Run Pumped Storage Project – FERC # 2355, Susquehanna River. Contracted by Maryland Power Plant Project to provide biological and fish passage assistance during relicensing and post licensing. Principle issues are entrainment and the impact of the project on river flows.

New Home Dam Project – FERC # 6096, Millers River

Post licensing flow issues - run of river requirement.

Northfield Mountain Pumped Storage Project – FERC # 2485, Connecticut River

License amendment allowing more storage in upper pond. River bank erosion concerns. Amendment application withdrawn.

Woronoco – FERC # 2631, Westfield River

Relicensing of project and 401 certification – bypass minimum flows, freshwater mussel protection, downstream fish passage (salmon smolts, adult Atlantic salmon, American eels, riverine fish), upstream passage for American eels, and recreation issues.

Analyzed telemetry data from downstream smolt test to provide independent review of results.

York Haven – FERC # 1888, Susquehanna River

Contracted by Maryland Power Plant Project to provide biological and fish passage assistance during relicensing. Relicensing is currently involved in settlement discussions with project owner, Olympus Power. Principle issues are up- and downstream fish passage for American shad and American eel and bypass flows.

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Exhibit B

Table 7.1.1.2-2: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 1 (Transects 10 & 11) for High Backwater Condition																						
Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft ²)	120 (cfs)	150 (cfs)	200 (cfs)	250 (cfs)	400 (cfs)	500 (cfs)	600 (cfs)	700 (cfs)	800 (cfs)	1000 (cfs)	1200 (cfs)	1400 (cfs)	1600 (cfs)	1800 (cfs)	2000 (cfs)	3000 (cfs)	4000 (cfs)	5000 (cfs)
					0.02 (cfsm)	0.02 (cfsm)	0.03 (cfsm)	0.03 (cfsm)	0.06 (cfsm)	0.07 (cfsm)	0.08 (cfsm)	0.1 (cfsm)	0.11 (cfsm)	0.14 (cfsm)	0.17 (cfsm)	0.2 (cfsm)	0.22 (cfsm)	0.25 (cfsm)	0.28 (cfsm)	.42 (cfsm)	0.56 (cfsm)	0.7 (cfsm)
American Shad	Juvenile	June-Oct	2,000	668,444	43.9%	47.7%	53.5%	58.6%	52.9%	55.3%	57.5%	59.2%	61.2%	64.6%	74.4%	83.0%	88.7%	94.4%	100.0%	95.5%	88.1%	80.6%
Fallfish	Juvenile	Year Round	1,800	260,011	57.8%	63.6%	71.2%	77.0%	73.3%	74.3%	76.2%	77.6%	79.5%	82.8%	89.5%	93.4%	98.0%	100.0%	99.5%	80.4%	61.6%	44.0%
Fallfish	Adult	Year Round	2,000	549,907	67.5%	70.9%	76.2%	80.6%	75.7%	75.7%	71.2%	67.1%	63.5%	59.8%	70.4%	80.6%	86.7%	93.4%	100.0%	89.6%	74.3%	60.5%
Longnose Dace	Juvenile	Year Round	1,800	155,504	13.0%	16.4%	22.0%	27.6%	23.1%	27.7%	31.3%	34.2%	37.4%	44.0%	64.0%	81.7%	95.7%	100.0%	94.9%	39.8%	12.7%	3.6%
Longnose Dace	Adult	Year Round	2,000	413,608	9.3%	11.7%	15.8%	19.8%	16.1%	18.5%	20.4%	22.8%	25.4%	31.5%	51.4%	69.4%	84.2%	94.0%	100.0%	54.4%	17.0%	4.2%
White Sucker	Adult/Juvenile	Year Round	250	362,803	75.0%	85.5%	95.4%	100.0%	82.0%	71.1%	60.5%	50.9%	43.7%	45.5%	63.6%	77.0%	78.1%	73.4%	63.4%	29.9%	8.2%	2.6%
Walleye	Juvenile	Year Round	120	870	100.0%	82.4%	52.9%	32.4%	26.5%	23.5%	17.6%	14.7%	11.8%	8.8%	4.7%	3.5%	3.5%	2.4%	2.9%	0.0%	0.0%	0.0%
Walleye	Adult	Year Round	120	36,453	100.0%	80.4%	48.8%	24.5%	19.4%	15.8%	13.0%	12.9%	12.9%	13.1%	13.5%	14.1%	14.6%	14.9%	15.6%	20.0%	14.3%	4.4%
Tessellated Darter	Adult/Juvenile	Year Round	1,800	133,736	12.2%	15.4%	20.9%	26.5%	18.0%	22.0%	26.7%	31.9%	36.7%	45.3%	66.1%	84.5%	98.2%	100.0%	96.7%	28.7%	0.9%	0.0%
Macroinvertebrates	Larva	Year Round	4,000	918,412	0.0%	0.1%	0.4%	0.9%	6.0%	10.0%	14.0%	17.7%	21.3%	26.9%	30.4%	36.1%	44.7%	55.2%	67.1%	91.6%	100.0%	97.6%
Shallow Slow	Shallow Slow	Year Round	700	818,354	93.6%	94.1%	95.4%	97.1%	96.6%	97.5%	98.3%	100.0%	100.0%	93.0%	80.8%	78.2%	75.5%	71.7%	68.0%	21.5%	0.0%	0.0%
Shallow Fast	Shallow Fast	Year Round	1,600	535,297	24.8%	30.7%	40.4%	49.7%	26.1%	31.1%	36.2%	41.7%	49.0%	63.3%	83.5%	96.4%	100.0%	97.1%	88.9%	32.3%	9.1%	2.9%
Deep Slow	Deep Slow	Year Round	500	615,160	90.7%	91.4%	93.3%	95.7%	96.1%	100.0%	88.5%	65.6%	59.0%	67.0%	73.3%	78.9%	80.3%	64.2%	54.8%	22.2%	3.6%	1.2%
Deep Fast	Deep Fast	Year Round	3,000	124,411	2.4%	6.7%	15.0%	23.1%	37.8%	53.4%	69.1%	79.4%	82.8%	89.5%	88.3%	89.1%	91.6%	94.4%	99.6%	100.0%	89.8%	52.9%

Exhibit C

Habitat in square feet for species and life stages present in Reach 1 from July 1 to November 15 as calculated from Table 7.1.1.2-2 (Exhibit B).

Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft2)	120 (cfs)	150 (cfs)	200 (cfs)	250 (cfs)	400 (cfs)	500 (cfs)	600 (cfs)	700 (cfs)	800 (cfs)	1000 (cfs)	1200 (cfs)	1400 (cfs)	1600 (cfs)	1800 (cfs)	2000 (cfs)	3000 (cfs)	4000 (cfs)	5000 (cfs)
					0.02 (cfsm)	0.02 (cfsm)	0.03 (cfsm)	0.03 (cfsm)	0.06 (cfsm)	0.07 (cfsm)	0.08 (cfsm)	0.1 (cfsm)	0.11 (cfsm)	0.14 (cfsm)	0.17 (cfsm)	0.2 (cfsm)	0.22 (cfsm)	0.25 (cfsm)	0.28 (cfsm)	.42 (cfsm)	0.56 (cfsm)	0.7 (cfsm)
American Shad	Juvenile	June-Oct	2,000	668,444	293,447	318,848	357,618	391,708	353,607	369,650	384,355	395,719	409,088	431,815	497,322	554,809	592,910	631,011	668,444	638,364	588,899	538,766
Fallfish	Juvenile	Year Round	1,800	260,011	150,286	165,367	185,128	200,208	190,588	193,188	198,128	201,769	206,709	215,289	232,710	242,850	254,811	260,011	258,711	209,049	160,167	114,405
Fallfish	Adult	Year Round	2,000	549,907	371,187	389,884	419,029	443,225	416,280	416,280	391,534	368,988	349,191	328,844	387,135	443,225	476,769	513,613	549,907	492,717	408,581	332,694
Longnose Dace	Juvenile	Year Round	1,800	155,504	20,216	25,503	34,211	42,919	35,921	43,075	48,673	53,182	58,158	68,422	99,523	127,047	148,817	155,504	147,573	61,891	19,749	5,598
Longnose Dace	Adult	Year Round	2,000	413,608	38,466	48,392	65,350	81,894	66,591	76,517	84,376	94,303	105,056	130,287	212,595	287,044	348,258	388,792	413,608	225,003	70,313	17,372
White Sucker	Adult/Juvenile	Year Round	250	362,803	272,102	310,197	346,114	362,803	297,498	257,953	219,496	184,667	158,545	165,075	230,743	279,358	283,349	266,297	230,017	108,478	29,750	9,433
Walleye	Juvenile	Year Round	120	870	870	717	460	282	231	204	153	128	103	77	41	30	30	21	25	0	0	0
Walleye	Adult	Year Round	120	36,453	36,453	29,308	17,789	8,931	7,072	5,760	4,739	4,702	4,702	4,775	4,921	5,140	5,322	5,431	5,687	7,291	5,213	1,604
Tessellated Darter	Adult/Juvenile	Year Round	1,800	133,736	16,316	20,595	27,951	35,440	24,072	29,422	35,708	42,662	49,081	60,582	88,399	113,007	131,329	133,736	129,323	38,382	1,204	0
Macroinvertebrates	Larva	Year Round	4,000	918,412	0	918	3,674	8,266	55,105	91,841	128,578	162,559	195,622	247,053	279,197	331,547	410,530	506,963	616,254	841,265	918,412	896,370
Shallow Slow	Shallow Slow	Year Round	700	818,354	765,979	770,071	780,710	794,622	790,530	797,895	804,442	818,354	818,354	761,069	661,230	639,953	617,857	586,760	556,481	175,946	0	0
Shallow Fast	Shallow Fast	Year Round	1,600	535,297	132,754	164,336	216,260	266,043	139,713	166,477	193,778	223,219	262,296	338,843	446,973	516,026	535,297	519,773	475,879	172,901	48,712	15,524
Deep Slow	Deep Slow	Year Round	500	615,160	557,950	562,256	573,944	588,708	591,169	615,160	544,417	403,545	362,944	412,157	450,912	485,361	493,973	394,933	337,108	136,566	22,146	7,382
Deep Fast	Deep Fast	Year Round	3,000	124,411	2,986	8,336	18,662	28,739	47,027	66,435	85,968	98,782	103,012	111,348	109,855	110,850	113,960	117,444	123,913	124,411	111,721	65,813

December 7, 2016

MEMORANDUM

To: Andrea Donlon, CRWC
David Deen, CRWC

From: Laura Wildman, P.E., Princeton Hydro, LLC
Paul Woodworth, Fluvial Geomorphologist, Princeton Hydro, LLC
Melinda Daniels, PhD, Fluvial Geomorphologist, Stroud Water Research Center

Re: **FERC Re-Licensing Process for FirstLight Power Resources Inc.
Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations
Impact on Existing Erosion and Potential Bank Instability Study Report (October 2016)
Princeton Hydro Bullet List of Major Points**

The Connecticut River Watershed Council (CRWC) is a stakeholder and participant in the re-licensing process of the Federal Energy Regulatory Commission (FERC) for two hydropower facilities owned by FirstLight Power Resources Inc. on the Connecticut River, Northfield Mountain and Turners Falls Operations. Princeton Hydro, with the Stroud Water Research Center, was retained by CRWC to complete a peer-review of Relicensing Study 3.1.2, Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report, Volume I – Executive Summary and Summary Report, Volume II – Main Report, and Volume III – Appendices, dated October 2016. As part of this work, we reviewed the Revised Study Plan (RSP), dated August 14, 2013, and the FERC Study Plan Determination dated September 13, 2013. Revisions to the approved RSP were made by FirstLight to incorporate an analysis of the effects of icing (see Initial Study Report dated September 15, 2014). In addition, the Updated Study Report dated September 14, 2015 indicated that the study methods for the boat wave analysis deviated from the RSP, and that boat wave sensors were installed along the river¹.

FRAMEWORK FOR THIS PEER REVIEW

Our comments have been structured to address the questions outlined within the Integrated Licensing Process (ILP) regulations 18 CFR § 5.15(d)(1) regarding Conduct of Studies, specifically:

Were the studies completed as per the Revised Study Plan?

1. Were the objectives set in the Revised Study Plan (RSP) met?
2. Was the analysis described in the RSP conducted? And if not, what was omitted.
3. Were the methods described in the RSP utilized?
4. Was the Study conducted in a manner consistent with generally accepted scientific practice?

¹ Our review was limited to the RSP and Relicensing Study 3.1.2, Volumes I through III. No field work was conducted as part of our review, so we cannot comment if the observations stated in the study accurately reflect field conditions within the project reach, and if the observations were applied in an impartial manner. In addition, we did not review the numerous other studies submitted to FERC as part of FirstLight's recent submittal.

5. Were the conclusions of the study consistent with the scientific evidence presented?
6. Were the deliverables promised in the RSP included in the final study report submittal?

As stated in the RSP, the goal of Study 3.1.2 is to “evaluate and identify the causes of erosion in the Turners Falls Impoundment and to determine to what extent they are related to Project operations.” Due to the complexity of the study and the length of the report volumes, our review primarily focused on two of the objectives to meet the study goal:

- “Identify the causes of erosion present in the Turners Falls Impoundment, the forces associated with them, and their relative importance at a particular location. Conduct various data analyses to gain a better understanding of these causes and forces”
- “Conduct detailed studies and analyses of erosion processes at the fixed riverbank transects”
- “Evaluate the causes of erosion using the field collected data and the results of the proposed data analyses. This evaluation will include quantifying and ranking all causes present at each fixed riverbank transect as well as in the Turners Falls Impoundment in general.”

We have focused this memorandum summarizing our peer review into four primary categories. These categories are:

1. **Problems with the Analysis** – This section reviews specific problem areas regarding how the analysis proposed in the RSP was conducted.
2. **Omissions in the Analysis** – This section relates to omissions in the analysis.
3. **Problems with the Extrapolation Methodology** – This section reviews the methodology proposed and then how it was applied and expanded from the RSP.
4. **Validity of the Study Conclusions** – This section reviews the validity and impartiality of the conclusions resulting from the field data collection, analysis and methodology applied to synthesize and summarize the data.

For ease of review of this memorandum we have italicized, placed in quotes, and referenced page numbers for any text taken directly from the Revised Study Plan (RSP) and the Relicensing Study 3.1.2.

PROBLEMS WITH THE ANALYSIS

The Bank-Stability and Toe-Erosion Model (BSTEM) was used in the Relicensing Study 3.1.2 to understand the effects of hydraulic shear stress due to flowing water and the impact of water level fluctuations as related to the constant wetting and drying of the banks, and to quantify the relative percentages due to different causes of erosion, and to compare the results for the different causes analyzed. The use of BSTEM is consistent with the analysis proposed in the RSP. We agree that a BSTEM analysis is a generally accepted scientific practice appropriate for the proposed analysis.

However, we did find several problem areas with the BSTEM analysis. These either prevent us from being able to evaluate whether or not the work is consistent with generally accepted scientific practice, or indicate to us that the study goals were not met. We offer the following comments regarding the application of the BSTEM model by FirstLight and their consultants to assess the causes of erosion for the Turners Falls Impoundment (TFI).

1. **Difficult to review:** It was difficult to review the results of the BSTEM model without actually being given the input and output files, as well as the version of the program used for this assessment. There were multiple output graphs missing that might have helped in a more detailed review of this modeling effort, as discussed throughout this review.

In addition, the low resolution of multiple figures, particularly in Section 5 of Volume II, made them nearly impossible to read. Specifically, bank cross-section figures presented in Section 5.4.3 BSTEM Simulation Results were too pixelated and of low resolution to discern where the lines were overlapping or not, for the different model runs/simulations. The figure on page 364 of Volume II is an important figure to demonstrate impacts of water surface elevation (WSE) fluctuation but again was hard to read and does not seem to be repeated for all the cross-sections (also on page 410). This makes understanding and interpreting these results extremely difficult.

Recommendation: 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.

2. **The Comparison of Erosion Rates by Volume of Material Eroded, Disregards Cyclical Erosion Process:** BSTEM analysis distinguishes ‘hydraulic erosion’ from ‘geotechnical erosion’ and calculates the volume eroded by each separately (Volume 1, page 43 and PDF page 51). The Relicensing Study 3.1.2 then takes these volumetric results and assesses each as a percent contribution to erosion (i.e. the larger the volume of sediment eroded from the bank for a given cause, the larger the percentage it is granted as a contributing cause). However, this approach seems to overlook the cyclical nature of this process, and disregards the causal relationship between the two modes of erosion. Specifically, hydraulic erosion at the toe of a bank can lead to geotechnical failure, which in turn can re-set the erosion process whereby hydraulic erosion then becomes dominant again, as noted on Figure 5.1.3-7, Volume II, page 5-22 [PDF page 305]). The importance of one mode of erosion (i.e. causes that initiate erosion at the toe of the bank) should not be dismissed based solely on the volume of material eroded, especially when it may instigate or perpetuate the cycle of erosion that later leads to a bank failure, for which this assessment would attribute only to a high flow event. Figure 5.1.3-7 in the Relicensing Study 3.1.2 also depicts how lower bank hydraulic erosion leads to upper bank geotechnical failure; therefore without lower bank erosion, the upper bank would remain stable. The volumetric approach transferred to percentages does not seem to allow for an assessment of the connectivity of causes.

Recommendation: 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.

3. **WSE Fluctuation Precludes Riverbank Vegetation:** Daily water surface fluctuations can preclude the establishment of stabilizing vegetation. The BSTEM analysis conducted did not include the likely change in geotechnical conditions of the bank if permanent vegetation were allowed to become established. This lack of vegetation likely occurs at the toe of the bank or the lower bank, where hydraulic erosion is likely greatest even at higher flows.

Recommendation: 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.

4. **Upper and Lower Bank Terms are Used Inconsistently:** The report states that WSE fluctuation only acts on lower bank, or what the Study refers to as the beach area on page 5-208 and 5-217 in Volume II, but multiple graphs show it acting at toe of bank, “the intersection of upper and lower bank” according to their definitions.

In addition, the lower bank definition used throughout the report is problematic. The beach-like lower bank identified, is not a bank feature but instead is a wave-cut terrace platform resulting from long-term erosion at the water surface. Water stage fluctuations correspond to this “lower bank” surface as indicated by plots of stage versus bank profiles. Photographs of these features clearly show ripples parallel to the upper, true, bank indicating wave motion and sediment transport perpendicular to the upper bank. The water contact point at the junction between upper and “lower” banks will continue to be a focus for wave/ice erosion.

Recommendation: 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.

OMISSIONS IN THE ANALYSIS

We offer the following comments regarding omissions in the analysis as prepared for the Relicensing Study 3.1.2., as per what was proposed for analysis in the Revised Study Plan (RSP).

5. **No Model Run Isolates the Effects of the Turners Falls Operations:** While the primary objective of this study was to “evaluate and identify the causes of erosion in the Turners Falls Impoundment (Connecticut River) and to determine to what extent they are related to Northfield Mountain and Turners Falls Project Operations” (Volume 1, page *i* [PDF page 2]), there was no analysis of data or a numerical modeling run that specifically targeted (e.g. by isolation or exclusion) the impacts of Turners Falls operations (Volume 1, page 26 [(DF page 34)]). Hydraulic modeling and the Bank Stability Toe Erosion Model (BSTEM) was utilized to analyze existing conditions, along with the impacts of waves, and the Northfield Mountain Project operations, which were isolated in “Scenario 1”. Northfield Mountain operations account for only 2 feet of WSE fluctuation during low flow (Volume 1, page 19). While the label “Scenario 1” implies that subsequent scenarios should follow, no comparable model run was performed that specifically targeted Turners Falls operations that would have provided a basis for comparison. Nor was there a run with all operation related WSE fluctuation “turned off”, such that the impacts of the combined operational WSE fluctuations could be assessed. Without analyzing this additional modeling scenario (e.g. a “Scenario 2” or “Scenario 3”), the overall conclusions of this study are incomplete. 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). This additional scenario could be assessed by isolating erosion caused by high flows from its co-dependence on destabilizing toe erosion. For example, a scenario should be run where the toe of bank is stabilized for each site, compared to Baseline Conditions for all sites (excluding the restored versions of the sites) such that erosion rates can be assessed where relatively

minor erosion at the toe is instigating future erosion at high flows. In absence of creating a scenario where all the toes of the streambank have been artificially stabilized, this could perhaps be assessed by comparing the sites that have both pre-stabilization and post-stabilization data, and determine if the toe stabilization implemented at these sites did, in fact, reduce the sites potential for erosion during both low and high flows.

Recommendation: 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.

6. Large Portions of the Turners Falls Impoundment Remain Unassessed:

Multiple additional runs and analysis seem to still be needed in BSTEM in order to complete the assessment proposed in the Revised Study Plan, see gaps shown in the table below. Many of these gaps were justified in the Study 3.1.2 Report under the rationale that operations only impacted the reach in which they were designated because of the use of the Energy Grade Line and the report’s focus on the impacts of high flow. As previously stated, we do not agree with the application of the EGL assessment to justify the exclusion of reaches from analysis and we do not agree that operational WSE impacts are limited to the reaches where the facilities exist, since the analysis shows these impacts extending throughout the TFI. See table below that highlights the reaches not assessed in the Study 3.1.2 Report.

<i>Primary Cause of Erosion</i>	<i>Reach 1 (Near Turners Falls Dam)</i>	<i>Reach 2 (Vicinity of NFM tailrace)</i>	<i>Reach 3</i>	<i>Reach 4 (Downstream of Vernon Dam)</i>
Moderate or High Flows	Assessed	Assessed	Assessed	Assessed
Boat (Waves)	Assessed	Assessed	Assessed	Assessed
Vernon Operations	Not Assessed	Not Assessed	Not Assessed	Assessed (but discounted for lower half of reach)
Northfield Mountain Operations	Not Assessed	Assessed (but discounted, even though model output showed significant impact)	Not Assessed	Not Assessed
Turners Falls Operations	Assessed, qualitatively, without BSTEM	Not Assessed	Not Assessed	Not Assessed
Land Use	Assessed qualitatively only			
Ice	Assessed qualitatively by visual observation only			

Recommendation: 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.

7. 2D Modeling Not Used: Previous comments were submitted by USFWS dated 1/12/16 regarding channel roughness and the use of the 2D modeling prepared for Study 3.3.9. It is unclear in reading

the Relicensing Study 3.1.2. if these corrections relating to the calibration of the roughness coefficients were implemented for the River2D model proposed for use in the RSP for this study. These corrections are critical, especially as they related to composite friction coefficients and the near bank velocity and shear stress computations. 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.

The RSP in Task 5a stated on page 3-41 that, *“Both HEC-RAS and RIVER2D modeling will be used to analyze near-bank velocity to determine shear stress along the bed and riverbanks. RIVER2D computes velocity vectors showing the magnitude and direction of velocity across the channel at each node representing the channel geometry. Of particular interest are the velocity vectors in the near-bank region where the flow of water directly affects the bank. At the fixed riverbank transects, the velocity vectors will be determined over a range of flow conditions.... Results of RIVER2D will allow the analysis to focus on the region of the flow next to the banks where flowing water exerts hydraulic forces that directly affect the riverbanks.”* 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.

Recommendation: 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.

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 Conditions 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-electric operations.

Recommendation: 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.

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 (11/28/16) 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 observation were conducted at one location only, approximately 50 feet away from the Connecticut River.

Recommendation: 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.

10. **No Assessment of Downstream Impacts:** Given that the Study 3.1.2 Report includes an analysis and determination of impacts due to the upstream Vernon Dam operations on the TFI, it would follow that WSE fluctuations cause by the releases at the Turners Falls Dam are potentially impacting reaches downstream of the Turners Falls Dam. While the study added an assessment of the Vernon operation, the study does not assess the impacts on bank erosion that the Turners Falls Dam operations have on the reach downstream of Turners Falls Dam, and we recognize that assessment of the downstream reach was not included in the RSP. However because the Study 3.1.2 results do demonstrate that the Vernon operations impact streambank erosion within the TFI, it would follow that in a complete assessment of operational impacts due to TF and NFM on streambank erosion would include the reach downstream of Turners falls Dam..

Recommendation: 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.

PROBLEMS WITH THE EXTRAPOLATION METHODOLOGY

In the Study 3.1.2 Report, the BSTEM analysis at each of the transects was extrapolated out into the entire reach of the streambanks between the Turners Falls Dam and the Vernon Dam. The RSP in Task 6 stated simply that, “This evaluation will include quantifying and ranking the primary causes of erosion present at each fixed riverbank transect as well as in the Turners Falls Impoundment in general.” Therefore, the RSP provided no detail as to the methodology of the extrapolation process. Our review focuses on this methodology and identifies several flaws.

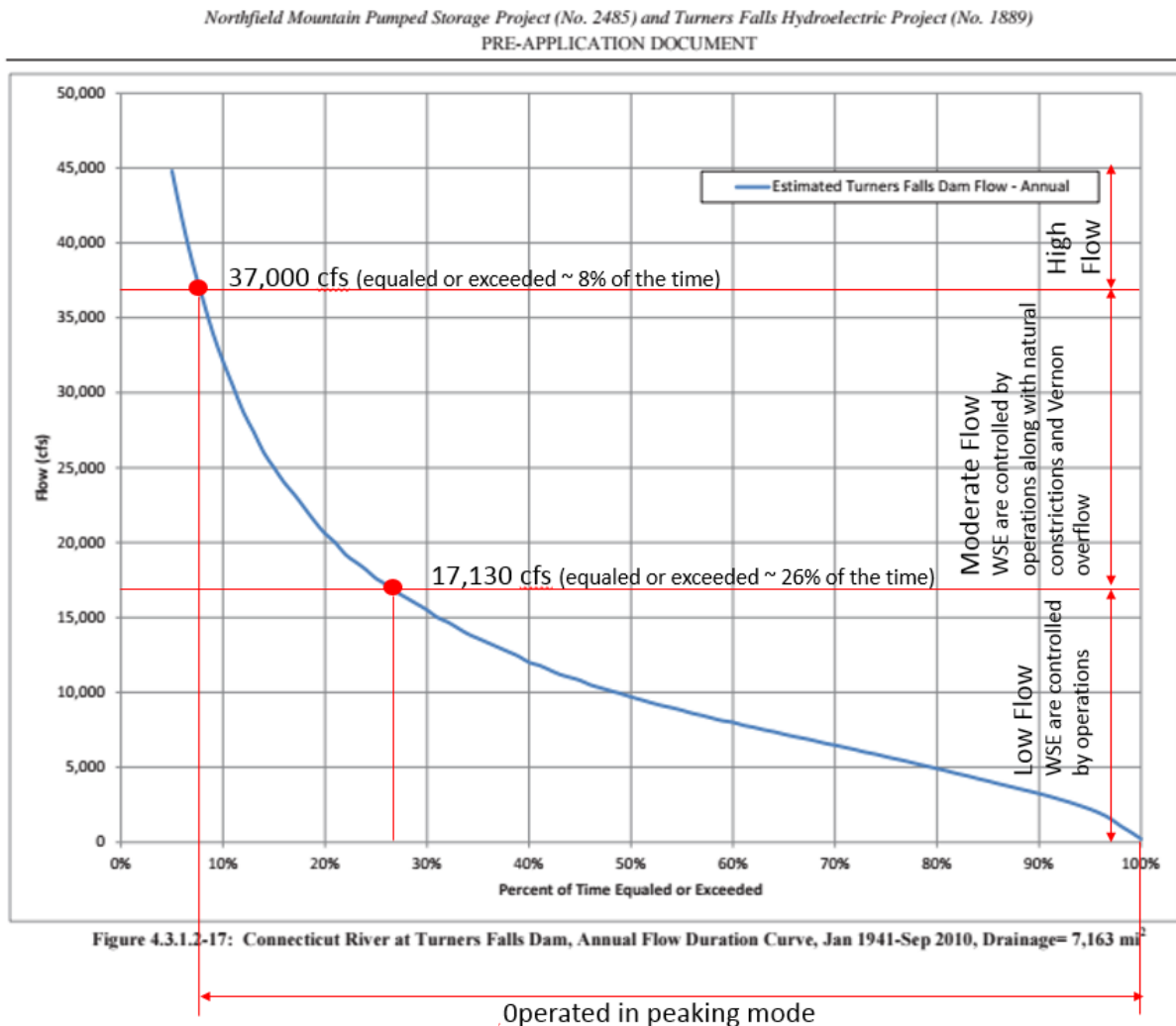
The following section regarding our review of the extrapolation methodology is divided into 7 sections, based on the 8 steps included in the extrapolation methodology utilized in the Relicensing Study 3.1.2, (summarized on pages 45-51 of Volume I); the final two steps have been grouped into one section. We start each section by briefly describing the methodology included for the step we are reviewing (shown in *italics* under the bolded name of the step), followed by our peer review comments regarding the implementation of the methodology for that step and our recommendations.

11. Step 1: Analyze the variability of hydraulic forces throughout the TFI

This step defines the hydraulic reaches and limits the analysis based on them

We do not agree with the determination that operations only impact the reach in which they have been allotted to in the Relicensing Study 3.1.2 (i.e. TF to Reach 1, NFM to Reach 2, and Vernon to Reach 4). The Energy Grade Line (EGL) approach described appears to only apply when looking at impacts associated with high flow (>37,000) where the 1-dimensional velocity and sheer stresses determined through HEC-RAS play a dominant role in erosion. The report is clear that for flows below 37,000 cfs (moderate and low flows as per their definition), which occur over 90% of the time according to Figure 4.3.1.2-17 from the October 30, 2012, PRE-APPLICATION DOCUMENT (see figure that follows), the hydroelectric operations of Turners Falls and Northfield Mountain are both controlling factors for the WSE elevation fluctuation throughout the entire TFI, and that for flows below 17,130 cfs, Turners Falls, Northfield Mountain, and Vernon operations are the dominant influence controlling WSE fluctuation throughout the entire TFI. The analysis should not be limited based on hydraulic reaches that only seem applicable for high flows when over 90% of the time the flows in the TFI are lower than the defined high flow, and almost all of the WSE fluctuation caused by the combined hydropower operations is happening below the defined high flow, which is only equaled or exceeded less than 10% of the time.

Figure 4.3.1.2-17 from the October 2012 Pre-Application Document: Shows the Annual Flow Duration Curve for the Connecticut River at Turners Falls Dam. We have overlain the high moderate and low flow thresholds, as described by the Relicensing Study 3.1.2 and their associated percentage of time equaled or exceeded.



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 as per USFWS recommendations (1/12/16). Once corrected the 2D analysis would have provided more accurate near-bank hydraulic forces.

In addition, since stage-discharge relationships could not be determined for the Turners Falls Dam operations and limited study site data was available in the lower reach, the Turners Falls Dam operations were not assessed in a similar manner to Northfield Mountain operations, where operations were turned “off” or “on” and scenarios were then directly compared. Instead the TF operations were completely ruled out based on a series of assumptions and observations that were not quantifiable. This has been discussed in our comments #6 and #7 as well. Furthermore the USDA (11/28/16) review 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 Turner Falls operations to be analyzed in a similar manner as was the Northfield Mountain operations.

The use of the energy grade line approach to segment reaches and assess only the reaches where the operations were located, was not included as part of the methodology described in the Revised Study Plan (page 3-40 to 3-41). Nor was the conversion of stage values to discharge values, to calculate erosion exceedance probabilities, included in the RSP. Therefore these two approaches within the methodology were not previously reviewed or agreed upon by the stakeholders.

Recommendation: 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.

12. Step 2: Analyze and review the site specific BSTEM results

This step defines which study sites are dominant or contributing

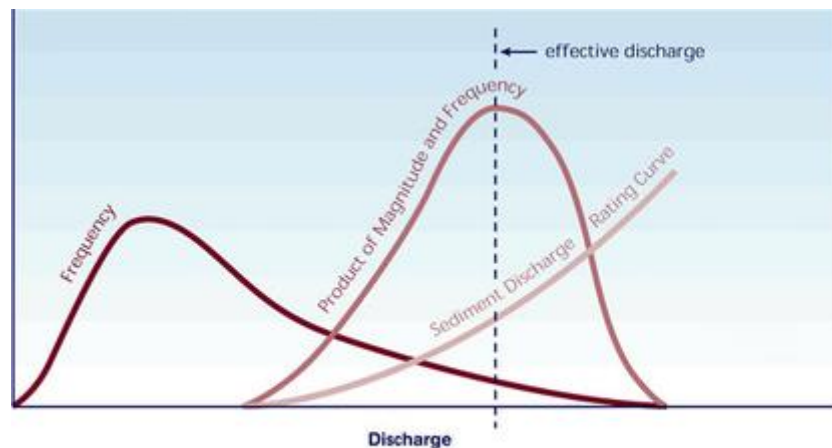
While the RSP stated that both primary and secondary causes of erosion would be assessed, it did not give a definition of those terms. The Relicensing Study 3.1.2 now renames these causes to dominant primary, contributing primary and secondary causes (page 621-622 of Vol II). It then arbitrarily defines the dominant primary as “one that is responsible for 50% (or >50%) of the erosion at a cross-section” and the contributing primary as being responsible for between 50% and 5% of the erosion at a cross-section. This was not described in the Revised Study Plan, nor was it agreed to by the stakeholders. These definitions are arbitrary in nature, lead to dismissing lesser but still important causes, and disregard multiple site specific impact results that come very close to the 5% limit that are associated with operational WSE fluctuations. Once a cause has been dismissed as not being a “dominant primary cause” it is then interpreted as 0% in the subsequent steps of the assessment. This is just one example where the Relicensing Study 3.1.2 uses arbitrarily assigned thresholds, not included in the Revised Study Plan, that potentially introduce bias to the results and limit what is truly being assessed (other examples include the flow thresholds, and the delineation of hydraulic reaches). Later in the Relicensing Study 3.1.2 (as shown on page 38 Vol 1) the document classifies the sites having “measurable/significant rates of bank erosion” by stating “[I]n order to be classified as having measurable/significant rates of bank erosion, the rate of erosion at a given site must be greater than the erosion rate that represents the lowest 5% of all rates or 0.163 ft³/ft/yr.” Again the threshold

applied seems arbitrary and in this case includes restored sites with little erosion post stabilization of the toe of bank.

It is noted that the use of these arbitrary thresholds to define dominant primary and contributing causes, as well as to define what are measurable/significant rates of bank erosion, was not included as part of the methodology described in the Revised Study Plan, and therefore the use of these thresholds was never agreed upon by the stakeholders or FERC.

In addition, step 2 of the methodology weighs anthropogenic factors against the significant river-forming natural processes, which significantly biases the results because the volumetric values associated with erosion of a particular type (i.e. WSE fluctuation) are converted to relative percentages and compared against the contributing percentages that are associated with natural river-forming processes. This approach ends up dismissing anthropogenic impacts such as WSE fluctuation merely because volumetrically they do not compare to the natural forming processes of a river. This approach also does not seem to adequately account for key causes that initiate larger bank stability issues as described in our review comment #2 and #6.

By lumping natural sediment transport/erosion processes (i.e. the effects of high flow events) with anthropogenic causes of erosion (i.e. WSE fluctuation due to operations) when determining the final percentages, and basing these percentages on a comparison of volumetric estimates of erosion, critical anthropogenic causes are discounted just because they do not compare in magnitude to the natural forming processes of a river. While the RSP does say they will assess the impacts of high flow, the final result is that they have proved that rivers are primarily formed by flow, and that the highest percentage of channel formation (i.e. sediment transport and erosion) is accounted for during higher flow events. These are all things we already know about rivers based on simplified theories of effective discharge (see graph below).



From Wolman and Miller, 1960.

Fig. 7.5 – Effective discharge determination from sediment rating and flow duration curves. In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98. Interagency Stream Restoration Working Group (ISRWG)(15 Federal agencies of the US).

However, studies conducted under the Integrated Licensing Process (ILP) are geared towards evaluating impacts of project operations on streambank erosion and if these impacts instigate additional long-term erosion. For example we know that the sun heats the earth, we also know that climate change due to anthropogenic impacts is a reality. However, if we were to compare the percent increase in warming due to climate change to the percent of daily warming that the sun provides, and then state that the causes only matter if they account for more than 50% of the solar warming, we would basically end up concluding that the anthropogenic effects of climate change are negligible and therefore, should not be addressed.

Recommendation: 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 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.

13. Step 3: Analyze the Riverbank Features, Characteristics, and Erosion Conditions

This step identifies which segments are “similar” to the studied sites

It is difficult for us to review this step in any detail, since no field verification was included in our peer-review budget and tight timeline and data referenced from 1998 were not shown in the Study 3.1.2 Report. However the analysis for this step seems to show significant bias, relating to how the analysis was limited to comparisons to specific hydraulic reaches, (even when the Q_{e95} was low), and how the results to other segments were subjectively compared (only within given reaches and seemingly only considered similar when they were near exact matches) to extrapolate river lengths impacted by varying causes. An example of this potential bias has been extracted below:

“A similar analysis was then conducted for Site 8BR-Pre. Due to the fact that 8BR is a restoration site, the riverbank features and characteristics as observed during the 1998 FRR were compared against the features and characteristics identified during the 2013 FRR for all riverbank segments found in reach 2 to determine if similarities exist at other locations within the reach. No riverbank segments were found in reach 2 with the same characteristics as were observed at Site 8BR in 1998. Although no riverbank segments were found to be an exact match, three FRR segments were identified as having very similar characteristics – 75, 87, and 109.” (Page 47 Vol I; emphasis added)

This paragraph from the report above shows how the results of this step of the extrapolation methodology can be easily subjectively biased toward a specific outcome. The report stated that they would determine if “similar” reaches existed, they then state none were found based on their conclusion that the segments were not the “same” (meaning an exact match), and then they report there were however three that were “very similar”. This type of summary and assessment make us, as peer reviewers, question if this report was prepared in an impartial manner when they were identifying segments with similar characteristics. This comparison and assessment is a critical part of their extrapolation to determine the “% of river reach” impacted, and if not conducted in an impartial manner, could significantly skew the report’s final conclusions. The RSP also did not state that the 1998 erosion data would be compared against 2013 data. We have no knowledge as to whether the data are actually comparable.

Recommendation: 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.

14. Step 4: Assign each riverbank segment dominant and contributing causes of erosion

This step applies the dominant and contributing causes to river segments

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. We do not agree with the limitations the report is applying to its assessment, as previously stated in our review comments #6, #7, #11. 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. It would seem to make intuitive sense to base this analysis on only pre-stabilized sites and not the sites that have since been modified with engineered stabilization, since the results are primarily being extrapolated to non-stabilized river segments. By including the stabilized sites in the data, the results could demonstrate a bias towards less impact associated with operational WSE fluctuations, since typically the restoration work focused on stabilizing the toe of the riverbank.

This potential bias in the extrapolation methodology and report results is perhaps best characterized by comparing the results of the BSTEM analysis listed in Table 5.4.2.2-2 on page 5-73 of Volume II and Table 13 on page 40 of Volume I, to the summary table of project results, Tables 15 and 16 on pages 51 and 52 in Volume I. While Table 5.4.2.2-2 shows multiple sites relating to NFM operations that would qualify as a dominant primary cause (i.e. demonstrate percentages of contributing erosion greater than 50%) and Table 13 actually lists NFM as a dominant primary cause, NFM operations are not listed in Table 15 as a dominant primary cause of erosion, and NFM operations are only listed as a contributing cause in Table 16 responsible for 4% of total riverbank length. The summary tables therefore do not accurately reflect the analysis results, due to the bias incorporated into the extrapolation methodology. In fact it appears that Figure 5.4.3-1 on page 5-88 of Volume II, which summarized the erosion rates at all study sites for both baseline and Scenario 1 (NFM turned off), demonstrates that site 8BR-pre has the highest and most significant change in erosion rates based on a comparison of the two scenarios, and this erosion is associated solely to NFM operational impacts, but later disregarded in the summary tables.

Recommendation: 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.

15. Step 5: Conduct supplemental hydraulic and geomorphic analyses in Reach 1 to determine the impact, if any, of Turners Falls Project operations

This step assesses the potential impacts of the Turners Falls Operation only in Reach 1

According to the Study 3.1.2 Report the analysis for TF operations can't be assessed the same way NFM operations were assessed, because FirstLight's consultants were unable to develop stage-discharge relationships and did not have enough studied sites in the reach. They conclude that TF operations have no impact on Reach 1 (or any other reach) and that WSE management during high flows may even aid in the prevention of erosion of Reach 1 (page 49 Volume I), based on little data

and multiple subjective assumptions. We do not agree with this conclusion based on the data they provided. Please refer to our review comment #11 relating to why the stage discharge relationships developed in the study are not appropriate for use in analysis and how the TF operations can be assessed with BSTEM if the original HEC-RAS stage and discharge data is utilized.

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 (although we have not conducted a field investigation to confirm these observations), 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.

Recommendation: 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.

16. Step 6: Analyze land-use and width of riparian buffers

This step assesses impacts associated with land use

The analysis of land use utilizes a completely different methodology and yet still results in "percentage of total riverbank length" that is then directly compared and included with the total percentages calculated with volumetric results from BSTEM. This direct comparison seems misleading.

Recommendation: 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.

17. Steps 7 and 8: Create a map identifying the causes of erosion and calculate summary statistics

This step maps the results by river segment and provides the summary statistics in table format

As previously discussed in our review comment #14, 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. This study conclusion also relates back to our concern that by comparing natural river-forming processes to anthropogenic impacts in a volumetric only manner, the report disregards the additional long term impacts that can be initiated by facility operations.

"Once the extrapolations steps were complete, the dominant and contributing primary causes of erosion were quantified based on the total number of FRR segments, the total length of those segments (in both feet and miles), and the % of total TFI riverbank length for each primary cause (excluding ice)." page 51 Vol I

"the dominant and contributing primary causes of erosion were quantified using relative percentages for every TFI riverbank segment identified during the 2013 FRR" page 52

"Northfield Mountain operations were not found to be a dominant cause of erosion at any riverbank segment in the TFI." page 52 Vol I

Recommendation: 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.

VALIDITY OF THE STUDY CONCLUSIONS

18. **Historic Geomorphic Conclusion is Incomplete:** The FERC Study Plan determination stated, "To provide more detailed methodology (section 5.9(b)(6)), we recommend that FirstLight's perform its historic geomorphic assessment using available mapping such as the 1970 vintage ground survey of the impoundment as a base map, comparing it against more recent aerial imagery and available survey data to analyze trends in bank position within the Turners Falls impoundment. We estimate the costs of the recommended study modification to be \$20,000." However, the geomorphic assessment within Relicensing Study 3.2.1 is based heavily on former reports that were not part of the FERC process and therefore not reviewed and edited. The assessment looked at 20 cross-sections where erosion was already present and that were likely selected for that reason. This assessment of historic erosion appears to be limited and does not seem to analyze the before and after operation data in a meaningful way. The Relicensing Study 3.1.2 therefore does not appear to comply with FERC's determination.

Recommendation: We recommend that an analysis be prepared that compares past aerial photos with current aeriels 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.

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 a 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 Figures 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.

Recommendation: 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.

20. **Inaccurate Conclusion on Erosion Commencement:** Page 24 Vol 1 of the Relicensing Study states that "it is not until the water surface reaches the upper bank that erosion processes can potentially commence". This statement only makes sense if you consider the toe of bank as being part of the upper bank, since WSE fluctuations clearly impact the toe of the bank. The Relicensing Study then continues by stating that "even then the flow threshold to initiate erosion process was found to be greater than 37,000 cfs at the majority of detailed study sites". We question how this statement can be accurate since that would mean that there was basically no undercut bank formation (i.e. toe erosion) and even if there was that this toe erosion was not considered the initiation of the erosion process. This is counter-intuitive based on the cycle of erosion and the visual observations of multiple cross sections where undercut bank is evident, as well as on other cross sections where the toe of the bank was stabilized due to historic observations of undercut banks. In addition, the written descriptions of the individual cross-sections specifically note erosion observed at the toe of the bank.

Recommendation: 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.

21. **Counter-intuitive Conclusion Regarding WSE Fluctuation Impacts:** 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 band 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 1, page 28). This conclusion is counter-intuitive.

Recommendation: 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.

22. **Inaccurate Conclusion:** Page 28 Vol 1 of the Relicensing Study states "The operational difference 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.

Recommendation: 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.

23. **Conclusion Misleading:** The Relicensing Study's conclusions 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.

Recommendation: 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.

24. **Conclusion Regarding Ice Potential:** 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.

Recommendation: We recommend that the study investigate the potential for increased ice impacts due to operational WSE fluctuations.

SUMMARY OF OUR PEER REVIEW

Based on our review of the Relicensing Study 3.1.2 Volumes I, II, and III, our review team has made 23 recommendations as discussed earlier in this memorandum.

In general, we have identified several areas where the study was not done according to generally accepted scientific practice, or did not follow a methodology described in the RSP. We also believe that a number of erroneous assumptions have been made that may severely skew the results. Without recommended revisions, the Study 3.1.2 Report does not accomplish the overall study goal to "evaluate and identify the causes of erosion in the Turners Falls Impoundment and to determine to what extent they are related to Project operations."

Most critically, we find that the Relicensing Study 3.1.2 did not include an analysis of any scenarios without operational WSE fluctuations. Both the Baseline Conditions and Scenario 1 include significant WSE fluctuation due to operations impacts. The Baseline Conditions include the daily WSE fluctuation from Vernon, NFM and TF, and Scenario 1 includes the daily WSE fluctuation from Vernon and TF. A non-fluctuating WSE run was not developed or analyzed to compare what the baseline conditions prior to the current operational impacts might have been. See review comment #6.

There are significant gaps in the analysis for the Relicensing Study 3.1.2 including entire reaches where no analyses was completed, as well as no BSTEM analysis completed to assess the operational impacts of Turners Falls, even though we believe this analysis is possible to conduct, contrary to what the study suggests, by utilizing the HEC-RAS data for stage and discharge. See review comment #7 & #11.

The extrapolation methodology utilized in the Relicensing Study 3.1.2 includes multiple arbitrary definitions and thresholds, not included in the RSP and therefore not agreed upon in advance, that potentially bias the study results. The extrapolation methodology also includes subjective observations that appear to not maintain impartiality, and may also be biasing the study results. See review comments #11 through #17.

The Relicensing Study's comparison of percentages of erosion based solely on a volumetric interpretation of the erosion rates, ignores the cyclical processes of erosion, whereby a small amount of toe erosion due to anthropogenic causes (i.e. WSE fluctuation along with its resulting groundwater and vegetation

impacts, and boat waves) can instigate more significant erosion and accelerate bank failure due to natural causes (i.e. high flow).

FirstLight should revise the Relicensing Study 3.1.2 or issue an Addendum to the study that includes the revisions as per the recommendations set forth in this peer review, as well as the USDA (11/28/16) recommendations.

**UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION**

FirstLight Hydro MA LLC

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Docket No. 1889-000

Northfield Mountain LLC

Docket No. 2485-000

**AFFIDAVIT OF EDWIN T. ZAPEL
ON BEHALF OF THE CONNECTICUT RIVER CONSERVANCY**

1. My name is Edwin T. Zapel. I am a Senior Hydraulic Engineer for Northwest Hydraulic Consultants. I am a civil engineer with 36 years of experience in hydraulic, hydrologic, and fisheries engineering developed in a variety of engineering assignments throughout the western United States, Alaska, and Canada. These include such projects as spillway designs, sluice gate designs, high pressure valves and outlet works, small hydropower facilities, water temperature control withdrawal structures, energy dissipation structures, river intake structures, reservoir hydropower intake and outlet structures, and river sediment control structures. I have designed numerous fish exclusion, guidance, and screening and bypass systems for low and high-head dams and reservoirs for both juvenile and adult salmonids up to 5,000 cfs capacity. My experience also includes a variety of river engineering projects, including sedimentation and erosion analysis and management, debris flows, fish passage barrier removal and channel restoration, habitat enhancement, and general fisheries engineering. In addition to my consulting practice, I spent 13 years as a hydraulic engineer and Water Management Section Chief with the U.S. Army Corps of Engineers' Seattle District. My current business address is: Northwest Hydraulic Consultants Inc, 12787 Gateway Drive S., Tukwila, Washington 98168. My curriculum vitae is attached as **Exhibit A**.
2. I have participated in dozens of hydroelectric projects in various capacities that have been before the Federal Energy Regulatory Commission ("FERC"), including: Eugene Water and Electric Board (EWB) - Carmen-Smith Project, FERC Project No. 2242-078; Portland Water Bureau (PWB) - Bull Run Dam No. 1 (FERC Project No. 2821); Southeast Alaska Power Association (SEAPA) - Swan Lake Dam (FERC Project No. 2911); Seattle City Light (SCL) - Diablo Dam (FERC Project No. 553); Susitna-Watana Hydroelectric Project, Alaska (FERC Project No. 14241-000).
3. To provide this affidavit testimony, I reviewed the 31 March 2023 First Light Offer and the Settling Parties' Explanatory Statement, the Connecticut River American Shad Management Plan, the 11 May 2023 First Light Response to FERC Additional Information Request, the March 2018 Barrier Net Study Plan for Northfield Mountain Tailrace, the October 2016 First Light Fish Entrainment and Turbine Passage Mortality

Study Report, the March 2017 First Light Evaluation of Downstream Passage of American Eel Study Report, and the February 2016 First Light Evaluation of Upstream Passage of American Eel at the Turners Falls Project Study Report. I also reviewed the 'FishBase' species summary for American Shad for specific biology and life history traits of American Shad extent on the east coast of North America.

4. The purpose of my affidavit is to provide technical support to the Connecticut River Conservancy's ("CRC") opposition to the offer of settlement ("Offer") as it relates to the timing of construction of upstream and downstream fish passage at the Turners Falls Dam. The Offer proposes several operational and structural modifications to the Turner's Falls project, two categories of which relate to fish passage through the various features of the project. These are divided into upstream passage facilities and downstream passage facilities, for the apparent purpose of establishing a preferred construction schedule for completion of each system. In the Settling Parties' Explanatory Statement, they state that the preference to construct the downstream passage facilities first, followed by the upstream passage facilities at Cabot Station and at Turner's Falls Dam "is consistent with the fish and wildlife agency objective to recruit as many repeat adult shad spawners as possible to the lower Connecticut River to enhance overall shad population." Explanatory Statement at 20. The Statement cites the Connecticut River American Shad Management Plan as having an objective of achieving an adult shad stock structure repeat spawner component of 15% for each sex. *Id.* at n.13. However, there is no stated preference cited from this Plan for downstream passage over upstream passage specific to Turner's Falls, and thus the Plan does not actually support the Settling Parties' sequencing preference. Further, it is not clear from the Offer why prioritizing downstream passage over upstream passage would increase repeat shad spawner populations in the lower Connecticut River below Turner's Falls Dam.
5. The Explanatory Statement states that the downstream passage features would be constructed first, followed by 20 years of monitoring for effectiveness. Similarly, the Statement also states that the upstream passage facilities would be constructed next, followed by 25 years of monitoring. Of the two fish passage facilities, the upstream passage facilities represent a much more extensive construction effort, resulting in the construction of a modern fish lift at Turner's Falls Dam, abandonment of the Cabot Station fish ladder, and enhancement of passage flows through the "bypass reach" between Turner's Falls Dam and Cabot Station. The Settling Parties acknowledge that upstream passage success is necessary to enhancement of shad passage, and that the existing facilities have well-documented and well-defined deficiencies. The downstream passage deficiencies have also been documented, though these deficiencies likely require less capital investment to correct even though First Light does not explicitly state this in the Offer.
6. As explained below, there does not appear to be substantial evidence in the record that would preclude construction on upstream and downstream fish passage facilities simultaneously. To the contrary, based on my experience and understanding of the proposed modifications, it appears that it would be feasible to undertake both the upstream and downstream facility modifications simultaneously, with the possible

exception of the potential in-water work area isolation conflicts between the plunge pool construction and fish lift construction.

7. Further, if any sequencing is necessary, the Settling Parties have not provided substantial evidence to support prioritizing downstream fish passage over upstream fish passage as proposed in the schedule for implementation, and, in fact, such prioritization is counter-intuitive, especially as it relates to American Shad, the primary species for which the fish passage is being upgraded. American Shad are known to be iteroparous, and may repeat their migration up to several times from the ocean to fresh water to spawn and then return to the ocean to rejuvenate their spawning fitness.¹ They are known to be fecund, with average egg production ranging from 30,000 to as many as 150,000 eggs per spawn. They prefer sandy river bed and very small gravels in shallow areas for spawning, and do not cover their eggs with substrate. They are not necessarily known to exhibit preference for natal homing to return to the site of their emergence during upstream spawning migration, unlike some other important anadromous species are. Shad will readily colonize accessible habitat, and when introduced can quickly establish viable populations where they did not previously exist (such as the Sacramento River and the Columbia River on the west coast of the United States). In the Connecticut River, available spawning habitat preferred by shad occurs throughout the river system above and below Turner's Falls dam, except for the higher elevations in the watershed where suitable small substrate and shallow slackwater areas are not readily available for spawning. Given the species' proclivity for rapid colonization, significant fecundity, and lack of natal homing, the notion that increasing downstream passage of juvenile and outmigrant adult shad through the Turner's Falls project will increase recruitment of repeat spawners in the lower Connecticut River more readily than enhancing upstream passage to achieve more upriver spawning and consequently significantly greater juvenile production and subsequent outmigration to the ocean appears counterintuitive and begs additional justification and material support from physical data and observations.
8. Further, since repeat spawner escapement (regardless of upriver or downriver natal origin) and resulting recruitment contributing to the lower Connecticut River spawning population represent a rather small proportion of the total population of spawning shad in the lower River, it is unclear how an increase in downstream passage would be any more beneficial than an increase in upstream passage in the near term, and I am unaware of any record evidence that would substantiate this. This is especially true if current upstream passage is inhibited and functions to limit the numbers of successful spawners reaching upstream of Turner's Falls Dam, a fact which the Offer acknowledges and which is addressed in their proposed upstream fish passage improvements. *See* Explanatory Statement, at 22 ("The Turners Falls Project includes a complex of facilities that impose potential barriers to upstream fish passage."). The Settling Parties' stated preference for constructing the downstream passage facility prior to the upstream passage facility is not supported by the biology and behavior of the shad population, or more specifically by its spawning and repeat spawning behavior. Both upstream and downstream passage improvements are acknowledged by the Settling Parties' to be necessary to enhance the overall Connecticut River shad population.

¹ See <https://www.fishbase.us/summary/SpeciesSummary.php?ID=1584&AT=american+shad>, n.d..

THE PROPOSED IMPLEMENTATION SCHEDULE FOR UPSTREAM FISH PASSAGE FACILITIES AT TURNER'S FALLS APPEARS LONGER THAN NECESSARY

9. First Light has proposed several elements of the upstream fish passage system at Turner's Falls, listed as follows:
 - a) Within 9 years of license issuance, construct a Spillway Fish Lift at the Turner's Falls Dam
 - b) Within 9 years of license issuance, rehabilitate the Gatehouse Trapping/sampling Facility
 - c) Retire or remove the Cabot Station fish ladder within 2 years after the Spillway Fish Lift becomes operational
 - d) Within 1 year of license issuance, install and operate interim upstream eel passage in the vicinity of the existing Spillway Ladder
 - e) Conduct up to 2 years of eelway siting studies after the Spillway Fish Lift becomes operational.
10. If design commences on issuance of the license, it is reasonable that the new fish lift could be designed within about 2 to 2.5 years, given that fish lift design typically follows standard guidance derived for previous prototype configurations within the proposed 30%, 60%, 90%, and final design milestones. In other words, fish lifts like the one proposed have been designed and implemented under fairly predictable schedules of lesser duration than that proposed here, with few construction or design unknowns that would necessitate the 9-year timeline proposed in the Offer. Construction of the lift system would require cofferdamming and isolation of the work area from the tailwater pool below the spillway, and would likely be constrained to in-water work windows mediated by high river flows and fish passage seasons. However, that is the lone element of the fish passage features proposed that would likely be affected by or constrained by construction of other elements and require an extended schedule for completion.
11. I am familiar with similarly complex fish passage facilities on the Columbia River federal hydropower dams, constructed under similar conditions and constrained by similar in-water work window limitations, that have been completed within 2 to 4 years. Unless the fish lift design would require an uncertain and lengthy amount of review and negotiation with the design staff at the regulatory agencies at each of the proposed 4 design milestones (30%, 60%, 90%, and final), 9 years to full implementation is particularly conservative. Based on previous fish passage facility design and implementation, a schedule for full implementation could be approximately 4–6.5 years, depending on the timeliness of agency reviews and First Light design consultant competence and availability. Since the construction of the proposed plunge pool below bascule gate No. 1 would not be constructed until the fish lift was completed, full implementation of the plunge pool could be completed within 6 to 8.5 years after license issuance.
12. Rehabilitation of the Gatehouse Trapping facility could reasonably be accomplished within about 2 to 3.5 years (versus the proposed 9 years), given that no new structures should be necessary, and upgrades would likely be limited to interior spaces, conveyance

channels and hydraulic control features, and electrical upgrades with modern equipment replacing old equipment. Though no details are provided in the Offer, my experience with rehabilitation of hatchery and fish passage sampling and monitoring stations in the Pacific Northwest suggests that the process should be expected to require about 1 to 2 years for design and adaptation to existing facilities, with about 1 to 1.5 years of construction to reach full implementation.

13. The relative simplicity and small size of eel passageways suggest that a 1-year full implementation schedule for the interim upstream eel passage system is reasonable.

THE PROPOSED IMPLEMENTATION SCHEDULE FOR DOWNSTREAM FISH PASSAGE FACILITIES AT TURNER'S FALLS APPEARS LONGER THAN NECESSARY

14. The Settling Parties have proposed several elements of the downstream fish passage system at Turner's Falls Dam, listed as follows:
- a) Within 4 years of license issuance, replace the existing Cabot Station trashrack structure with a new full-depth trashrack with 1-inch clear spacing and multiple openings to pass downstream migrant fish into the existing trash trough and an entrance and conduit to pass fish from the left intake wall to the trash trough.
 - b) Within 4 years of license issuance, construct a $\frac{3}{4}$ -inch clear spacing bar rack at entrance to Station No. 1 branch canal.
 - c) Within 9 years of license issuance, construct a plunge pool downstream of the Turner's Falls Dam bascule gate No. 1 as part of the upstream passage Spillway Fish Lift.
15. If design commences on issuance of the license, it is reasonable that the new trashrack could be designed within about 2 years, with fabrication and installation to occur in the third year. I am familiar with a similar deep trashrack replacement that is currently underway at Seattle City Light's Diablo Dam project to mitigate damage from trashrack clogging and a structural failure of the original trashrack. The accelerated design commenced in the late summer of 2022 and fabrication has already been initiated, with construction and installation scheduled for the summer of 2023. Given that no agency input was required on the Diablo trashrack design, it was possible to accelerate the full implementation schedule to about 1.5 years. With agency review and input on the proposed Cabot Station trashrack expected and included, the design schedule could likely be completed within 2 years and fabrication and construction could reasonably be completed within an additional year to 1.5 years, depending on construction schedule constraints due to in-water work periods. Therefore, it seems reasonable to expect that full implementation of the Cabot Station trashrack might be possible within 3 years to 3.5 years of license issuance.
16. Similarly, the proposed trashrack at the Station No. 1 branch canal could be completed in about 3 years. Although the new trashrack may be smaller than at Cabot Station, new support structures would be required, all of which would need to be constructed in water and include moderate depth caissons or cofferdams to enable construction. Therefore, it is

reasonable to expect that full implementation of the Station No. 1 branch canal trashrack could also be fully implemented within 3 years from license issuance.

17. The Offer describes the third downstream fish passage element plunge pool below the Turner's Falls Dam bascule gate as being connected with the fish lift upstream passage element. Based on that connection, the construction and full implementation would logically follow after the schedule developed for the fish lift element, though, as explained above, the fish lift implementation schedule should not require 9 years and therefore the plunge pool can also be constructed on a faster timeline consistent with the faster timeline described above for the fish lift.

THE PROPOSED IMPLEMENTATION SCHEDULE FOR BARRIER NET AT NORTHFIELD MOUNTAIN PUMPED STORAGE INTAKE APPEARS LONGER THAN NECESSARY

18. The Settling Parties have proposed an element of fish protection at the Northfield Mountain Pumped Storage system intake above Turner's Falls Dam, listed as follows:
 - a. Within 7 years of license issuance, construct a barrier exclusion net to prevent entrainment of fish into the pump-turbine units
19. If design commences on issuance of the license, it is reasonable that the new barrier net could be designed within a single year and implemented within the following 2 years. I am familiar with similar very large barrier exclusion nets currently deployed in the Lake Shannon- Lower Baker Lake hydropower facility in NW Washington State that were designed within about 2 years of license issuance and constructed the following year, even though they are much deeper (more than 200 feet) and the reservoir experiences much more significant water level variations (which is one of the most problematic design issues with barrier nets).

CONCLUSIONS AND SUMMARY STATEMENTS

20. Based on the reviewed documents and background information available to me, it appears that the proposed 9-year implementation schedule for upstream fish passage features is unnecessarily long and could potentially be reduced by as much as 2.5 to 5 years.
21. Based on the reviewed documents specifically and on shad biology generally, there appears to be little justification for prioritizing implementation of downstream passage features over the upstream passage features. Both could be commenced concurrently, and implementation of the upstream passage features would potentially have greater positive impact on increasing shad populations above the Turners Falls project more immediately than would the downstream passage features.
22. Based on the reviewed documents and background information available to me, it appears that the proposed 4-year implementation schedule for downstream fish passage

features is unnecessarily long and could potentially be reduced by as much as 0.5 to 1 year.

23. Based on the reviewed documents and familiarity with other constructed barrier net projects, it appears that the proposed 7-year implementation schedule for downstream fish passage features is unnecessarily long and could potentially be reduced by as much as 4 to 4.5 years.

**UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION**

FirstLight Hydro MA LLC

Northfield Mountain LLC

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Docket No. 1889-000

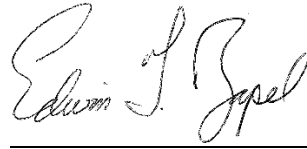
Docket No. 2485-000

DECLARATION

EDWIN T. ZAPTEL states that I prepared the affidavit to which this declaration is attached and that the statements contained therein are true and correct to the best of my knowledge and belief.

Pursuant to Rule 2005(b)(3) (18 CFR § 385.2005(b)(3), citing 28 U.S.C. § 1746), I further state under penalty of perjury that the foregoing is true and correct.

Executed on May 18, 2023.



Edwin T. Zapfel, M.S., P.E.

**EDWIN T. ZAPEL, M.S., P.E.****Senior Hydraulic Engineer****Education**

B.S. in Civil Engineering,
Washington State University,
1984 (Honors)

M.S. in Civil Engineering,
Washington State University,
1987 (Cum Laude)

*Ph.D. studies Fisheries
Science, University of
Washington (dissertation not
completed)

License/Affiliations

Registered Professional
Engineer; Washington,
Alaska, and Idaho

Member, American Society of
Civil Engineers (ASCE)

Member, American Fisheries
Society (AFS)

Member, American Water
Resources Association
(AWRA)

Years of Experience

36

Areas of Expertise

Hydraulic Design

Fisheries Engineering

River Engineering

Water Intakes

Sediment Transport

Physical Modeling

Mr. Zapel is a civil engineer with 36 years of experience in hydraulic, hydrologic, and fisheries engineering developed in a variety of engineering assignments throughout the western United States, Alaska, and Canada. These include such projects as spillway designs, sluice gate designs, high pressure valves and outlet works, small hydropower facilities, water temperature control withdrawal structures, energy dissipation structures, river intake structures, reservoir hydropower intake and outlet structures, and river sediment control structures. Mr. Zapel has also designed numerous fish exclusion, guidance, and screening and bypass systems for low and high-head dams and reservoirs for both juvenile and adult salmonids up to 5,000 cfs capacity. His experience also includes a variety of river engineering projects, including sedimentation and erosion analysis and management, debris flows, fish passage barrier removal and channel restoration, habitat enhancement, and general fisheries engineering. Mr. Zapel's experience includes more than twenty-one years in private consulting practice and thirteen years as a hydraulic engineer and Water Management Section Chief with the U.S. Army Corps of Engineers' Seattle District.

Selected Project Experience**USACE, BUREC, TVA, and other Independent Expert Project Reviews and Board of Consultants Work**

Carmen-Smith Hydropower Project Board of Consultants, OR: Currently serving on FERC Board of Consultants as the hydraulics expert for planned upgrades to the Carmen-Smith projects on the McKenzie River in western Oregon state. Project upgrades currently under design or analysis includes spillway upgrades, overtopping protection, foundation and plunge pool scour analysis, geotechnical deficiency correction, and other features.

Cave Buttes Dam Outlet Structure IEPR Project Review, Phoenix, AZ: Cave Buttes Dam is an existing flood control embankment dam constructed by the USACE on Cave Buttes Creek, north of Phoenix, Arizona for Maricopa County Flood Control District. A new outlet structure and discharge tunnel is required to enable the impoundment to be drawn down within the required time frame under Department of Dam Safety rules. The new outlet facilities include a new intake structure, a new tunnel under the left dam abutment in rock, and an impact-type discharge structure for energy dissipation.

Baltimore District - Raystown Dam Outlet Gates Value Engineering: VE Workshop and study of potential cost savings for low level sluice outlets for Raystown Dam in Pennsylvania. The technical leads for the project are in the Portland District of the USACE, and this evaluation is intended to help upgrade and modernize the 50+ year old multipurpose dam.

Kansas City District – Swope Park Levee, MO IEPR Project Review: IEPR Review of USACE plans for new ring levee around Swope Park industrial development near Kansas City, MO.

Kansas City District – St. Joseph, MO levee upgrade IEPR Project Review: IEPR Review of USACE levee upgrade for right and left banks of the Missouri River at St. Joseph, MO. Review included design of several local drainage release structures penetrating levee embankment.

Edwin T. Zapel, M.S., P.E.

Total Dissolved Gas Analysis and Mitigation

Rocky Reach Dam TDG Analysis, WA: Review of historical database for TDG at Rocky Reach and Rock Island Dams for Chelan PUD to determine if distribution of flow between the powerhouse and the spillway could be modified through operational changes to reduce effective TDG below the Rocky Reach dam.

Structural Gas Abatement Feasibility Design for all eight Corps of Engineers Lower Columbia and Snake River Dams: Feasibility level design of auxiliary spillway, sluice, and turbine modifications for each of the eight Corps dams on the Columbia and Snake River Dams. Spillway structures included stepped, smooth, baffled, and conventional deflected spillway types. Submerged sluices, additional spillway bays, and powerhouse modifications were also examined.

Boundary Dam Dissolved Gas Analysis: Development of methodology to evaluate and analyze dissolved gas production at Boundary Dam on the Pend O-Reille River in NE Washington. Dissolved gas is either entrained or reduced in the tailrace by spillway discharge, depending on upstream ambient dissolved gas levels and spillway/powerhouse discharge combinations.

Columbia and Snake River Gas Abatement Structural Alternatives: Feasibility-level design development for wide range of structural dissolved gas abatement alternatives for application at all eight lower Snake and Columbia River Corps of Engineers dams.

Stepped Spillway Model – Dissolved Gas Abatement: Project manager and lead technical engineer for a physical model of a stepped spillway for Lower Columbia River projects. This model study was a part of the U.S. Army Corps of Engineers dissolved gas abatement studies.

Bonneville Dam TDG Abatement Alternatives: Involved in the development of TDG abatement alternatives specifically designed for Bonneville Dam. Proposed concepts included new spillway gate configurations, new spillway chutes, new spillway structures, and others.

Chief Joseph Dam Spillway Deflector Testing and Evaluation: Evaluation of foundation pressure readings throughout spillway monolith footprint to determine critical seepage path and evaluate potential sealing program alternatives, in conjunction with spillway tests of recently constructed flow deflectors on Chief Joseph Dam on the Columbia River. Flow deflectors were installed to reduce the entrainment of atmospheric gases at depth, which results in high Total Dissolved Gas (TDG) levels and gas bubble embolism disease in fishes inhabiting the tailrace and downstream areas of the river.

Long Lake Dam Conceptual Spillway Alternatives Development: Development of conceptual alternatives for auxiliary spillway structures for Long Lake Dam on the Spokane River, WA. Purpose of the auxiliary spillways is to reduce atmospheric gas entrainment into high velocity spillway flow, which elevates Total Dissolved Gas concentration in downstream river flow. High TDG levels are detrimental to fish survival.

Dam Overtopping and Rock Scour Assessments

Talbott and Townes Dams Overtopping and Rock Scour Assessment Review, NC: Senior technical hydraulic reviewer for review of rock erosion and scour assessment for Talbott Dam and Townes Dam, both owned by the City of Danville, North Carolina. Previous work by other consultants had identified potential scour of the dam foundation and abutment toe resulting from significant overtopping arising from very large PMF flood events (between 15 and 16 feet over the parapet wall for both dams). Both dams are structural arch concrete dams founded on rock of fair to good quality and are regulated under the Federal Energy Regulatory Commission's (FERC) authority, as both are associated with hydropower plants.

Bull Run Dam No. 1 Overtopping and Scour Analysis, OR. (2021): Portland Water Bureau. Senior technical advisor and hydraulic design lead for the evaluation of overtopping scour at the Bull Run Dam No. 1, a nearly 100 year old concrete gravity arch-type water supply dam operated by the Portland (OR) Water Bureau. Recent PMF studies indicate that the dam crest and parapet wall may be overtopped by up to 5 feet during a PMF event, due to inadequate spillway capacity. The dam is founded on basalt.

Edwin T. Zapel, M.S., P.E.

Eagle's Nest Dam Spillway Evaluation and Overtopping Scour Analysis, NM (2020-2021): New Mexico Department of Game and Fish. Senior technical advisor and hydraulic design lead for the evaluation of the existing 100+ year old concrete gravity arch-type water supply dam in New Mexico for the Department of Game and Fish. The existing dam has an undersized abutment spillway, and a recent stability analysis suggests that overtopping scour from dam overtopping may erode the dam foundation toe and put the structure at risk of failure. Recent PMF analysis suggests that the dam may be overtopped by several feet during a PMF event.

Laprele Dam Spillway Design and Overtopping Scour Analysis, WY. (2020-2021): Wyoming Dam Safety Office. Senior technical advisor and hydraulic design lead for the evaluation of the existing 100+ year old concrete Ambursen buttress and slab-type water supply dam on Laprele Creek in Wyoming, and development of spillway design for replacement RCC and embankment dam alternatives to rehabilitating the existing deteriorated dam structure. Recent PMF analysis suggests that the spillway is inadequately sized and the dam may be overtopped by as much as 12 to 16 feet during an extreme PMF event. The dam is founded on sandstone and limestone.

Skookumchuck Dam Spillway Capacity and Sidewall Overtopping and Rock Erosion Analysis, WA: Technical advisor for development of hydraulic model for Skookumchuck Dam spillway in southwestern Washington State, and using rock erosion and scour modeling tools to determine extent of potential rock erosion during PMF flood events. Approach included use of 2D numerical model tool, with Annandale rock erosion methodology and the most recently developed block plucking and uplift for basalt channel wall erosion assessment.

Oroville Dam Flood Control Spillway Emergency Scour Assessment, Oroville, CA: Emergency response development of predictive spillway slab failure and erosion calculations and modeling to assist with the mitigation measures to address failure of the Oroville Flood Control Outlet spillway. Coordinated selection of emergency response hydraulic analysis team with colleagues George Annandale and Henry Falvey to assist California DWR with 24/7 development and refinement of predictive model to estimate the progression of erosion and continued slab failure as the event unfolded. Determined initial cause of failure and assisted with development of design of repairs to spillway.

Spillways & Stilling Basins

Moccasin Dam Emergency Spillway Modifications, CA (2019-2023): Preliminary evaluation of Moccasin Dam emergency spillway capacity and alternatives development for the Moccasin Reservoir reregulating reservoir for San Francisco Public Utilities Commission, including a physical scale hydraulic model study in NHC's Vancouver, B.C. laboratory. The spillway was determined to be inadequately sized, and suffered considerable damage during recent flood events, and the utility has engaged the study of alternatives to increase the spillway capacity.

Laprele Dam Spillway and Dam Design, WY (2019-2023): Evaluation of inadequate existing spillway for PMF and Spillway Design Floods and development of spillway design for replacement Roller Compacted Concrete dam. Hydraulic evaluation and technical development included routing analysis to determine appropriate PMF and spillway design. Study has progressed into Feasibility Level design, and hydraulic design work continues, including construction of a 1:40 scale physical hydraulic model study at NHC's laboratory in Seattle..

Iron Canyon Dam Spillway Hydraulic Analysis (2022-2023): Hydraulic evaluation of the Iron Canyon Dam spillway in California using the BUREC's EM-42 numerical hydraulic model. PG&E engaged the study of the hydraulic capacity of the Iron Canyon Dam spillway to determine the risk of cavitation and hydraulic uplift (i.e. 'slab jacking') for the project's spillway structure, which includes a semi-circular ogee crest and a converging chute and tunnel with superelevated exit channel.

McCloud Dam Spillway Hydraulic Analysis (2022-2023): Hydraulic evaluation of the McCloud Dam spillway in California using the BUREC's EM-42 numerical hydraulic model. PG&E engaged the study of the hydraulic capacity of the McCloud Dam spillway to determine the risk of cavitation and hydraulic uplift (i.e. 'slab jacking') for the project's spillway structure, which includes a multiple-gated spillway, converging chute, and steeply sloping exit section with flip bucket.

Big Creek Dam Spillway and Outlet Works Design, OR (2018-2022): Evaluation of Big Creek watershed hydrology, water supply potential, and spillway design to pass PMF and Spillway Design Flood. The existing dam owned by the City of Newport is structurally deficient and a new Roller Compact Concrete dam is proposed to address seismic instability of the existing embankment dam.

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New Exchequer Dam Spillway Hydraulic Analysis (2018-2019): Technical review of hydraulic evaluation of the New Exchequer Dam spillway in California. The spillway is an earthen spillway channel cut into the native bedrock and controlled by an uncontrolled ogee crest structure with multiple open discharge bays. Rock erosion has been noted as a result of periodic spillway events, and the Merced Irrigation District was tasked to determine the rate of erosion and the potential for future progressive erosion that might jeopardize the stability of the control crest structure. The analysis was accomplished using Computational Fluid Dynamic modeling, the results of which were used to quantify expected rock scour and erosion.

Charlotte Airport Detention Storage Reservoir Spillway and Outlet Works, NC (2020-2021): Charlotte Airport Authority. Senior technical advisor and hydraulic design reviewer for roughened rock spillway chute and terminal energy dissipator basin. The spillway structure provides overflow discharge capacity for a detention storage reservoir providing flood control for the watershed above the Charlotte airport. The spillway width and the footprint of the energy dissipation basin were physically constrained by existing topography and infrastructure, requiring maximizing unit discharge, slope, and pushed the limits of roughened rock spillway design.

Scotts Flat Dam Spillway Evaluation and Physical Modeling, CA (2020-2021): Nevada Irrigation District. Senior technical advisor and hydraulic design lead for the evaluation of the trapezoidal shaped spillway chute for Scotts Flat Dam in California, owned by the Nevada Irrigation District. The spillway terminal structure is founded on weak material and has been determined to be at high risk of undercutting and failure during a large spill event. The work included preliminary analysis of the existing spillway, followed by physical modeling of the spillway at Northwest Hydraulic Consultants' laboratory. The modeling confirmed that the spillway chute is inadequate to safely pass the PMF event without overtopping the trapezoidal chute sidewalls and eroding the foundation material under the terminal plunge pool lip structure. Physical modeling was used to refine and confirm the hydraulic design performance of chute modifications to resolve the sidewall overtopping issue and modify the terminal structure to reduce the potential for erosion of the foundation.

Pyramid Dam Service Spillway Hydraulic Uplift and Cavitation Analysis, CA (2018-2021): California DWR. Senior technical advisor and hydraulic analysis lead for the assessment and evaluation of the Pyramid Dam service spillway chute and slab. Following a field inspection and structural assessment of the Pyramid Dam service spillway, a number of deficiencies were identified in the chute slabs and joints that could place the integrity of the spillway at risk under high spillway discharges. A numerical hydraulic model was assembled and executed to evaluate hydraulic uplift forces that might arise from poorly functioning underdrains, stagnation pressure on slab joints, and cavitation, with the results used to recommend repairs and monitoring efforts to gage spillway performance. The work also included the selection and installation of under-slab pressure monitoring equipment to measure slab uplift pressures.

Clarke County Reservoir and Dam Design, IA: Senior technical advisor for development of design of hydraulic structures for proposed new earthfill dam in Iowa for Clarke County water utility. The new dam will be approximately 60 feet in hydraulic height, with a morning glory principal spillway structure and an earthen auxiliary spillway channel on the left abutment. The dam is founded on glacial loess and till soils and will provide several thousand acre feet of storage.

Conklingville Dam Spillway Rating Curve Review, NY: Senior technical review of project PMF discharge rating curve by previous consultant for the Conklingville Dam project on the Hudson River in New York. FERC's response to filings by the project owner required an independent review of the development of the project discharge rating curve for the hydro development, which includes a spillway, several deeply submerged valve release outlets, siphon spillway, powerhouse, and log chute. All outlets are fed by a single, narrow forebay channel, which develops highly complicated and turbulent, mixed regime flow conditions approaching the spillway and other outlet structures, and tailwater conditions for the siphon spillways are adversely affected by the adjacent spillway flow jet and large vortices that form in the immediate vicinity of the submerged outlet valves. The original design discharge capacity cannot be met due to these adverse conditions, and as a result the reservoir impoundment maximum PMF water surface elevation would be higher than originally planned in order to drive the necessary PMF outflow capacity.

Lake Leon Emergency Spillway Modification, TX: Senior technical advisor for the development of design for modifications to an existing inadequate capacity excavated earthen and rock spillway channel across the left reservoir rim. The existing spillway flooded severely several years ago, washing out a major state highway and causing considerable damage. The redesign considered erosive material of the chute, and determined a design that is

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anticipated to be stable during events across a range of recurrence intervals using a combination of vegetated channel surface, riprap roughened chute, and preformed scour and launching toe at the base of the emergency spillway.

Frenchman Dam, Antelope Dam, and Grizzly Valley Dam Spillway Chute Inspection and Cavitation/Uplift Preliminary Analysis, CA: Senior technical advisor for physical inspection and hydraulic evaluation of the service spillway chutes for these three dams on the upper Feather River watershed, all owned by the California Department of Water Resources. These dams are an integral part of the California DWR's Water Project, authorized in the late 1950's and constructed across the state throughout the 1960's and 1970's. They provide storage of the snowmelt runoff from the high Sierras for use in water storage for irrigation, municipal, and environmental purposes.

Pyramid Dam Service and Emergency Spillway Hydraulic and Erosion, CA: Lead hydraulic engineer for detailed evaluation of gated service spillway chute for cavitation and uplift analysis for chute slabs. Technical advisor role for spillway chute hydraulic modeling for both the gated service spillway and also the adjacent unlined rock-cut emergency spillway chute.

Turkey Peak Dam Spillway and Stilling Basin Design, TX: Technical guidance and direction for final design of spillway and stilling basin for new water supply dam in Texas. Spillway is designed as a stepped spillway for typical high recurrence interval spill events, with the stilling basin energy dissipation characteristics designed as a conventional spillway with hydraulic jump energy dissipation basin at the toe. The project footprint is constrained by a downstream highway and other infrastructure limiting the available area for the downstream spillway channel conveyance to the receiving stream for spillway flow.

Fordyce Dam Spillway Capacity Analysis, CA: Preliminary hydraulic analysis of the Fordyce Dam spillway capacity to carry the expected PMF event. Led hydraulic analysis of the gated and flashboarded hybrid spillway to determine maximum capacity and develop modifications to prevent dam embankment overtopping during PMF event.

Upper Black Bear Reservoir Outlet Structure Design, OK: Development of design for new intake and outlet system for Upper Black Bear Reservoir in Oklahoma, and earthen excavated emergency spillway design. Existing dam hydraulic structures could not pass the required PMF flow, which required redesign of the inlet riser and discharge conduit as well as the construction of a new excavated emergency spillway.

Chehalis Flood Control Storage Study – Chehalis Dam, WA: Preliminary design of proposed new flood storage and flow augmentation dam on the Chehalis River in southwest Washington State. The project is being designed to mitigate significant flooding in the Chehalis River valley by controlling runoff from the Chehalis River upper watershed area. Two alternatives have been proposed; the first that only stores water during flood events and another that includes reservoir storage to augment low stream flows and enhance salmon habitat during summer months in addition to flood storage. Project design includes multiple high-head outlet sluices, spillway, and energy dissipation facilities.

Big Creek Dam Replacement Spillway Design, Newport, OR: Development of spillway and outlet works design for new Roller Compacted Concrete dam for the City of Newport, Oregon to replace two aging and inadequate embankment dams on Big Creek. The reservoir provides municipal water supply for the City of Newport.

Cedar Springs Spillway Cavitation and Uplift Analysis, CA: Review of Cedar Springs Dam spillway chute inspection reports, development of preliminary evaluation of cavitation potential and uplift.

Pyramid Dam Spillway Chute Uplift and Cavitation Assessment, CA: Preliminary evaluation of the Pyramid Dam chute spillway slab and sidewall uplift and cavitation potential, and comparison to spillway inspection reports for forensic evidence of adverse hydraulic conditions.

Calero Dam Spillway Analysis, San Jose, CA: Development of alternatives for increasing the capacity of existing spillway at Calero Dam to accommodate increased anticipated PMF discharge. Existing spillway structure dates from the early 1930's and has been found inadequate to pass the expected Probable Maximum Flood (PMF) discharge. Potentially unstable hydraulic control, inadequate crest length, and inadequate energy dissipation at the toe of the spillway chute were identified as deficiencies. Duties included technical guidance and review of hydraulic analysis and design modifications.

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Osceola Dam Spillway and Outlet Culvert, Des Moines, IA: Technical guidance and review for analysis of existing semi-circular spillway weir and discharge box structure for small flood storage dam in Des Moines, Iowa. Analysis focused on flow regime and hydraulic control transitions between outlet conduit, outlet conduit entrance structure, control weir, and reservoir approach.

Antero Dam Emergency Spillway Design, Hartsel, CO: Development of erodible spillway design for service/emergency spillway for Antero Dam, a water storage dam and reservoir located in central Colorado, providing augmentation to the South Platte River and the City of Denver water supply. Design included a trapezoidal spillway crest section and trapezoidal roughened riprap spillway chute channel, scour cutoff wall, and overtopping containment dikes. Project included construction engineering and review/observation of spillway construction to ensure design intent was met.

Scoggins Dam Spillway and Outlet Works Design, OR: Development of new spillway design for Scoggins Dam Alternative 3, an RCC replacement of an existing at-risk embankment dam on Scoggins Creek in northwestern Oregon State. Rehabilitation of the existing embankment dam and outlet works, and replacement of the existing dam at a downstream site are under consideration for the project. Project also included design of new outlet works facilities for the new RCC dam alternative to provide low flow capacity and water supply connection to an existing pipeline.

Swan Lake Reservoir Raise and Spillway Plunge Pool Analysis, AK: Development of design for a reservoir raise of 15 feet for Swan Lake Dam near Ketchikan, Alaska. Swan Lake is a thin arch dam on the Swan River, built in the early 1970's to supply power to the Southeast Alaska Power Authority's grid serving Ketchikan, Wrangell, and the surrounding communities. Existing dam had a narrow ungated ogee with flip bucket casting the spillway jet into a deep bedrock plunge pool. Design included an operational vertical gate with new pier and guides to manage all typical spill events up to the 20 year recurrence interval, and the remainder of the spillway provided with 15 foot high flashboards with innovative tipping mechanism triggered by the reservoir rising higher than a predetermined amount. Spillway plunge pool erosion scour estimates were developed using historical surveys, Annandale Erodibility Index method, and Mason and Arumugam Jet scour method. Project has been constructed. The project underwent an FERC Board of Consultants review, in which the design proposed met with full approval.

Scott Dam Spillway Capacity Evaluation & Design, CA: Physical modeling of Scott Dam Spillway on the Eel River in northern California to determine existing spillway capacity and develop design for modification to increase capacity up to PMF event.

Highfield Dam Spillway Alternatives Design: Provided technical review and senior engineering expertise in the development of the design of several spillway alternatives for the Highfield Dam, a water storage reservoir near Regina, Saskatchewan. The existing outlet works and spillway capacity were determined to be inadequate to pass the expected maximum flood event, and enlargement or replacement of the spillway was necessary to meet the desired regulatory criteria. From the conceptual design alternatives, a preferred option was selected and carried through feasibility design, including estimated construction costs.

Arundell Dam Spillway Analysis: Evaluation of a side channel and closed portal spillway design for a flood control dam in Southern California in a physical scale model in the laboratory. The existing spillway capacity was insufficient to carry the expected PMF event, and was determined to be limited by the outlet portal conduit dimensions and the side channel spillway configuration. Minor modifications to the spillway, approach area, and discharge conduit were successful in increasing the capacity to the desired level.

Lower Monumental Dam Spillway Stilling Basin Erosion Analysis: Analytical evaluation of stilling basin erosion damage at Lower Monumental Dam on Snake River. Assessed risk to spillway structure resulting from continued erosion by analyzing historical spillway discharge data and periodic bathymetry surveys over the project's entire period of operation. Developed empirical relationship between rate of erosion and spillway discharge operation to predict future erosion damage and quantify relative risk to spillway structure integrity.

Arroyo Pasajero: Conducted feasibility level hydraulic designs for flood control project elements on the Arroyo Pasajero, Central San Joaquin valley. Designs included uncontrolled overflow spillways and a spillway controlled by fusegates.

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Pump Stations and Pumps - General

Lake Kachess Emergency Drought Relief Pump Station Conveyance Design, WA. (2019-2021): Roza Irrigation District. Design of pump discharge conveyance system to carry pumped flows from Lake Kachess to the existing Kachess Dam outlet tower. The Roza Irrigation District is developing an emergency drought relief pump station to overdraft Lake Kachess below the level of the existing dam outlet works such that the deep glacially formed lake could supply additional flow to the Yakima River for downstream irrigation uses during emergency drought years. The pump station requires a combination of buried discharge pipelines from the 6 large lift pumps, a hydraulic energy dissipation structure, and an open channel canal to allow the pumped flow to reach the outlet tower forebay.

Flathead River Pumping Plant, MT (2019): Flathead Irrigation District. Field assessment of vibration in several large high head vertical shaft pumps lifting irrigation water from Flathead Lake to the Flathead Irrigation System canal near St. Ignatius, Montana. One of the three large 3,000 hp pumps in the lift pump station experienced severe vibration and subsequent bearing failure, which caused it to shut down during the early portion of the irrigation season. An emergency field visit was conducted to investigate the potential cause and possible consequences of the damaging vibration. The damaged pump bearing was replaced and vibration monitoring equipment was deployed. The investigation revealed a resonant frequency problem originating in the pump machinery and extending through the lift penstocks, causing them to vibrate as well, causing fatigue in the steel penstocks. A more detailed vibration analysis was then conducted and a suite of potential solutions were developed to mitigate the problem.

Pond Creek Flood Control Pump Station Pump Failure Assessment and Repair, KY (2018-2019): Louisville Flood Control District. Assessment of bearing failure and vibration of large, 4,000 Hp low head lift pumps installed at the Pond Creek Pump Station, part of the flood protection system for Louisville, Kentucky. Pump #2 had experienced extreme vibration following a lower bearing carrier failure. The pump impeller, bowl assembly, and shaft were disassembled and shipped to the contractor's repair facilities in Kansas City, where shop inspection and evaluation of potential causes of the apparent misalignment and bearing failure could be made. Upon detailed inspection, it was determined that the impeller casting was cracked and required eventual replacement. A repair and refit plan was developed for Pump #2 and subsequently Pump #3 to realign the pump shaft, bowl assembly, bearings, and bearing carriers for temporary replacement until a new pump impeller could be manufactured.

Pumped Storage Hydropower Projects

Iowa Hills Pumped Storage Inlet/ Outlet Works Hydraulic Design, CA: Development of layout and design of pumped storage inlet/outlet structure for upper reservoir and lower inlet/outlet in Slab Creek Reservoir. Upper reservoir structure included vertical shaft leading to powerhouse constructed deep inside the hill side below the upper reservoir. Lower reservoir structure included a horizontal tunnel discharging into and expansion and diffuser inlet/outlet designed to minimize net approach and exit velocities. The narrow setting of the Slab Creek reservoir and the noted slope instability of the reservoir shoreline and submerged valley walls were of concern to the client. This concern was addressed through the development and refinement, including the use of CFD modeling, of the inlet/outlet configuration to minimize the possibility of a concentrated jet impacting the submerged reservoir flank, leading to erosion and potential failure of upper slopes.

Confidential Pumped Storage Projects, Western US: Lead hydraulic engineer for development of conceptual designs for intake, conveyance, and powerhouse facilities for several pumped storage projects for confidential client in the western US. Project power plant sizes ranged from 100 to 1100 MW, with conveyance sizes up to 28 feet diameter tunnel and multiple turbine-generator units.

Municipal Intakes

City of Fort Collins Poudre River Intake Reach Stabilization, CO: Senior technical advisor for development of river training and bedload sediment exclusion guide wall structures for mitigating sediment entrainment into the City's municipal water supply intake structure on the Poudre River above Fort Collins, CO. The severe wildfire damage throughout the watershed in 2019 and 2020 is expected to result in significantly increased volumes of sediment passing through the reach immediately upstream of the City's intake structure and diversion dam. Training structure consisted of riprap dikes and temporary bedload sediment guidance structures to reduce entrainment.

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Yellowstone River Water Supply Intake River Training Works: Development of design of river training works in the Yellowstone River near Billings, MT to maintain a deep thalweg adjacent to the planned new water supply intake for the City of Billings. The project included numerical modeling of the river channel, desktop and numerical sediment transport evaluations, and design of stone training structures to maintain a favorable channel alignment to encourage sediment throughput, minimize deposition in front of the intake, and protect infrastructure upstream and downstream from the intake location, including a state highway bridge.

Middle Fork Nooksack River Diversion Dam Removal and Replacement Water Intake, WA: Revisitation of the Middle Fork Nooksack River diversion dam removal and intake replacement study for the City of Bellingham in which a new intake alternative was developed and the existing diversion dam is removed to enable fish passage to the upper reaches of the watershed.

City of Longview Water Intake Design: Development of feasibility level designs and construction cost estimates for replacement of troublesome municipal water intake for the city of Longview, Washington, on the Cowlitz River. Continuous aggradation and very high sediment transport rates in the Cowlitz River in response to watershed disturbance caused by the 1980 eruption of Mt. St. Helens frequently renders the existing intake facility useless due to sedimentation. Study included development of five alternative remediation concepts, and included river training structures, intake modifications, and fish protection and passage features to protect salmonids and surf smelt.

White River Water Diversion Dam and Lake Tapps Water Intake Fish Passage Facilities: Development of new fish passage design and diversion dam design for the White River diversion into Lake Tapps below Mud Mountain Dam, near the city of Enumclaw, Washington. The existing diversion dam and intake originally provided water supply to an artificial lake and hydropower facility, but has suffered from high maintenance cost since construction in the early 20th century. Project included development of design for the new dam, control gates, surface water diversion screens and juvenile bypass facilities, and adult fish ladder and trap and haul facilities, in conjunction with design of new water supply intake for the adjacent hatchery complex operated by the Muckleshoot Indians.

Edwards Municipal Water District Intake Modification: Development of feasibility level designs and construction cost estimates for replacement or modifications to the existing failing water intake structure on the Eagle River, Colorado, near the city of Vail. The existing intake suffers from high rates of sediment entrainment, screen failure, and fish losses into the pumped water supply system. In addition, it lacks capacity to provide the necessary raw water supply to the cities of the Vail valley.

Glendale Weir Water Intake Diversion Design: Design of new diversion and intake screening structure for Truckee River in Reno, Nevada that incorporates adult and juvenile fish bypass features for Cui-ui and Lahontan Cutthroat Trout.

Middle Fork Nooksack Diversion Dam Removal and Intake Replacement Final Design, WA: Project manager and lead designer for final design plans and specifications for removal of existing diversion dam on the Middle Fork Nooksack River in NW Washington State for the City of Bellingham's active municipal water intake and diversion tunnel. The existing dam is a fish passage barrier, and has been under study for removal for nearly 20 years, and the final design plans include replacement of the existing tunnel intake with a new intake structure upstream that does not require a dam. The old dam is being removed in 2020 and 2021, and the project should be completed in late 2021.

Middle Fork Nooksack River Diversion New Intake Preliminary Engineering Design: Design and management of preliminary engineering study for new intake system for City of Bellingham's Middle Fork Nooksack River diversion. Capacity of diversion 160 cfs; new design utilized unique artificial constriction and scour pool formation with flush intake screens in abutment structures and penstock to existing aqueduct tunnel entrance.

Middle Fork Nooksack River Intake Siphon Conceptual Design Study: Hydraulic design and analysis of proposed siphon intake concept to divert flow from the Middle Fork Nooksack River into the City of Bellingham's existing diversion tunnel and aqueduct. The existing intake diversion dam is in poor repair, and is a complete barrier to anadromous fish passage upstream to available spawning habitat, and the City has investigated a number of concepts to replace its aging intake with a different concept that can include removal of the existing dam structure. The siphon would withdraw flow from an existing deep scour pool immediately below the existing dam, and would discharge into a modified rock tunnel and aqueduct.

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Middle Fork Nooksack Diversion Dam Alternatives and Fish Ladder Studies: Project manager for the design of a fish ladder to provide upstream fish passage at a diversion dam. Project is located in a remote location and along a very steep reach of the river. Second phase of project included an alternative intake analysis study. Managed physical model of the new intake structure. Model included a moveable bed to study the impacts on sedimentation and the impact to the new intakes.

Skagit PUD Pump Intake: Hydraulic design of fish exclusion screening facility and intake structure for large municipal water supply pump intake facility on the Skagit River. Intake utilized Formed Suction Intakes for the five pumps, with embedded high pressure water jet cleaning nozzles to remove accumulated silt and glacial flour deposited each year during the off-pumping season.

Hatchery & Irrigation Intakes

Kennewick Irrigation District Intake Design: Development of the design and civil layout of a new intake structure for a moderate sized pump station withdrawing water directly from the Yakima River near Benton City. The new intake facility pumps flow to the Red Mountain vineyard area of southeast Washington State. The facility includes a series of inclined screens within a large intake structure, constructed along the south bank of the Yakima River. An air burst cleaning system provides capacity for clearing debris from the screens, which are designed to meet current NOAA Fisheries and WDFW screening criteria for juvenile salmonids. RH2 Engineering provided the final design and construction plans and specifications, and Mr. Zapel participated in the commissioning phase of the project.

Issaquah Creek Hatchery Intake Design: Development of the design and civil layout, and development of construction cost estimates for a new hatchery water intake structure on Issaquah Creek, near the City of Issaquah, Washington. The original antiquated intake dam and screen system afforded very poor passage success, and was in jeopardy of failure. Analysis included dam removal alternatives design, conceptual design of a new intake, physical modeling of the proposed structure to refine the design and improve sediment and debris passage, and final design and construction plans and specifications for the new structure and the boulder weir grade control for the downstream 800 feet of channel. The completed project provides unimpeded passage of endangered Puget Sound Chinook salmon.

Muckleshoot Indian Tribal Hatchery Water Intake Design: Development of conceptual design alternatives for replacement of existing intake structure supplying water to the tribal fish hatchery on the White River, near Buckley, Washington. The existing intake suffers from significant sediment entrainment and sedimentation, and requires frequent dredging to keep it open. The Tribe is interested in finding alternatives to the existing intake that require less maintenance and can reduce the volume of glacial silt and sand entrained into their pumps and raceways.

Soos Creek Hatchery Intake Design: Provided technical guidance and review for design of new water intake structure and channel reach modifications for the Soos Creek Hatchery upgrade project for Washington Department of Fish & Wildlife. The existing Soos Creek intake entrains significant volumes of sediment from Soos Creek, and is located in a less-than-ideal location to provide consistent water supply to the existing hatchery complex. The new intake was modeled in the laboratory, and sediment transport characteristics were assessed for purposes of refining the final intake design.

Antoine Creek Irrigation Intake Design: Provided analysis and design through construction for precast modular intake and screen structures to supply screened irrigation withdrawals without need for a dam or diversion weir. Existing dam was removed, affording unobstructed steelhead passage to upper watershed habitat areas.

Skookum Creek Hatchery Intake Alternatives Design: Design of new intake facility and boulder-roughened downstream channel grade control for Skookum Creek salmon hatchery operated by the Lummi Indian Nation.

Dungeness River Hatchery Intake Design: Design of new water intake and fish screening system for WDFW's Dungeness River salmon hatchery on the Dungeness River, Sequim, Washington. The study was in support of a comprehensive water supply plan for the hatchery complex.

Vern Freeman Diversion Fish Passage: Development of fish passage improvements to the Vern Freeman diversion and water intake dam on the Santa Clara River in southern California. The existing diversion dam does not provide adequate passage for adult steelhead, and provides sub-criteria juvenile fish screening protection from entrainment

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into the intake. The study provided supporting engineering for the NOAA Fisheries Biological Opinion, which requires the project operator to modify the facility to ensure safe and timely passage for adult and juvenile salmonids.

Icicle/Peshastin Irrigation District: Water conservation study for Icicle/Peshastin Irrigation District in Cashmere, Washington. Field inspection and review of all facilities. Development of facility rehabilitation and water conservation plans and construction schedules.

Elwha Tribal Hatchery Intake Evaluation and Feasibility Design: Investigation of Elwha Tribal Hatchery intake structure adequacy for anticipated high sediment loads resulting from future Elwha and Glines Canyon dam removal. Feasibility level design of new hatchery intake structure and flood protection works.

Hydropower Intakes, Outlet Works & Hydraulic Structures

Folsom Dam Hydropower Intake Water Temperature Control Shutter System Design (2022-2023): The hydropower intake system at Folsom Dam on the American River in California includes three individual intake towers with a system of vertical panel bulkheads, or 'shutters' that are used to adjust the elevation at which water is drawn into the intakes in order to manage the temperature of the powerhouse outflows. The existing shutter and intake system is cumbersome and difficult to manage, and adjustments require considerable labor to make gate changes to maintain the required downstream water temperature. The new design required the determination of anticipated static and dynamic hydraulic loads on the shutter panels, the towers themselves, and the hoist cable system. In addition to consideration of steady-state loads as a result of powerhouse operation, the wire rope hoist system was analyzed for vibration to determine if mitigation measures would be necessary.

Diablo Dam Hydropower Intake Trashrack Hydraulic Analysis (2022-2023): The Diablo Dam hydro intake on the Skagit River in NW Washington state is protected from debris entrainment by a very deep inclined trashrack structure which experienced structural failure of the trashrack assembly due to excessive debris accumulation. Seattle City Light convened a team of structural engineers and NHC to evaluate the cause of the failure of the existing trashrack and develop a design for a new trashrack system. An analysis of hydraulic head losses through the existing failed rack system with and without debris was accomplished, and the results used to determine an appropriate design for a new trashrack. In addition, a vibration analysis of the proposed new trashrack system was accomplished to reduce the potential for flow-induced vibration which could damage the new rack system under clean and clogged conditions where debris is collected against the new rack system in varying amounts.

Electron Diversion Hydropower Intake Rehabilitation / Physical Modeling: Development of scale physical hydraulic model of the Electron diversion on the Puyallup River near Electron and Orting, Washington, which was originally constructed in 1904. The intake and diversion sill is undergoing rehabilitation to enable another 120 years of operation providing clean renewable hydropower generation to improve sediment exclusion systems and improve fish passage and fish exclusion from the 11 mile long flume that carries diverted flow to the head pond 860 feet above the powerplant. The project is of historical significance, as it was one of the first large scale hydropower projects in western Washington state, utilizing the rapidly falling Puyallup River gradient and high runoff to generate electric power. A modern juvenile fish screen and several innovative sediment exclusion and handling systems are being modeled in the lab to optimize performance at returning the significant volume of fine sediment generated by the Puyallup River back to the stream at the diversion, and also excluding juvenile salmonids from the flume by screening then bypassing them back to the river at the diversion rather than at the head pond 11 miles downstream.

Snoqualmie River Plant #2 Intake Structure Flow Line Hydraulic Assessment, WA: Hydraulic evaluation of the new Snoqualmie River Plant #2 intake structure and flow line for Puget Sound Energy's Snoqualmie development. The new intake cannot supply the full desired plant capacity of 2,000 cfs due to excessive head losses through various features of the intake. Design of replacement fine debris screen system to reduce head losses and enable full performance of the system.

Deer Creek Dam New Outlet Works and Intake Tower, UT: Development of new intake tower conceptual design and connection to existing pressure tunnel at Deer Creek Dam on the Provo River in Utah. The existing outlet works includes two large slide gates that have never been repaired and have been damaged. The new intake tower would permit withdrawal of reservoir water from different temperature strata, enable mixing and control of downstream

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release water temperatures, and permit inspection and evaluation of the tunnel connection and appurtenant structures.

Tazimina River Hydro Project New Trashracks and Diversion Repair, AK: Development of design for new, glycol-heated trashrack assemblies for existing hydro plant intake on Tazimina River, Alaska. Sub-arctic environment results in considerable ice development, including frazil ice prior to complete freeze up. New trashracks designed to melt ice and shed frazil accumulations, as well as withstand impact and shearing loads from sheet ice during spring breakup events.

Glacier Creek Diversion Sediment Sluice and Closure Gate Repair, AK: Design of repair system for concrete sediment sluice channel and control gate for hydropower intake at King Cove, Alaska. The Glacier Creek intake structure, constructed about 25 years previously, had experienced significant concrete abrasion damage and erosion as a result of stream sediments sluiced through the purpose-built sediment sluice gate and sluiceway. The diversion operates on a very flashy, high sediment load glacial runoff stream and requires regular operation of the sluice to clear sediment deposits from the turbine intake. A UHMW liner plate design and anchor system was developed to repair the sluiceway, and a new gate and thimble assembly was selected. The project is to be constructed by Public Works staff for the City of King Cove, an important fishing and fish processing village located near the far western end of the Alaskan Peninsula about 800 air miles from Anchorage.

Jackson Project Hydropower Tunnel Rock Trap Repair, WA: Hydraulic analysis and design of repair to timber crib separation bulkheads and deck lids for compartmented rock trap for the Jackson Hydropower Development on the Sultan River, near Monroe, Washington. The rock trap deck lid connections had failed due to corrosion and fatigue. The cause of the unexpected hydraulic loads was determined, and a new design to avoid future failure was developed and will be fabricated and installed in the spring of 2018.

Sunset Falls Hydro Intake Design: Development of layout and design of new intake structure proposed for a new hydro intake on the Skykomish River near Index, Washington. The proposed intake structure is designed to limit sediment entrainment while withstanding the high flow flood conditions, heavy floating debris loads, and large sediment transport capacity through the intake reach. Design efforts included 1D and 2D flow modeling, as well as physical modeling of the intake and the associated river reach, including sediment transport characteristics, in the laboratory to refine the design.

Bull Run Intake Tower Modifications: Hydraulic design and physical modeling of proposed modifications to the north and south intake towers at Bull Run Dam #2 to accommodate temperature withdrawal from different reservoir strata. The existing outlet works cannot withdraw flow from surface or mid-elevation reservoir locations and cannot meet downstream desire water temperature requirements. Physical model constructed and tested to verify the efficacy of the proposed tower modifications.

Mud Mountain Dam: Design of high head intake and outlet works for the Dam Safety Modification Program at Mud Mountain Dam on the White River. Hydraulic design of flood control water passages and regulating gates. Coordination and management of physical model study conducted at Waterways Experiment Station, Vicksburg, Mississippi. Conducted miscellaneous construction inspections during Phase I construction.

Skookumchuck Dam Flood Control Outlet Value Engineering Study: Technical Value Engineering Study to revisit previous flood control tunnel outlet works design to achieve sufficient cost savings to achieve a net benefit-to-cost ratio of 1:1 or greater. Project was intended to enable reservoir to be drawn down for flood control storage well below the spillway crest. Original estimated construction costs were about \$25 million, and the resulting design revision achieved the same level of flood control storage (including draw down and additional surcharge with the addition of spillway gates) for less than \$15 million.

Owen Gorge Hydropower Plant Turbine Pressure Relief Valve Cavitation Analysis: Senior hydraulic engineer for analysis of cavitation damage to needle valve pressure relief valves (PRV's) for three high head hydroturbines on the Owen River project for Los Angeles Department of Water and Power. The existing PRV's were in use in sustained operation as bypass outlets for 600 foot plus head turbine units during regular maintenance and repair activities. Severe cavitation damage had occurred within the energy dissipation structure and valve body, and LADWP wished to develop alternative energy dissipation facilities to enable long-term bypass operation safely without jeopardizing plant integrity.

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Potter Valley Hydro Plant Energy Dissipation and Bypass Control Valve Analysis & Design: Hydraulic design of 135 cfs high head energy dissipation structure modifications to reduce residual energy entering tailrace channel of recently constructed turbine flow bypass system. The newly constructed system failed to perform as designed as a result of unexpected upstream air entrainment, excessive and unacceptable vibration, and poor performance. Emergency retrofit design effort focused on eliminating as much upstream air entrainment as practical, and adding energy dissipation with the most basic modifications to the stilling vault.

Spaulding Hydro Plant Energy Dissipation and Bypass Pressure Relief Valve Erosion and Cavitation Analysis, Design, and Modeling, CA: Hydraulic analysis and evaluation of cavitation and erosion damage of Spaulding Hydro Plant turbine pressure relief valve energy dissipation chamber, and physical modeling of energy dissipation chamber. Senior technical advisory role in development of alternatives to provide effective energy dissipation for pressure relief valve that had destroyed cauldron-type dissipation chamber. This project included physical modeling of the existing valve and dissipation chamber, with modifications as proposed.

Cedar Falls Powerhouse Energy Dissipator: Design and prototype testing of energy dissipator for tailrace pool at Cedar Falls powerhouse on the Cedar River, Washington. Turbine load rejection bypass valve and bursting plate operation previously caused dewatering of tailwater pool, allowing high velocity jet to exit tailrace structure barrier weir and rise to greater than 90 feet elevation and collapse upon substation switch gear and transformer structure. Prototype tests of simple energy dissipator structure eliminated dewatering effect and contained high velocity jet within tailrace pool.

Canyon Dam Outlet Tunnel Hydraulic Analysis: Rigorous mathematical and numerical hydraulic analysis of hydraulic conditions causing serious vibration problems within outlet tunnel and tower at Canyon Dam on the Feather River in northern California.

Minne Lusa Storm Sewer Tunnel Hydraulic Analysis: Hydraulic analysis and design of large storm water tunnel in Omaha, NE. Evaluation included determination of capacity, flow regime, minimum and maximum allowable velocities, sediment transport, energy dissipation, and transient analysis. Tunnel design was tested in a physical scale model in the laboratory to verify criteria and operating characteristics.

Los Angeles Reservoir Drop Shaft Design: Design and physical scale model analysis of drop shaft design for Los Angeles Reservoir. Drop shaft provides energy dissipation for flow entering Los Angeles Reservoir from the California Aqueduct.

Bahia Lagoon Lock and Lagoon Filling and Drainage System Design: Design of small boat navigation lock for Bahia Lagoon and fish exclusion and screening system for lagoon filling and water exchange system on the Petaluma River.

Hiram Chittendon Locks: Design of new salt water drain intake facility for Lake Washington Ship Canal Hiram Chittendon Locks facility.

Napa Creek Flood Control Bypass Culvert: Hydraulic evaluation of proposed flood control bypass culverts on Napa Creek in northern California. The US Army Corps of Engineers had developed a conceptual design for the proposed bypass culverts, which were then evaluated in a physical scale model setting in the laboratory, which determined that the capacity and flow characteristics of the bypass culverts could not meet the desired capacity. Subsequent design development and analysis determined that intake improvements and culvert crown raise would permit the desired capacity to be reached and even increased. The concept was tested and its efficacy verified in the physical model.

Guadalupe River Downtown Reach Flood Damage Reduction: Hydraulic design of large bypass conduit for conveying Guadalupe River flood flows through downtown San Jose, California. Capacity of the bypass was about 75% of the total river design flow of up to 20,000 cfs. Bypassed reach included very sensitive riparian and anadromous fish habitat features that required 100% preservation.

Lummi Sea Ponds Tide Gate Structure Feasibility Design: The Lummi Tribe operates a man-made saltwater aquaculture facility in Lummi Bay, consisting of a three mile long dike, with a half dozen large inflow and outflow tide channel structures. Severe deterioration of the steel and concrete structures have left the Sea Pond facility vulnerable to loss of water volume and possible oil contamination in the event of an oil spill in Puget Sound. A feasibility level design for replacement of these structures was completed.

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Port Stanley Tide Gate: Design and preparation of construction plans and specifications for tide gate on Port Stanley lagoon drainage culvert on Lopez Island. Effort included construction supervision of installation of tide gate and adjustment over a season as observations of performance clarified the desired gate settings.

Edison and McElroy Slough Tide Gates: Development of design and construction plans and specifications for side hinged swing type tidal control gates for tidal prism restoration project on Edison Slough and McElroy Sloughs in Skagit County.

South Aberdeen – Cosmopolis Flood Control Project: Developed hydraulic design of tidal control gates for new flood control levee and interior salt marsh restoration project. Design included hydrologic evaluation of interior flood storage, estuarine exchange processes, and development of unique and innovative adjustable side hinged swing gate system for passing salmonids into restored salt marsh and achieving closure for flood control purposes.

Northwest Hydropower Facilities: Responsible for review and technical comments on FERC license, permit, and exemption documents for all proposed and existing hydropower facilities in the Northwest.

Gates, Valves, Sluices, Energy Dissipators, and Rotating Hydraulic Machines

Westminster Pump Station Isolation Valve Selection and Specification, CO: Assessment of applicability for limited clearance, 48 inch diameter double acting isolation valve for Westminster Pump Station in Westminster, CO. Specifications included 200 psi valve, 48 inch diameter, with less than 8 inch face-to-face allowable dimension. Specified valve was a 48 inch bonneted knife gate valve with resilient seats.

Sepulveda Feeder Pipeline Isolation Valve Rehabilitation, CA: Metropolitan Water District of Southern California (MWD) requested a workshop to assist in assessing alternatives for replacement or rehabilitation of existing pipeline isolation valves, and addition of two new isolation valves for the Sepulveda main feeder pipeline in Los Angeles. The feeder pipeline ranges in size from 7 feet to 12 feet, and the valves in question are rated for pressures up to 300 psi and 100 fps flow velocity during closure. MWD currently relies upon cone-type plug valves for the pipeline, but was interested in alternatives capable of similar pressure and velocity ratings. Workshop required development of suite of valve types and available manufacturers for each of the multiple isolation valve locations and presentation of those alternatives within a workshop setting to discuss the pros and cons of each.

Glacier Creek Diversion Sediment Sluice and Closure Gate Repair, AK: Design of repair system for concrete sediment sluice channel and control gate for hydropower intake at King Cove, Alaska. The Glacier Creek intake structure, constructed about 25 years previously, had experienced significant concrete abrasion damage and erosion as a result of stream sediments sluiced through the purpose-built sediment sluice gate and sluiceway. The diversion operates on a very flashy, high sediment load glacial runoff stream and requires regular operation of the sluice to clear sediment deposits from the turbine intake. A UHMW liner plate design and anchor system was developed to repair the sluiceway, and a new gate and thimble assembly was selected. The project is to be constructed by Public Works staff for the City of King Cove, an important fishing and fish processing village located near the far western end of the Alaskan Peninsula about 800 air miles from Anchorage.

New Exchequer Dam Outlet Bypass Fixed Cone Valve Discharge Chamber Emergency Repair, CA: Provided technical guidance and review for emergency repair of steel liner for large 108 inch diameter Howell Bunker fixed cone valve for powerhouse bypass discharge chamber. The steel liner in the 23 foot diameter discharge chamber for the valve failed and was destroyed by the high velocity flow emanating from the valve. Potential causes of the liner failure were assessed, and a new liner assembly was designed. Particular attention was devoted to the anchorage requirements for the new liner plating attaching it to the interior of the valve discharge chamber to resist the very high potential pore pressure uplift forces. The liner plate anchor stud attachment detail included consideration of potential cavitation where the liner plate might be exposed to very high jet velocities.

Lay Dam and Jordan Dam Headgate Downpull/Uplift Analysis, AL: Senior technical advisor leading the evaluation of penstock closure headgates for Lay Dam and Jordan Dam for Alabama Power Company. The existing gates date from the early 20th century and are scheduled to be replaced and the hoisting system rehabilitated or replaced. Analysis evaluated the uplift and downpull thrust reversals throughout the range of gate motion to determine if the gate weight needed to be increased the gate motion to overcome seal friction and to enable closure under flow, and then the

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capacity of the hoist to lift the weighted gate. All three dams are very similar in design, as are the general headgate arrangements.

Martin Dam Spillway Gate Downpull/Uplift Analysis, AL: Analysis of downpull and uplift forces on vertical lift spillway gate for Martin Dam. Existing vertical lift gates are being rehabilitated, to include new seals and seat beam, support rollers, and dogging devices. Analysis of downpull and uplift forces through the range of gate motion was necessary to assess gate hoist loads that may occur with the new gate lip design that extends the base of the gate down and resolves the current hoist capacity limitation imposed by the potential downpull.

Folsom Dam Emergency Closure Gate Uplift/Downpull Analysis: Baseline evaluation of potential uplift/downpull forces on proposed new emergency closure cable hung slide gates for Folsom Dam new outlet structure on the American River in central California. In addition, led workshop evaluation of proposed design and provided technical support and critical review of USACE-Sacramento District Hydraulic Design staff analysis.

Pyramid Dam Low Level Outlet Valve Study, CA: Development of preliminary design and selection of new 78" fixed cone valve to provide low level outlet regulation for Pyramid Dam.

Agnew and Gem Lake Dams New Bypass Valve Design, CA: Development of design for new high pressure bypass valve on high head penstock at Agnew Lake for Southern California Edison during extremely high snowmelt runoff in spring 2017 to provide additional hydraulic capacity for Gem and Agnew Lakes hydropower plant near Mammoth, CA. Record high snowpack and spillway operation restriction prevented spillway use and required considerable additional capacity to maintain reservoir elevations below FERC-mandated restriction.

Thermalito Dam Low Flow Outlet Valve Spillway Erosion Assessment, CA: Preliminary review of historical erosion damage to existing spillway apron resulting from long-term discharge of high velocity flow and spray from existing fixed cone valve passing discharge across spillway apron. Concrete erosion mapping, hydraulic characteristics of the cone valve jet, and time of exposure data were used to analyze the rate of erosion and develop potential modifications to the valve to reduce or eliminate the erosion processes on the concrete spillway apron surface.

Lake Mathews Forebay Energy Dissipation and Flow Bypass System Design, CA: Development of design for new bypass system for Lake Mathews flow distribution facility in Riverside, CA for Metropolitan Water District of Southern California. Facility is the terminus of Colorado River Aqueduct and serves to route all CRA water to member agencies and water treatment plants throughout southern California. Design included development of design requirements and valve selections for large, high capacity energy dissipating valves, bypass control gates and valves, weirs, and penstocks.

Don Pedro Dam Low Flow Outlet Works Rating Curve Development, CA: The Turlock Irrigation District (TID) was interested in development of a precise discharge rating curve for the low flow outlet valves at Don Pedro Dam. A field measurement and testing program consisting of the design and fabrication of a Replogle Flume and instrumentation was conducted to carefully and precisely measure outflows from each of the three low level release slide gates in the outlet tunnel. Measurements were collected at several approximate flow settings, and the resulting discharge data were correlated with the precise valve settings during each test. The results were summarized to TID in a detailed Technical Memorandum that included approximate accuracy, the field measurement program, and the summary rating curves for each valve.

Spaulding Hydro Plant Energy Dissipation and Bypass Pressure Relief Valve Erosion and Cavitation Analysis, Design, and Modeling, CA: Hydraulic analysis and evaluation of cavitation and erosion damage of Spaulding Hydro Plant turbine pressure relief valve energy dissipation chamber, and physical modeling of energy dissipation chamber. Senior technical advisory role in development of alternatives to provide effective energy dissipation for pressure relief valve that had destroyed cauldron-type dissipation chamber. This project included physical modeling of the existing valve and dissipation chamber, with modifications as proposed.

Fish Passage, Screening, & Collection Systems

Nelson Dam Removal, WA: Physical modeling of Nelson Dam, on the Naches River, and development of dam removal concept. Nelson Dam has been used to divert flow from the Naches River in southeast Washington State for more than a century, but has been identified as a partial barrier to anadromous salmonid upstream migration. Conceptual design

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of the dam removal and water intake modification to enable continued diversion of municipal and irrigation water preceded a physical scale model that was used to verify the concept.

Lower Baker Lake Floating Fish Collector Hydraulic Deficiency Correction, Concrete, WA: Determined several deficiencies in the final constructed floating fish collector for Lower Baker Lake for Puget Sound Energy. Specifically, identified hydraulic short-circuiting of collector screens due to excess open perforated plate head loss control panels. Additionally, corrected effects of mis-registration of HDPE sliding perforated control plate against stainless steel control plate through methodical calculation of open area and effective head for each of more than one hundred screen panel control sections by applying several different simple closure tabs to eliminate excess perforations. Work included initial and follow up collector velocity data collection to verify flow distribution correction.

White River Water Diversion Dam and Lake Tapps Water Intake Fish Passage Facilities, Enumclaw, WA: Development of new fish passage design and diversion dam design for the White River diversion into Lake Tapps below Mud Mountain Dam, near the city of Enumclaw, Washington. The existing diversion dam and intake originally provided water supply to an artificial lake and hydropower facility, but has suffered from high maintenance cost since construction in the early 20th century. Project included development of design for the new dam, control gates, surface water diversion screens and juvenile bypass facilities, and adult fish ladder and trap and haul facilities, in conjunction with design of new water supply intake for the adjacent hatchery complex operated by the Muckleshoot Indians.

Susitna River – Watana Dam Fish Passage Facilities Conceptual Design, AK: Participated in scientific advisory role for agency review of proposed fish passage facilities for proposed Watana Dam on the upper Susitna River in Alaska. Work involved collaborative Design Team workshops, design development, and construction cost development for both upstream and downstream anadromous and resident fish species for proposed 700-foot high concrete hydropower dam on the Susitna River. Species included anadromous salmonids, burbot, adfluvial whitefish, bull trout, suckers, and other species

Soda Springs Dam Fish Screen and Fish Ladder Balancing: Balancing and adjustment of new fish screen for hydro intake and new fish ladder AWS system for Soda Springs Dam on the North Umpqua River near Roseburg, Oregon. Work included approach velocity measurement at screens with ADV probe and flow measurements with Swoffer and Price AA meters.

Mill Creek Fish Ladder, CA: Senior technical review for new fish ladder to be constructed on the Mill Creek irrigation diversion dam, near Redding, California.

Lower Deer Creek Falls Fish Ladder, CA: Development of fish ladder design alternatives for remote site on Deer Creek near Lassen Park in northern California. These included slot-type, denil, pool-and-weir, and pool-and-chute ladder designs. The site limitations suggest a modified slot type with upstream head control would function best, and a design was prepared. The project would require all materials and equipment to be aerially lifted to the site, and largely hand work to construct.

California Department of Water Resources Bioengineering Research: Various projects in the Sacramento River Delta region to improve understanding of fish behavior and fish protection at DWR intakes, Delta Cross Channel, Yolo Bypass Toe Drain, Clifton Court forebay intake structure.

Wynoochee Dam Fish Passage: Design of downstream migrant juvenile anadromous fish passage facility for high head, widely-variable forebay elevation, flood control, hydropower, and water supply dam.

Albeni Falls Fish Bull Trout Monitoring: Assisted with the bull trout monitoring plan for the USACE Albeni Falls project on the Pend Oreille River. Project will require fish trap and haul facilities in the future.

Cedar Falls Powerhouse – Tailrace Fish Barrier: Managed the hydraulic design for tailrace fish barriers for Cedar Falls. Also managed the construction and testing of the design in a physical hydraulic model. Evaluated the hydraulic characteristics of the proposed fish barrier weirs.

Cushman Dam Upstream Fish Collection Facility: Fisheries engineer providing support to conceptual design of fish collection facility options at a high head dam. Facility includes a trap and haul design as well as new turbine units to supply the auxiliary water supply for the fish facility.

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Cougar Dam Fish Passage: Fisheries engineering involved in the development of fish collection and passage system for high head flood control and water supply dam. Alternatives addressed both adult Chinook and Bull Trout passage, and juvenile downstream passage and collection concepts.

Omak Creek Steelhead Broodstock Collection Trap: Design and construction management of semi-permanent floating picket weir, trap, and holding area for steelhead recovery broodstock collection facility for the Colville Confederated Tribes.

Okanogan River Adult Fish Collection Weir: Design of an adult salmon collection weir facility for the Colville Confederated Tribes' anadromous fish hatchery and harvest management program for the Okanogan River. The Tribes will use this weir to monitor and evaluate the summer Chinook salmon migration up the Okanogan River, in addition to the collection of broodstock for their Chief Joseph Dam Hatchery, which will be constructed in 2011. Surplus hatchery fish may be harvested at the weir as well. The project is a key component of the Tribes' efforts to restore the extirpated Chinook and steelhead populations that once proliferated throughout the Okanogan River watershed prior to settlement in the later 1800's.

Cedar River Broodstock Collection Weir: Design and management of overall feasibility design of sockeye salmon broodstock collection weir for the City of Seattle's hatchery facilities on the Cedar River.

Okanogan Rotary Smolt Trap Design: Design and installation of pilot rotary trap installations on the Okanogan River for downstream migrant sampling. Effort included development of anchorage system and debris handling.

Swift Dam Floating Surface Collector: Fisheries engineering support for the design of a floating surface collector for juvenile fish. Providing technical input and fisheries criteria guidance to team. Providing ITR on hydraulic design aspects of project.

Baker Lake Juvenile Fish Collection System Value Engineering Study: Technical Value Engineering study of proposed Baker Lake juvenile fish migrant collector. Study was conducted in order to discover and configure cost-savings measures over the course of the week-long evaluation. Study cost savings achieved were on the order of \$50 million out of an original estimated total construction cost of more than \$150 million. Juvenile fish collector is barge-mounted, with up to 1000 cfs pumped inflow capacity.

East Tonasket Smolt Rearing Pond Design: Design and construction of new fish release outlet system for East Tonasket Irrigation Settling Pond for use as winter rearing facility for spring Chinook salmon. Effort included retrofitting an existing irrigation pump system inlet such that winter flows could be released directly to the Okanogan River, and juvenile chinook salmon could be released through a surface spill directly into the river in spring.

Mayfield Dam Louvered Intake – CFD Modeling, Data Collection: Managed the development of a computation fluid dynamics model of the louvered intake at Mayfield Dam. Also managed velocity measurement program to verify model and fish tracking done by HTI. Compared fish tracking results to hydrodynamic flow field. Provided input on potential modifications to the intake.

The Dalles Dam Juvenile Fish Bypass & Combined System Outfall: Design of combined purpose high flow Ice and Trash Sluice outfall and juvenile fish collection and passage outfall for The Dalles Dam. Feature Design Memorandum level design of this combined purpose outfall included high capacity dewatering system (up to 2,500 cfs), and high capacity juvenile fish outfall capacity (up to 5,000 cfs). Worked extensively with the agencies to develop the high flow outfall design. Also managed physical models of the bypass system.

Little Goose Dam and Lower Granite Dam Fishways: Hydraulic evaluation of the adult fishway systems at Little Goose and Lower Granite Dams. Development of numerical models of the fishway systems. Completed field pump tests to determine the performance of the existing AWS pumps. Model development included collecting field data to calibrate model. Completed a hydraulic evaluation of the existing fishway and studied a proposed change to the Little Goose Fishway auxiliary water supply system.

High Capacity Juvenile Fish Collection and Outfall for Bonneville Dam Second Powerhouse: Preliminary design of modification and extension of the existing Ice and Trash Sluice for use as high capacity juvenile fish passage outfall. Features included modification of existing control gate, weir crest, and outfall channel.

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Lower Monumental Emergency Auxiliary Water Supply (AWS) Study: Hydraulic evaluation of the adult fishway system. Development of a numerical computer model of the fishway and fish ladder system at Lower Monumental Dam. Fishway system includes two ladders and fishway transportation channels. Completed field pump tests to develop pump curves for the existing AWS pumps (three pumps, rated capacity of 800 cfs). Numerical model development included collecting field data and calibrating model. Numerical model used to develop emergency water supply concepts for the fishway system in the event of a pump failure.

Little Goose Dam and Lower Granite Dam Fishways: Hydraulic evaluation of the adult fishway systems at Little Goose and Lower Granite Dams. Development of numerical models of the fishway systems. Completed field pump tests to determine the performance of the existing AWS pumps. Model development included collecting field data to calibrate model. Completed a hydraulic evaluation of the existing fishway and studied a proposed change to the Little Goose Fishway auxiliary water supply system.

Granlees Dam Fish Ladder: Technical review of fish ladder design for Granlees Dam on the Mokelumne River.

Bonneville Fish Ladder AWS Study: Development of numerical model of Bonneville Dam adult fishway system, and use of this model to study hydraulic changes in the fishway associated with modifications to the auxiliary water supply system. Documented criteria violations in fishway. Developed an operation manual for the fishway for emergency operating conditions when one of the turbine supply sources fails. Collected field velocity measurements and water surface elevations in fishway.

Bonneville Dam Second Powerhouse Forebay Corner Collector: Hydraulic design of upstream surface-oriented fish collection and bypass system. Included design and evaluation of physical hydraulic model study of collection system.

John Day Dam Fish Ladder Modifications: Development of numerical model of adult fishway system at John Day Dam on the Columbia River, and hydraulic analysis of adult fishway system with this model. Also included development of potential modifications to the fish ladders and auxiliary water supply system.

Stilliguamish River Cook Slough Flow Distribution Weir Fish Passage Design: Provided technical guidance and design for boulder-roughened fishway to remediate low-flow fish barrier created by USACE flow distribution weir on Cook Slough of the lower Stilliguamish River near Arlington, Washington.

Yolo Bypass Toe Drain Fish Collection Trap: Final design of collection and sampling facility for sturgeon, salmonid, and other large body fishes in the Yolo Bypass Toe Drain. Facility included sheet pile abutments, floating pickets, adaptable and adjustable concentration section, holding area, access walkways, and release chute system. Project was designed for the California Department of Water Resources.

Mission Creek Flood Control Channel Fish Passage Alternatives Physical Modeling: Consultation to laboratory staff and development of modeling approach for laboratory testing of various passage alternatives identified in previous feasibility study. Physical modeling included moveable bed materials, with which the sediment transport characteristics of the proposed passage alternatives were evaluated and their impacts on flood control channel capacity were determined.

San Jose Creek Flood Control Channel Fish Passage Alternatives Analysis: Development of fish passage channel modifications to the existing concrete paved San Jose Creek channel in Goleta, California. Existing paved channel is considered impassable to anadromous steelhead. Channel modifications were evaluated to determine relative passage success potential, sediment transport characteristics, and flood discharge capacity.

Howard Hanson Dam Fish Passage: Design of downstream migrant juvenile anadromous fish passage facility for high head, widely-variable forebay elevation, flood control and water supply dam. Included high flow exclusion screen system and bypass. Three-year study required significant resource agency coordination effort and design formulation and presentation from reconnaissance level design through feasibility level design.

Robles Diversion Dam Intake Fish Passage & Sediment Passage: Development of conceptual level designs for rehabilitation of adult fish passage facilities at the Robles diversion and water intake on the Ventura River in southern California, near the city of Ojai as part of the larger project to reconstruct the dam and gate control structures to allow

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passage of expected large quantities of sediment once Matilija Dam is removed. Adult steelhead passage through the dam structure and diversion works was the primary focus of the study, which is ongoing at present.

Santa Ynez River Fish Passage: As a continuation of previous work to identify fish passage alternatives for Bradbury Dam on the Santa Ynez River, this work consisted of participation in a team working environment with agency staff and consultant engineering staff to develop conceptual upstream and downstream fish passage facilities for Bradbury Dam and two additional dams in the upper watershed of the Santa Ynez. The study report proposed verification studies and design work to validate or invalidate each alternative presented, or to identify modifications necessary to ensure complete success in passage both adults and juvenile steelhead.

Barnaby Creek Culvert Fish Passage Modification Analysis: Development of passage modification alternatives for perched culvert outlet to Barnaby Creek, a tributary to Lake Roosevelt, the reservoir impounded by Grand Coulee Dam on the Columbia River. Currently, at low lake levels, the culvert outflow tumbles down a large riprap roadway embankment with as much as 40 feet of vertical drop. At all but high lake levels, the existing culvert is entirely impassable to trout and other adfluvial fishes.

Omak Creek Culvert Replacement: Design and construction monitoring of two large bottomless culvert replacement projects on Omak Creek in North-Central Washington. The two road crossings replaced inadequately sized culverts that were subject to ice jams, woody debris blockage, and road washouts, and were significant fish passage barriers.

Lake Gardiner Outlet Access Roadway Culvert Replacement: Field design and construction monitoring of replacement of undersized culvert with prefabricated bridge structure to alleviate fish passage barrier problems.

Salmon Creek Culvert Replacement Project: Design of grade control weirs and bank stabilization downstream of formerly perched and impassable large paired box culverts over Salmon Creek.

Antoine Creek Culvert Replacement: Design and analysis of various alternatives for replacement of critically undersized road culvert on Antoine Creek in north central Washington State, a tributary to the Okanogan River. The existing culvert had been identified as a significant impairment to fish passage and a source of fine sediments which damage spawning beds when high flows continually wash out the existing roadway. Selected design incorporated an aluminum plate type bottomless box culvert with precast concrete footings and natural stone abutment and erosion protection.

River Engineering & Habitat Restoration

Roy G Park stream channel stabilization and restoration Drop Structure Design, TX: Review of design of channel stabilization and grade drop structures for ephemeral stream channel in Austin, Texas where large flood events have caused significant damage and initiated headcutting that is further destabilizing the stream channel and damaging surrounding public park space. Design concepts developed included a hybrid stepped spillway and labyrinth cycle weir to reduce gradient and arrest the headcutting process.

Somis Drain Drop Structure Design Review, Camarillo, CA.: Design review of replacement grade drop structures for the Somis Drain upstream from its confluence with the Calleguas Creek stream near Camarillo, CA. The Somis Drain is a constructed channel with riprap revetments along both banks, and a sand bed channel that mobilizes during flow events. The existing drop structures are inadequate and need to be replaced

Wallace River Streambank Stabilization: Design and construction monitoring of extensive bank stabilization works on Wallace River below Wallace Falls. Project was constructed entirely with mechanically anchored large woody debris.

Skook Creek Culvert Replacement and Grade Control Structures: Hydraulic design and configuration of perched culvert replacement with bottom concrete arch culvert and several hundred feet of channel stabilization using boulder grade control structures and Large Woody Debris (LWD) structures to provide channel boundary roughness and create complex instream habitat.

American River Site 5 Erosion Protection: Design of erosion protection measures for 2000 foot reach of right descending bank line site on American River. Design featured habitat enhancement with Large Woody Debris and riparian restoration.

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Pilchuck River Diversion Dam Fish Passage Barrier Removal: Developed design from planning phase through Preliminary Engineering for the removal of an anadromous fish passage barrier created by a municipal water diversion dam on the Pilchuck River near Granite Falls, Washington. The City of Snohomish has diverted municipal water supplies from the dam since the early 1900's, but the facility was identified in regional fishery restoration plans as a significant passage barrier to adult salmon returning to the upper Pilchuck River watershed to spawn. The study developed several concepts for removing the dam or rebuilding it with passage, or replacing it with another intake system that did not require a physical barrier. An alternatives assessment workshop was conducted, and the preferred concept was selected through a matrix evaluation process, and carried through to the Preliminary Design stage.

Swift Bypass Reach Habitat Restoration: Preliminary design of habitat restoration and habitat channel design for Swift hydropower project bypass reach on the Lewis River, Washington.

Hope Creek Restoration Design: Design and construction of extensive juvenile passage structures and wetland rehabilitation for Hope Creek coho overwintering habitat.

Hanford Creek Bank Stabilization and Habitat Restoration: Design of boulder and Large Woody Debris Toe stabilization structure for bridge replacement project. Project provided structural protection for eroding bankline upstream of new bridge and created overhanging and submerged woody habitat features.

Guadalupe Creek Restoration: Design and review of Large Woody Debris features and channel stabilization measures for restoration of Guadalupe Creek in San Jose.

Lower Guadalupe River Flood Damage Reduction: Design of setback levees, low flow channel, channel stabilization, bridge stabilization structures. Designs incorporated habitat enhancement and restoration features such as overbank riparian restoration, grade control structures, fish passage low flow channels, etc.

Nooksack River Comprehensive Flood Damage Reduction Study: Hydraulic analysis and design of flood damage reduction features for comprehensive basin-wide study of the Nooksack River floodplain.

Mill Creek (Michigan) Drain Flood Damage Reduction Study: Unsteady flow modeling of agricultural lands flooding throughout the Mill Creek drainage basin. Developed alternatives for reduction of flood damage and accommodated environmentally sensitive conveyance capacity increase. Selected alternative included bank and floodway vegetation thinning and selected clearing of accumulated sediment throughout various reaches of the Mill Creek drainage basin. Later phases of the project included construction monitoring to ensure compliance with design intent for minimal disturbance to the naturally maturing riparian forest cover and enhancement of climax forest characteristics, especially prescribed forest thinning operations and sediment removal from channel

Sycamore Phase II Issaquah Creek Restoration: Design of large woody debris placement, overbank flooding relief channels, channel modifications to restore previously dredged, ripped, and widened reach of Issaquah Creek to natural channel regime. Large wood habitat complex structures were included to encourage sediment feature generation to enhance spawning substrate diversity.

Sauk River Erosion Protection Design: Design of bank stabilization on Sauk River in Darrington, Washington. Project included mechanically anchored large woody debris engineered log jams designed to stabilize eroding bank line and provide submerged and overhanging wood cover elements.

Pilchuck River Bridge Replacement and Habitat Enhancement: Design of bank and pier stabilization project for bridge replacement project. Design included design of mechanically anchored large woody debris engineered log jams and barb structures to stabilize upstream bank line and enhance spawning and juvenile cover.

Franklin Creek Alluvial Fan Flood Damage Reduction and Fish Passage Restoration: Feasibility scoping of stream restoration techniques for Franklin Creek on the South Coast of California. Franklin Creek flows through a concrete flood control channel across the historic alluvial fan through the City of Carpinteria. Poor water quality, complete blockage of fish passage, and interest in restoration of the channel for environmental benefit to the public spurred the development of conceptual alternatives to the concrete channel for transporting the large quantities of sediment and high flood discharges to the Pacific Ocean while at the same time providing fish passage and environmental benefits during low flow periods.

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North Fork Newaukum River Boulder Grade Control and Boundary Roughness Structures: Hydraulic design and configuration of boulder and grade control and bank stabilization for severely degraded reach upstream of County road bridge crossing.

Lower Cedar River Sedimentation: Sediment transport and hydraulic analysis of the lower two miles of the Cedar River, Washington, for flood damage reduction study, including levee design and initial construction and maintenance dredging.

North Fork Skykomish River Bank Protection Design: Design and construction monitoring of mechanically anchored Large Woody Debris (LWD) revetment and groin structures protecting several hundred feet of bank and several residences along the North Fork Skykomish River above Index.

Okanogan River Channel Flow Distribution Structure Conceptual Design: Development of conceptual design for a flow distribution structure to divide Okanogan River flows between the Similkameen River and the Okanogan River near Oroville, Washington. The shifting Similkameen River channel and an enlarging cross channel between the two rivers has been starving the Okanogan River of flow, and has left several miles of prime steelhead and chinook spawning habitat unavailable. A conceptual design for a large flow and sediment distribution structure to provide assured hydrology to the Okanogan River channel was developed for the Colville Tribes.

Silver Creek Alluvial Fan Flood Damage Reduction: Conceptual analysis and design of alternatives for managing sediment deposition and flooding on large alluvial fan tributary to the Cowlitz River, near Randall, Washington. The alluvial fan of Silver Creek is the site of the town of Randall, including a large lumber mill, city and government offices, and a public school. Persistent flooding caused by chronic sediment deposition had previously been alleviated by periodic dredging of the channel, at significant environmental and fiscal cost to the lumber mill owners and the County. Potential solutions included sediment diversion, compound channel design, and channel efficiency improvements.

North Fork Thornton Creek Habitat Enhancement and Bank Stabilization: Development of design and construction monitoring for a habitat restoration, spawning bed enhancement, and failing bank protection project on North Fork Thornton Creek in a highly urbanized watershed at the northern boundary of the City of Seattle, Washington. Project design innovations included no use of riprap revetment, and included only natural wood, log, and rootwad construction materials, using mechanical anchorage systems.

Salinas River Flood Control Reconstruction: Design of abandonment and/or reconstruction of flood damage reduction setback levee systems for Salinas River following large floods of the winter of 1994-1995. Various levee projects extended over more than 100 miles of the river from near Castroville upstream to San Ardo, numbering several dozen individual levee systems.

Santa Ana River Flood Control Levee and Groundwater Recharge Cross Levee Inspection: Inspection and development of flood damage reduction levee system rehabilitation following 1995 floods.

Poway Creek Flood Control Channel Inspection: Inspection and development of flood damage reduction conveyance infrastructure for Poway Creek.

Bank Stabilization Design: Design and construction of numerous streambank erosion protection projects throughout Washington, Idaho, Montana, and California.

Sediment Transport

Snoqualmie River Basin Alluvial Fan Remediation Alternatives: Development of conceptual designs for remediation of sedimentation problems on several alluvial fan assemblages within the Snoqualmie River Basin in western Washington State. Large flood events have carried extreme sediment loads from steep, unstable watershed areas on tributary streams onto the Snoqualmie River floodplain, leading to destruction of access roadways, stream channel avulsion, fish habitat destruction, and passage corridor abandonment. Designs included sediment retention basins, diversions, ejectors, and compound channel configurations to enable more effective regular maintenance and removal of deposited materials.

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Mission Creek Flood Control Channel Sediment Transport Analysis: Hydraulic modeling and sediment transport modeling of the Mission Creek flood control channel in Santa Barbara, California in support of feasibility design of channel modifications to improve flood capacity.

San Jose Creek Flood Control Channel Sediment Transport Analysis: Hydraulic modeling and sediment transport modeling of the San Jose Creek flood control channel in Goleta, California in support of feasibility design of channel modifications to improve flood capacity.

Montecito Creek Debris Basin Fish Passage Modifications: Development of conceptual designs and evaluations for several alternatives for modifying the existing debris basin on Montecito Creek in Santa Barbara County, California. The existing debris basin is provided with a fish ladder, but sediment is currently recruited into the ladder, filling it quickly and rendering it largely impassable during flood events. Designs included natural roughened boulder spillways of several different slopes and configurations, and various sediment extraction alternatives for the existing ladder.

Lake Mills Dredge Disposal Slurry Pipeline Conceptual Design: Design of proposed dredge slurry pipeline to carry lake deposits to the Straits of Juan De Fuca prior to breaching and demolition of Elwha Dam on the Elwha River. Analysis of several different pipeline materials and configuration in highly abrasive environment.

Water Management & Reservoir Operations, Water Quality

International Joint Commission: Directed staff of hydrologists, hydraulic engineers, and technicians as the Chief of Water Management Section of the Seattle District of the US Army Corps of Engineers (from 2006 to 2009) in the analysis and execution of Columbia River Basin watershed reservoir control and water management. Tasks and studies under direct supervision included water supply and flood control reservoir operations on cross-border tributaries to the Columbia River, specifically the Kootenai and Okanogan Rivers. Duties included technical review of staff engineering products, and support to the US Representative to the IJC; the District Engineer of the Seattle District of the US Army Corps of Engineers, and Division and Headquarters command offices.

Libby Dam Operations: Directed staff of hydrologic and hydraulic engineers and engineering technicians (as Chief, Water Management Section) in the annual operation of Libby Dam on the Kootenai River. The Kootenai River flows into Libby Reservoir (Lake Koocanusa) from the Rocky Mountains of eastern British Columbia, Canada, and then through Idaho and back into Canada into the Kootenay Lake complex. From there, the Kootenai joins the Upper Columbia River at Castlegar, B.C., and then flows south into the Grand Coulee Reservoir (Lake Roosevelt) in northeast Washington State. Operation of the reservoir at Libby satisfies multiple stakeholders by providing hydropower generation, flood storage during the spring snowmelt, and water supply during the later summer, fall, and winter. Complex hydrologic and hydraulic analyses are required to forecast snow pack, runoff potential, and downstream river discharges, as well as hydropower demand and storage reserves. Subsequent coordinated project operations achieve primary flood control in the Bonners Ferry area of north Idaho and in the Kootenay Lake area of B.C., as well as coordinated hydropower generation in the United States and Canada.

Albeni Falls Dam Operation: Directed staff of hydrologic and hydraulic engineers and engineering technicians (as Chief, Water Management Section) in the annual operation of Albeni Falls Dam on the Pend Oreille River, in coordination with US Bureau of Reclamation operation of Kerr Dam and Hungry Horse Reservoir on the Flathead River. The Pend Oreille River flows through Albeni Falls Dam from Lake Pend Oreille, which is controlled during low to moderate flows by Albeni Falls Dam. Outflows from the Dam pass into Canada through several utility generation dams, joining the Upper Columbia River just north of the international border with Canada, and back into the Grand Coulee Dam Reservoir (Lake Roosevelt) in northeast Washington State. Operation of Albeni Falls Dam satisfies multiple stakeholders by providing hydropower generation, flood storage in Lake Pend Oreille during the spring snowmelt, and water supply and recreation during the summer. Complex hydrologic and hydraulic analyses are required to forecast snow pack, runoff potential, and downstream river discharges, as well as hydropower demand and storage reserves. Subsequent coordinated project operations achieve primary flood control in the Newport area of northeast Washington, as well as coordinated hydropower generation in the United States and Canada.

Chief Joseph Dam Operations: Directed staff of hydrologic and hydraulic engineers and engineering technicians (as Chief, Water Management Section) in the annual operation of Chief Joseph Dam on the Columbia River, in coordination with US Bureau of Reclamation operation of Grand Coulee Dam and upstream reservoirs in Canada and the United

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States. Chief Joseph Dam provides a small amount of flood control storage, and primarily acts as a regulating reservoir below Grand Coulee Dam. It has the largest US Army Corps of Engineers' hydropower generation capacity in the United States. Operations at Chief Joseph Dam are coordinated with the Bonneville Power Administration and multiple public utility districts on the middle Columbia and the Snake River to generate power and provide flood control in the Lower Columbia at Portland, OR and Vancouver, WA. Complex hydrologic and hydraulic analyses are required to forecast snow pack, runoff potential, and downstream river discharges, as well as hydropower demand.

Puget Sound Tributaries Flood Control Operations: Directed staff of hydrologic and hydraulic engineers and engineering technicians (as Chief, Water Management Section) in the annual operations of Mud Mountain Dam on the White River, Howard Hanson Dam on the Green River, and several other utility-owned storage and hydropower dams across the Puget Sound region (Seattle City Light's Upper Skagit River projects, Puget Sound Energy's Baker River projects, Tacoma Power's Wynoochee River project) to achieve flood control objectives and meet water supply needs. In addition, staff provided real-time flood coordination efforts on all unregulated rivers in the Puget Sound and Grays Harbor basins, as well as streams draining the Olympic Peninsula and east slope of the Cascade Mountains to assist local and regional flood emergency response agencies. Water Management flood control operations provided primary information to US Army Corps of Engineers' flood fighting crews actively engaged in emergency flood protection and response across Western Washington and the East slopes of the Cascades. Complex hydrologic and hydraulic analyses by Water Management staff were required to forecast flood runoff potential, downstream river discharges, and anticipated river flood stage.

Water Control Data Collection: Directed staff of engineering technicians and hydrologic engineers in the installation, maintenance, and operation of numerous snow pack measurement, rainfall gauges, stream gauges, and water quality (temperature and turbidity) throughout Washington, Idaho, and Montana owned by the US Army Corps of Engineers. These environmental monitoring stations provide real-time data for use in the coordinated operations of the multiple US Army Corps of Engineers (and other coordinating agencies) reservoirs and dams throughout the Pacific Northwest, and are essential to the successful operation of US Army Corps of Engineers project throughout the region. In addition, directed Water Management Hydromet Data processing staff in the processing, distribution, and archiving of all data collected as part of Water Management Section operations. Was directly responsible for data quality, computer equipment and network transmission of these data through critical staff at the Seattle District.

Pend O'Reille River Temperature Modeling Review: Technical review of Pend O'Reille water temperature modeling analysis with CEQUAL-W2. Temperature modeling was accomplished in support of USACE coordination with Idaho Department of Environmental Quality and the proposed temperature TMDL for the Pend O'Reille River.

Icicle/Peshastin Irrigation District: Water conservation study for Icicle/Peshastin Irrigation District in Cashmere, Washington. Field inspection and review of all facilities. Development of facility rehabilitation and water conservation plans and construction schedules.

Selected Publications

A.R. Firoozfar, **E.T. Zapel**, A.L. Strain, and N.B. Adams (2019), "Dam and Spillway Rehabilitation to Accommodate Increased Design Flood: Calero Dam." Proceedings of the 2019 ICOLD Symposium, Ottawa, Canada, 2019.

A.R. Firoozfar, K.C. Moen, **E.T. Zapel**, K.S. Dosanjh, T. Ford, (2018) Generalized Programmatic Framework for Spillway Inspection and Potential Failure Modes Assessment." USSD Dams and Levees, Fall 2018, Issue No. 176.

D. Hinton, B. Hughes, and **E.T. Zapel** (2015), "Scott Dam Spillway – Comparing Physical Model Study Results." HydroVision 2015, Portland, OR.

Zapel, E.T., H. Nelson, B.R. Hughes, S. Fry (2014), "Options for Reducing Total Dissolved Gas at the Long Lake Hydroelectric Facility." HydroVision 2014, Nashville, Tennessee, July, 2014.

Zapel, E.T. (2014). "Innovative Hybrid Design of Issaquah Creek Hatchery Water Supply Intake Using Physical Scale Modeling as a Collaborative Tool." International Conference on Engineering and Ecohydrology for Fish Passage 2014, Madison, WI.

Edwin T. Zapel, M.S., P.E.

Zapel, E.T., M. Whitman, D. Crowder, M. McGoogan, K. Harrison, J. Frye; "Constructed Flood Control Channels – Fish Passage Modifications: San Jose Creek, Mission Creek, Montecito Creek Physical Models." American Fisheries Society, 140th Annual Meeting, Pittsburgh, September 2011.

Larson, L.W., **Zapel, E.T.**, S. J. Schlenker, R.T. Lee, S.C. Milligan; "Predictive Numerical Computer Models of Adult Fishways and Application at US Army Corps of Engineers Dams." Proceedings of the Bioengineering Symposium at 132nd Annual American Fisheries Society Meeting. Baltimore, Maryland, August, 2002.

M.P. Gellis, **E.T. Zapel**, and M. Whitman (2009). "A Physical Model of Modifications to Concrete Flood Control Channels for Fish Passage."

Zapel, E.T., T.R. Molls, S.V. Johnston, P.A. Nealson, M.A. Timko, and M. G. LaRiviere; "Juvenile Salmonid Acoustic Tracking Correlation with CFD-Model Predicted Velocity Fields at the Mayfield Dam Louvered Intake." Proceedings of the Bioengineering Symposium at 132nd Annual American Fisheries Society Meeting. Baltimore, Maryland, August, 2002.

Ahmann, M.L., and **E.T. Zapel**, "Stepped Spillways, a dissolved gas abatement alternative." Proceedings of the International Workshop on Hydraulics of Stepped Spillways. Zurich, Switzerland, March, 2000.

Zapel, E.T., F.A. Goetz, and P.J. Hilgert. "Development of a Downstream Fish Passage System for Anadromous Salmonids at a High-Head Dam." Proceedings of Symposium at 127th Annual American Fisheries Society Meeting. Monterey, California, August, 1997.

Zapel, E.T. "Howard A. Hanson Dam Juvenile Fish Bypass System." Fish Passage Workshop. Milwaukee, Wisconsin, May, 1997.



United States Department of the Interior

FISH AND WILDLIFE SERVICE

5275 Leesburg Pike
MS-ES
Falls Church, Virginia 22041



In Reply Refer To:
FWS/AES/DER/BER/074532
ER 21/0036

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

Re: U.S. Fish and Wildlife Service Comments on the Federal Energy Regulatory Commission's Notice of Inquiry on Financial Assurance Measures for Hydropower Projects, Docket RM21-9-000

Dear Ms. Bose:

The U.S. Fish and Wildlife Service (Service) would like to thank the Federal Energy Regulatory Commission (Commission) for seeking comment on whether and how the Commission should require additional financial assurance mechanisms in the licenses and other authorizations it issues for hydroelectric projects. The Service engages in the Commission's authorization processes for hydroelectric projects through the following authorities, as amended: the Federal Power Act (16 U.S.C. §791 et seq.), the Fish and Wildlife Coordination Act (16 U.S.C. §661 et seq.), the Endangered Species Act (ESA; 16 U.S.C. §1531 et seq.), and the Migratory Bird Treaty Act (16 U.S.C. §§703–712).

The Service agrees with the need to require financial assurance measures in all of the Commission's hydroelectric project authorizations to ensure that licensees and exemptees can afford required environmental measures. Requiring financial assurances will help reduce the risk of project failure and the resulting environmental hazards. The Service recommends that the amount of assurances should be proportional to the estimated risk for a given project.

The Commission has requested responses to specific questions and three potential options for establishing financial assurance mechanisms in hydroelectric licenses. The Service's responses and comments are in the enclosed attachment. The Service provides these comments for the purpose of offering technical assistance and notes that these comments do not necessarily represent the views and comments of the Department of the Interior. If you have any questions on the Service's comments, please contact Ms. Frankie Green,

National Hydropower Program Manager, at either frankie_green@fws.gov or (703) 358-1884.

Sincerely,

**CRAIG
AUBREY**

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CRAIG AUBREY
Date: 2021.03.26
08:50:05 -04'00'

Craig Aubrey
Chief, Division of Environmental Review
Ecological Services Program

Attachment

Attachment**U.S Fish and Wildlife Service Responses to RM21-9-000
*Notice of Inquiry on Financial Assurance Measures for Hydropower Projects*****Federal Energy Regulatory Commission Questions****1. How and when the Commission should require financial assurance from licensees.**

Specifically, should a financial assurance requirement be included in original licenses and/or on relicense? If on relicense, should such a requirement be included in both new licenses for major projects and subsequent licenses for minor projects? Should the Commission also require financial assurance requirements in other authorizations, such as all exemptions, amendment requests, and transfers? Should the Commission reopen licenses to impose financial assurance measures?

Response: The Service recommends that the Commission require financial assurances for all projects (i.e., original licenses, relicensing, exemptions, amendment requests, and transfers) to ensure the protection of fish and wildlife and the preservation of other aspects of environmental quality throughout the duration of the license. In its Notice of Inquiry, the Commission mentions that approximately 88 projects under the Commission's jurisdiction are non-operational, often due to a lack of financial resources. The Service notes that a number of these projects, and others, are also out of compliance with license conditions related to Service trust resources. Environmental effects occur at both major and minor projects and financial assurances should be required to ensure that licensees can afford to implement the environmental mitigation measures that are required in the license. For license transfers, the Service also recommends that transferees demonstrate, prior to the transfer, that they have adequate financial assurance for required environmental measures, including mitigation. Transferees are responsible for all of the provisions of the existing license, and thus should demonstrate the financial capacity to implement measures needed to protect environmental resources. In terms of addressing environmental impacts, the Service recommends that financial assurance mechanisms be required for amendment requests requiring substantial additional investment where fish passage or other fish and wildlife concerns are central to the request. Based on projects' compliance records, the Commission should consider reopening licenses or exemptions as necessary to require financial assurance measures.

Because exemptions are issued in perpetuity, the Service strongly recommends that financial assurance mechanisms be required for all exemptions and exemptees. Ensuring the long-term capacity of the operator to maintain the project in good working order is particularly important. The Service recognizes that it is typically smaller projects that qualify for exemptions but notes that these projects may have potentially significant environmental impacts. For example, the Elba Hydroelectric Project (P-10691) on the Pea River in southern Alabama was granted an exemption in 1989 and has been inoperable since the dam was breached by a major flood in December 2015. The portion of the Pea River downstream of the dam is listed as critical habitat for Gulf Sturgeon, and both the upstream and downstream reaches are listed as critical habitat for three listed

freshwater mussel species. Although negotiations with the owner and various stakeholders to decommission the dam and restore the habitat are ongoing, outside funding may be required, as it appears there are insufficient financial resources to repair the facility. Requiring financial assurances in the case of exemptions would reduce the likelihood of similar situations arising in the future, which would clearly be in the public interest.

The Service also recommends that financial assurances address decommissioning costs, including the removal of project infrastructure and the restoration of habitat when a licensee or exemptee surrenders its license or otherwise voluntarily abandons a project. This would ensure projects that are abandoned do not pose a risk to the environment and would reduce the risk that taxpayers and ratepayers would have to pay to remove project infrastructure and restore habitat if a project is abandoned.

2. Potential Options identified by Commission staff for establishing financial assurance mechanisms in hydroelectric licenses.

A. Bonds: Requiring licensees to obtain bonds to cover the costs of safety measures and project operation and maintenance: *Should the Commission require licensees to obtain bonds as a financial assurance mechanism?*

Response: If bonds are selected as a financial instrument, the amount of the bond should reflect the potential costs to maintain the comprehensive development standard for that waterway, including the adequate protection of fish and wildlife and their habitats. The Service recognizes that bonds may not be within the resources of all licensees or exemptees so the Commission should consider which financial assurance mechanism is best for small hydroelectric projects.

B. Trusts: Establishing an industry-wide trust or remediation fund or requiring licensees to maintain an individual trust, escrow, or remediation fund: *Should the Commission establish an industry-wide trust or fund as a financial assurance mechanism?*

Response: If an industry-wide mechanism were employed the Service recommends that it should be structured so that only projects that meet their comprehensive development standard qualify for financial assurance support. Systems in support of a trust, similar to the Oil Spill Liability Trust Fund authorized in the Oil Pollution Act of 1990, could be established to encourage licensees and exemptees to maintain adequate financial assurance for maintenance, fish passage, and environmental mitigation, or removal of project infrastructure.

C. Insurance: Requiring licensees to obtain insurance policies for unforeseen safety hazards or dam failures.

Response: The Service notes that insurance would be a project-specific financial assurance mechanism that would not put an undue burden on any one sector of the industry.

General Comments

Non-operational or non-compliant projects pose risks to more than just human health and safety. Licenses are often issued with measures that are supposed to protect or mitigate damage to fish and wildlife resources and their habitats. When licensees do not comply or cease to comply with those measures, the fish and wildlife resources and their habitats may be put at risk. Requiring financial assurances of licensees is an additional mechanism that the Commission could use in exercising its authorities and fulfilling responsibilities to the public.

Financial assurance mechanisms employed by the Commission should not support projects where the protection of environmental resources outweighs their benefit. In its 1994 Decommissioning at Relicensing Policy Statement the Commission encourages licensees to plan accordingly for unforeseen circumstances and for projects that have reached the end of their utility but that continue to prevent or reduce fish passage and/or that have other continuing environmental impacts. The Service agrees that financial assurance mechanisms should be used to ensure operation and maintenance of a project and be adequate to support the challenges of an aging fleet, such as providing fish passage or for removal of project infrastructure and mitigation of project impacts. Committing to financial assurances is critically important to ensure that licensees and exemptees can fund and address known and unanticipated future environmental concerns. The Service believes that carefully developed financial assurance mechanisms required by the Commission will address these trust resource considerations and could provide a sustainable path forward for Commission licensed hydroelectric projects.

Attachment F



UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

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

Re: National Marine Fisheries Service Office of Habitat Conservation Comments on Financial Assurance Mechanisms for Federal Energy Regulatory Commission Licensed Hydroelectric Projects; Docket: RM21-9-000

Dear Ms. Bose:

The National Marine Fisheries Service (NMFS) would like to thank the Federal Energy Regulatory Commission (FERC) for the opportunity to provide feedback on the January 26th, 2021 Notice of Inquiry (NOI) on whether to require additional financial assurance mechanisms in the licenses and other authorizations FERC issues for hydroelectric projects. NMFS provides our comments under the following authorities that guide our interaction with hydropower development: the Federal Power Act (FPA), the Endangered Species Act (ESA), the Fish and Wildlife Coordination Act, and the Magnuson–Stevens Fishery Conservation and Management Act.

NMFS supports FERC requiring financial assurance from licensees. Financial assurance from licensees should support mechanisms that promote environmental conservation, forward planning, flexibility in terms of types of hydroelectric projects, and equity for communities affected by or reliant on hydroelectric projects.

- Conservation - Financial assurance mechanisms should help ensure licensees are financially able to carry out license terms and obligations for the protection and recovery of NOAA trust resources (i.e. FPA Section 18 prescriptions and 10(a) and 10(j) recommendations), and should include provisions to account for unforeseen circumstances, e.g., increasing severity of seasonal flooding and failure of antiquated infrastructure, which may require adjustments or new mitigation for trust resources.
- Forward planning - Mechanisms should help anticipate the long-term financial burden of multi-decadal projects and ensure that over its entire term, the license continues to reflect FERC's equal consideration balancing under FPA Section (4e) and FERC's assessment of a project's "best adapted to a comprehensive plan" standard for a waterway for the public's best interest is achieved (FPA Section 10(a)), including options for fish passage, environmental mitigation, decommissioning, and removal.



- Flexibility - Mechanisms should be available to address the diversity of hydroelectric projects, e.g., utility vs non-utility projects.
- Equity - Mechanisms should support equity in relation to communities affected by or reliant on hydroelectric projects.

Many past projects would have benefitted from requiring financial assurances. East Juliette (P-7019), Lower Mousam (P-14856), White River (P-2494) and Enloe (P-12569) are examples of projects where a trust or another mechanism may have helped reach a positive outcome for natural resources. East Juliette's license was revoked in 2014 because the licensee failed to comply with the license requirement to install fish passage. This project currently sits idle and continues to cause unmitigated harm to the environment. Lower Mousam was abandoned by the licensee because they could not afford to continue operation of the project. The project is now unpowered and remains a barrier to passage for diadromous trust species. The White River licensee, facing mounting costs to maintain their aging dam and fish collection facility, abandoned their project, which blocks upstream passage and threatens previous recovery efforts of Pacific salmonids in the watershed. Finally, the Enloe hydroelectric project was licensed to Public Utility District 1 of Okanogan County in 2013. The project has not produced power since 1954 and is a barrier to NOAA trust species such as migratory Summer Chinook Salmon and upper Columbia River Steelhead. If financial assurance mechanisms had been required by FERC to address fish passage and dam removals, then the environmental harm caused by these projects and others would have been mitigated.

The attached document provides detailed responses to the questions presented in the NOI for FERC's consideration. NMFS would welcome the opportunity to work with FERC on the development of this policy. If you have any questions or need additional information, please contact Mr. Nicholas Anderson at nick.anderson@noaa.gov or by phone at 301-427-8696.

Sincerely,  Digitally signed by
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Carrie Robinson

Attachment

NMFS Comments on The Commission's Options for Financial Assurance Mechanisms for Hydroelectric Projects (March 26th, 2021)

1. How and when the Commission should require financial assurance from licensees.

a. Specifically, should a financial assurance requirement be included in original licenses and/or on relicense?

Yes. Financial assurance requirements should be included in both the original and new licenses for hydroelectric projects. The diversity of Commission licensed projects underpins the need for multiple or flexible mechanisms for financial assurance(s) based on the specific characteristics of a project and covering different scenarios, e.g., general repair, environmental mitigation, disaster management. While NMFS does not recommend a specific financial assurance mechanism, we do recommend that FERC's requirements of each licensee be designed to achieve the same standards, i.e., consistent levels of financial assurance. NMFS offers the following recommendations in relation to how financial assurance mechanisms could be implemented by FERC.

Mechanisms should ensure sufficient funding to 1) complete and operate fish passage and protection facilities and other environmental mitigation measures required in the license, 2) remove project infrastructure and complete habitat restoration where licenses have been revoked or surrendered, and 3) maintain public safety for any remaining project infrastructure. Provisions should be incorporated into assurance mechanisms to provide for maintaining fish passage for diadromous species, including but not limited to ESA-listed species, and for mitigation for the species or their critical habitat to the extent required by the license and the provisions in any applicable biological opinion or incidental take statement under ESA section 7. Financial assurance requirements should also identify the distinct purpose for the use of all funds, e.g., maintenance, fish passage, or removal, and not exist as a general all-purpose fund.

NMFS believes that carefully developed financial assurance mechanisms required by FERC can address public safety and trust resource considerations and provide a sustainable path forward for Commission-licensed hydroelectric projects. For projects where hydropower is the best available option for a community, financial assurance measures should be adapted to support local communities (including tribes and rural communities), ratepayers, and public safety, as well as environmental resources.

- b. If on relicense, should such a requirement be included in both new licenses for major projects and subsequent licenses for minor projects?*

Yes. The requirement should apply to both original and subsequent licenses. Both major and minor projects have environmental impacts that need to be addressed in the license, and financial assurances should be required to ensure that environmental mitigation measures can be implemented in all cases.

- c. Should the Commission also require financial assurance requirements in other authorizations, such as all exemptions, amendment requests, and transfers?*

Yes, exempt projects have the same environmental and public safety concerns as licensed projects. These financial assurance requirements will require renewal as exemptions are in perpetuity. If a licensee/exemptee already has a financial assurance mechanism, we do not see the benefit in requiring an additional financial assurance mechanism during the amendment process. Finally, any license/exemption transfer should include all the existing financial assurances and other license requirements.

- d. Should the Commission reopen licenses to impose financial assurance measures?*

This depends on the financial assurance mechanism. Because exemptions are issued in perpetuity, NMFS strongly recommends that financial assurance mechanisms be required for all exemptions and exemptees, so they have financial assurance mechanisms for projects that may need to be repaired or removed to ensure public safety or to achieve sufficient mitigation or avoidance of impacts to environmental trust resources.

For license transfers, NMFS also recommends that new licensees demonstrate that they have adequate financial assurance for operation, maintenance, environmental mitigation, and eventual decommissioning prior to the transfer. As transferees are responsible for all of the provisions of the existing license, financial assurance obligations should also be transferred.

Not all amendment requests would require financial assurances; NMFS recommends financial assurances be required for amendment requests in which fish passage and/or dam safety issues that could require ongoing or future financial support are implicated by the request.

- e. Should the Commission require licensees to reaffirm or recertify that they have adequate financial assurance instruments every few years during their license term? If so, how often during a license term should the Commission require licensees to demonstrate that they still have adequate finances?*

Yes, FERC should require licensees to reaffirm or recertify that they have adequate financing to maintain the project and the capacity to reasonably address unforeseen circumstances. NMFS recommends that licenses should reaffirm or recertify that they have adequate financial assurance

every 5 to 10 years, depending on the type of project. Given the multi-decadal length of licenses and increasing rate of environmental change due to a changing climate, the maintenance and mitigation requirements and conditions as well as the evolving status of NOAA trust species affected by a project make such periodic reaffirmation and recertification necessary.

- f. Should the Commission require licensees to notify the Commission if the circumstances underlying their financial assurance instruments have changed?*

Yes. Licensees should be required to keep FERC apprised of licensees' ability to provide financial assurances. Notifications that financial assurance mechanisms have changed should be filed in the docket, so that all parties to license approval are aware of changes.

2. Bonds

- a. Should the Commission require licensees to obtain bonds as a financial assurance mechanism?*

NMFS does not have a position on whether FERC should require licensees to obtain bonds in relation to other potential financial assurance mechanisms (see comments under 1.a.).

- b. If so, how should the Commission determine the amount of the bond or what factors should the Commission consider when determining the bond amount?*

If bonds were required, the amount of the bond should reflect the potential costs to maintain and operate the project over the license term, including all terms and conditions relating to fishery resources, and to assure that the project remains adapted for the public's best interest. NMFS does not recommend an algorithm based solely on project power generation or capacity for determining the amount of the bond as such an approach does not account for other important criteria such as environmental impacts and public safety.

- c. Are bonds within the resources of all licensees, including those of small hydroelectric projects. Could the Commission mitigate these expenses?*

NMFS agrees that this an important consideration with respect to how financial assurance may potentially burden small hydropower development. For this reason, NMFS maintains that FERC should be flexible with regard to which mechanisms are appropriate for which projects, with options available for all licensees.

- d. What other challenges would bond requirements pose to individual licensees, municipal licensees, the public, or the Commission?*

No comment.

3. Trusts

- a. *Should the Commission establish an industry-wide trust or fund as a financial assurance mechanism?*

NMFS does not have a position on whether FERC should establish an industry-wide trust or fund in relation to other potential financial assurance mechanisms (see comments under 1.a.). However, if an industry-wide mechanism were employed, it should be structured so that only projects that equitably contribute to the trust and continue to serve the public's best interest, qualify for financial assurance support. A trust should not subsidize the rehabilitation of abandoned, license-revoked, or unsafe projects that can cause unmitigated harm to NOAA trust resources, and requirements to address these issues before they escalate would benefit mitigation of these projects.

- b. *If so, how should the Commission generate funds for the trust? Should the Commission consider using its annual charge authority to fund an industry-wide trust?*

No comment.

- c. *How should the Commission determine the appropriate level of funds for an industry-wide trust?*

No comment.

- d. *How should the Commission determine how funds are distributed?*

NMFS recommends that FERC use criteria for distribution that take into account the goals reflected in the FPA's requirements to serve a broad array of public interests, including NOAA trust resource goals and equitable contributions by licensees that have been made to the trust. Distribution should also take into account equity and environmental justice concerns as they pertain to ratepayers and local communities.

- e. *Should the Commission require licensees to maintain an individual trust or escrow fund as a financial assurance mechanism?*

Not necessarily. As aforementioned, NMFS is more concerned that appropriate financial mechanisms be required based on the specific needs of hydroelectric projects and their impact on public safety, environmental conditions, trust resources, etc. NMFS encourages FERC to consider that individual trusts may be a financial barrier for smaller (non-utility) projects, limiting their use as a financial assurance mechanism. Under these or similar circumstances, FERC could offer alternative mechanisms for financial assurance when appropriate.

- f. *For individual trusts, how should the Commission determine the appropriate level of the trust and what factors should the Commission consider in determining amounts?*

No comment.

- g. For individual escrows, should the Commission require licensees to retain a certain percentage of generation receipts in an escrow account?*

No comment.

- h. What other challenges would an industry-wide or individual trust pose on individual licensees, small hydroelectric project licensees, municipal licensees, the public, or the Commission?*

Please see NMFS' comments in section 3.a. and 3.e. that describe the challenges we anticipate from using different types of trusts.

4. Insurance

- a. Should the Commission require licensees to obtain insurance policies as a financial assurance mechanism for project maintenance?*

NMFS does not have a position on whether FERC should require licensees to obtain insurance policies as financial assurance mechanisms for project maintenance in relation to other potential financial assurance mechanisms (see comments under 1.a.).

- b. How should the Commission determine the amount of required coverage of an insurance policy or what factors should the Commission consider when determining the amount of coverage?*

No comment.

- c. What other challenges would a requirement to obtain an insurance policy pose on individual licensees, small hydroelectric project licensees, municipal licensees, the public, or the Commission?*

No comment.

Document Content(s)

Connecticut River Conservancy Comment on Flows and Fish Passage Settlement Agreement.pdf.....1



May, 22, 2024

Debbie-Anne Reese, Secretary
Federal Energy Regulatory Commission
888 First St., NE
Room 1A
Washington, D.C. 20426

Subject: Comments and Recommendations from the Connecticut River Conservancy for the Turners Falls Hydroelectric Project (Project No. 1889-085) and Northfield Mountain Pumped Storage Project (Project No. 2485-071), FirstLight MA Hydro LLC, Application Ready for Environmental Analysis

Dear Secretary Reese,

The Connecticut River Watershed Council, Inc., doing business as the Connecticut River Conservancy (CRC), is a nonprofit citizen group established in 1952 to restore and advocate for clean water, healthy habitats, and resilient communities to support a diverse and thriving watershed.

CRC has reviewed the February 22, 2024 *Notice of Application Accepted for Filing, Soliciting Motions to Intervene and Protests, Ready for Environmental Analysis, and Soliciting Comments, Recommendations, Preliminary Terms and Conditions, and Preliminary Fishway Prescriptions* ("REA Notice") for the Amended Final License Applications ("AFLA") filed by Northfield Mountain LLC and FirstLight MA Hydro LLC (collectively, "FirstLight") for the Turners Falls Hydroelectric Project (Project No. 1889-085) (Turners Falls Dam) and Northfield Mountain Pumped Storage Project (Project No. 2485-071) (Northfield Mountain) (hereinafter collectively "FirstLight Hydro Projects" or "Projects"), located on the Connecticut River in Franklin County, Massachusetts. FirstLight filed the AFLA for these Projects with the Federal Regulatory Energy

Commission (“FERC” or “the Commission”) on December 4, 2020. FERC issued a letter of deficiency and additional information request on January 14, 2021 and an additional information request on April 19, 2021. FirstLight then engaged interested parties in separate settlement negotiations starting in late 2021. On March 31, 2023, FirstLight filed a Flows and Fish Passage Settlement Agreement, which also included whitewater releases for recreation. On June 12, 2023, FirstLight filed a Recreation Settlement Agreement. CRC submitted comments throughout the process.¹

On May 21, 2024, CRC filed a Motion to Intervene in the relicensing proceedings for FirstLight Hydro Projects.² The following comments and recommendations are provided by CRC and respond to the proposed license terms in the AFLA, the Fish Passage and Recreation Settlement agreements, as well as other aspects of the proposed Projects.

For 72 years CRC has been working to protect and restore the Connecticut River and its tributaries. CRC represents thousands of members across four states, and as the only nonprofit organization dedicated to protecting the entire Connecticut River ecosystem, our comments consider not only the localized impacts of the projects, but also the watershed-wide implications of the proposed license articles.

¹ See Comments of Connecticut River Conservancy re the Offer of Partial Recreation Settlement for the Turners Falls Hydroelectric Project, et al., FERC Accession No. 20230710-5073 (July 10, 2023) (hereinafter CRC Comments on Recreation Offer); See also Comments of Connecticut River Conservancy in Response to the June 12, 2023, Motion to Strike of the FirstLight MA Hydro, LLC et al. for the Turners Falls Hydroelectric Project et al. under P-1889, et al., FERC Accession No. 20230620-5211 (filed June 20, 2023); See also Comments of Connecticut River Conservancy in Opposition to certain conditions from the March 31, 2023 Offer of Partial Settlement for the Turners Falls Hydroelectric Project et al. under P-1889 et al., FERC Accession No. 20230525-5090 (filed May 25, 2023) (hereinafter CRC Flows & Fish Passage Comment).

² Federal Energy Regulatory Commission, “Motion to Intervene of Connecticut River Conservancy under P-1889, et al.” FERC Accession No. 20240522-5024 (May 21, 2024).

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I. Background

The two FirstLight hydropower projects are located on the Connecticut River in Western Massachusetts and span the towns of Erving, Montague, Gill, and Northfield.³ Turners Falls Dam (“TFD”) is comprised of two generating stations—Cabot Station and Station No. 1—that can together generate up to 67.709 megawatts (MW) of electricity.⁴ Northfield Mountain (“NFM”) is a 1,166.8 MW pumped storage facility that consists of an upper and lower reservoir, a tailrace tunnel connecting the two, and a turbine generator.⁵ While these two hydropower facilities are an important component of New England’s energy landscape, for decades they have, and continue to, negatively impact the health and vitality of the Connecticut River, America’s first and only designated National Blueway.

TFD and NFM were first licensed by FERC in 1980 and 1968, respectively. These licenses both expired on April 26, 2018, and are now in a relicensing process that began in 2012. Over the last twelve years, CRC has been an active participant in the relicensing process of these two hydropower facilities, as well as three hydropower facilities in Vermont and New Hampshire, Wilder Dam (P-1892), Bellows Falls (P-1855), and Vernon Dam (P-1904), owned by Great River Hydro. CRC has previously submitted multiple comments, such as requesting specific studies, requesting modification of FirstLight’s Study Reports⁶, recommending recreation management improvements,⁷ analyzing battery storage information⁸ and economic feasibility of the projects,

³ Amended Final License Application for New License for Major Water Power Project – Existing Dam, Turners Falls Hydroelectric Project (FERC Project No. 1889) & Northfield Mountain Project (FERC Project No. 2485) (hereinafter “AFLA”) at ES-1, FERC Accession No. 20201204-5120 (filed Dec. 4, 2020).

⁴ Id.

⁵ AFLA, Figure ES-2: Northfield Mountain Pumped Storage Project Features, ES-23.

⁶ See ILP Comments or Study Request of Connecticut River Watershed Council, Inc. dba Connecticut River Conservancy under P-1889, et al., FERC Accession No. 20170501-5420 (filed May 1, 2017); Connecticut River Conservancy Comments on Updated Study Reports 2017 and Study Report Meeting held on October 9, 2018, FERC Accession No. 20181121-5092 (filed Nov. 21, 2018); Connecticut River Conservancy Comments on Updated Study Reports 2019 and Study Report Meeting held on March 29, 2019, FERC Accession No. 20190430-5431 (filed April 30, 2019).

⁷ CRC and AMC Recreation Management Plan, FERC Accession No. 20190730-5077 (filed July 30, 2019). FERC Accession No. 20200424-5251 (filed April 24, 2020).

⁸ ILP Comments of The Connecticut River Conservancy, et. Al. Under P-1892 et.al; submission of battery analysis. FERC Accession No. 20200424-5251

https://elibrary.ferc.gov/eLibrary/filelist?accession_number=20200424-5251&optimized=false

and providing input on the settlement process,⁹ as well as commenting on FirstLight's transfer of license process in 2018-19.¹⁰

More recently, CRC was involved in settlement negotiations with FirstLight and other stakeholders regarding environmental and recreational protection, mitigation, and enhancement measures for the FirstLight Hydro Projects. Ultimately, CRC did not sign the two offers of partial settlement that FirstLight proposed, for reasons outlined in extensive comments previously filed.¹¹ CRC incorporates, summarizes, and supplements those comments here in response to FERC's REA Notice, and requests that FERC consider this new comment submission in assessing the impacts of these Projects on environmental, recreational, and cultural resources.

CRC argues that there are deficiencies in the Amended Final License Application ("AFLA") including but not limited to insufficient flow level below the TFD from July through November, lack of monitoring for erosion in the Turner's Falls Impoundment ("TFI"), drawn out fish passage and barrier net installation timelines and deficiencies of monitoring plans, and absence of substantial evidence to support a longer license term length. CRC outlines these issues with the AFLA, alongside many more, in these comments.

⁹ Connecticut River Conservancy Concerns About Settlement Process and Request for Ready for Environmental Analysis (hereinafter "CRC Settlement Comments"), FERC Accession No. 20220819-5033 (filed August 19, 2022); Comments of Connecticut River Conservancy in Opposition to certain conditions from the March 31, 2023 Offer of Partial Settlement for the Turners Falls Hydroelectric Project et al. under P-1889 et al. (hereinafter "CRC Flows & Fish Passage Comment"), FERC Accession No. 20230525-5090 (filed May 25, 2023).

¹⁰ Motion to Intervene and Comments of American Whitewater, Connecticut River Conservancy, Appalachian Mountain Club, and New England Flow in the Application of Transfer of License, Substitution of Applicant, and Request for Expedited Consideration for the Turner Falls Hydroelectric Project (Project No. 1889) and the Northfield Mountain Pumped Storage Project (P-2485), FERC Accession No. 20190207-5098 (filed Feb. 7, 2019).

¹¹ Comments of Connecticut River Conservancy re the Offer of Partial Recreation Settlement for the Turners Falls Hydroelectric Project, et al., FERC Accession No. 20230710-5073 (filed July 10, 2023) (hereinafter CRC Comments on Recreation Offer).

II. The Proposed Flows Below Turners Falls Dam Fail to Comply with Massachusetts Water Quality Standards, Protect Aquatic Life, and Safeguard Recreational and Aesthetic Resources

A. CRC's Proposed Recommendation for Flows Below Turners Falls Dam

CRC recommends a minimum flow of at least 1,400 cubic feet per second (“cfs”) below TFD between July 1 – November 15, as supported by the previous CRC comment on the Fish Passage and Flows Settlement Agreement and the expert testimony of Donald Pugh.¹² In brief, a minimum flow of 1,400 cfs will uphold state water quality standards by (1) increasing available habitats for fluvial fish species and macroinvertebrates, (2) providing adequate recreational opportunities, and (3) enhancing the aesthetics of the approximately one-mile river segment below TFD by fully covering the riverbed with water.

B. Proposed Minimum Flows

Figure 1, below, excerpted from the proposed Flows and Fish Passage Settlement Agreement, outlines FirstLight's proposed minimum flows below TFD and the minimum bypass flows below Station No. 1.¹³ Of particular concern are the proposed minimum flows of 500 cfs during the period spanning from July 1 to November 15.¹⁴

¹² CRC Flows & Fish Passage Comment, FERC Accession No. 20230525-5090 (note that the Pugh affidavit begins on page 33 of the pdf).

¹³ FirstLight MA Hydro LLC et al. submits Response to Comments on the March 2023 Flows and Fish Passage Settlement Agreement, FERC Accession No. 20230612-5216 (filed June 12, 2023) (hereinafter FirstLight F&FP Comment Response).

¹⁴ Note that the proposed 500 cfs flows from July 1 through November may be referred to as “proposed flows,” “proposed minimum flows,” or “proposed summertime flows.”

Table 1. Minimum Flows below Turners Falls Dam and Total Minimum Bypass Flows below Station No. 1

Date	Minimum Flows below Turners Falls Dam	Total Minimum Bypass Flows below Station No. 1
01/01-03/31	• If the NRF is ≤ 400 cfs, the minimum flow shall be 400 cfs or the NRF, whichever is less. • If the NRF is > 400 cfs, the minimum flow shall be 400 cfs.	• If the NRF is ≤ 400 cfs, the total bypass flow shall be 400 cfs, or the NRF, whichever is less. • If the NRF is > 400 cfs, the total bypass flow shall be 1,500 cfs, or the NRF, whichever is less.
04/01-05/31	• If the NRF is $\leq 6,500$ cfs, the minimum flow shall be 67% of the NRF. • If the NRF is $> 6,500$ cfs, the minimum flow shall be 4,290 cfs.	• If the NRF is $\leq 6,500$ cfs, total bypass flow shall be the NRF. • If the NRF is $> 6,500$ cfs, the total bypass flow shall be 6,500 cfs.
06/01-06/15	• If the NRF is $\leq 4,500$ cfs, the minimum flow shall be 67% of the NRF. • If the NRF is $> 4,500$ cfs, the minimum flow shall be 2,990 cfs.	• If the NRF is $\leq 4,500$ cfs, the total bypass flow shall be the NRF. • If the NRF is $> 4,500$ cfs, the total bypass flow shall be 4,500 cfs.
06/16-06/30	• If the NRF is $\leq 3,500$ cfs, the minimum flow shall be 67% of the NRF. • If the NRF is $> 3,500$ cfs, the minimum flow shall be 2,280 cfs.	• If the NRF is $\leq 3,500$ cfs, the total bypass flow shall be the NRF. • If the NRF is $> 3,500$ cfs, the total bypass flow shall be 3,500 cfs.
07/01-08/31 ¹	• If the NRF is ≤ 500 cfs, the minimum flow shall be 500 cfs or the NRF, whichever is less. • If the NRF is > 500 cfs, the minimum flow shall be 500 cfs.	• If the NRF is ≤ 500 cfs, the total bypass flow shall be 500 cfs, or the NRF, whichever is less. • If the NRF is > 500 cfs and $\leq 1,800$ cfs, the total bypass flow shall be the NRF or 90% of the NRF. • If the NRF is $> 1,800$ cfs, the total bypass flow shall be 1,800 cfs, or 90% of the NRF, whichever is less.
09/01-11/15 ¹	• If the NRF is ≤ 500 cfs, the minimum flow shall be 500 cfs or the NRF, whichever is less. • If the NRF is > 500 cfs, the minimum flow shall be 500 cfs.	• If the NRF is ≤ 500 cfs, the total bypass flow shall be 500 cfs, or the NRF, whichever is less. • If the NRF is > 500 cfs and $\leq 1,500$ cfs, the total bypass flow shall be the NRF, or 90% of the NRF. • If the NRF is $> 1,500$ cfs, the total bypass flow shall be 1,500 cfs, or 90% of the NRF, whichever is less.
11/16-12/31 ¹	• If the NRF is ≤ 400 cfs, the minimum flow shall be 400 cfs or the NRF, whichever is less. • If the NRF is > 400 cfs, the minimum flow shall be 400 cfs.	• If the NRF is < 400 cfs, then the total bypass flow shall be 400 cfs, or the NRF, whichever is less. • If the NRF is > 400 cfs and $\leq 1,500$ cfs, the total bypass flow shall be the NRF or 90% of the NRF. • If the NRF is $> 1,500$ cfs, the total bypass flow shall be 1,500 cfs, or 90% of the NRF, whichever is less.

¹From July 1 to December 31, the Total Minimum Bypass Flows below Station No. 1 is the NRF or 90% of the NRF. If the Total Minimum Bypass Flows below Station No. 1 is reduced by 10%, it will not be taken from the Minimum Flows below Turners Falls Dam.

Figure 1: Proposed flows below TFD and below Station No. 1¹⁵

FirstLight has primarily based its harmful lower flows below TFD for most of the year on the presence of two state-listed threatened or endangered plants (Tradescant's Aster and Tussock Hairgrass) that have established themselves in the bypass reach.¹⁶ There are multiple issues with FirstLight's position that will be outlined here.

First, whether Tradescant's Aster and Tussock Hairgrass are designated as Aquatic Life Use ("ALU") by the Clean Water Act is unclear; they both typically occur in wetlands, however,

¹⁵ Flows and Fish Passage Settlement Agreement and Explanatory Statement, FERC Accession No. 20230331-5600 (filed Mar. 31, 2023) (hereinafter Flows and Fish Passage Settlement Agreement).

¹⁶ See FirstLight F&FP Comment Response, at 6—7.

they have also been found in non-wetlands, meaning they are not riverine or aquatic species. However, not enough information is known about these plant species' residence in the bypass to make any determinations. If the plants are not ALUs, the Clean Water Act would require that FirstLight prioritize protecting actual ALUs over these plants, such as Burbot, Longnose Sucker, etc, (elaborated on below) despite their listed status.

Additionally, little is known about these two plant species and their locations. FirstLight cannot publicly disclose information about the specific locations of the plants pursuant to a data release agreement with the Natural Heritage and Endangered Species Program in Massachusetts.¹⁷ In fact, so little is publicly known about their presence that some critical questions remain unanswered, such as whether the plants are suitable for relocation (as has been done in other relicensing proceedings (Deerfield P-2323) or whether their seeds can be preserved so that they may be planted elsewhere. Moreover, if evidence of the plants exists, their presence does not justify lower flows that impair a designated use for Reach 1, as CRC explained in a detailed letter to the Massachusetts Executive Office of Energy and Environmental Affairs.¹⁸ Still, despite the lack of transparency in public information, FirstLight justifies in part its minimum flow proposals for summer, fall, and winter on keeping flows low so that they do not inundate the plants.

Furthermore, the floods during July 2023 caused flows as high as 105,000 cfs¹⁹ to pass downstream by the Northfield gage. Given that Turners Falls maximum hydraulic capacity is 13,728 cfs, this means that approximately 91,000 cfs of flow was being spilled into the Bypass reach. This is much higher than the 500 cfs proposed to protect these two species. There has been no public evidence of the plants surviving the 2023 summer floods, and therefore the plants may no longer be present there. Or if they are present there today, then they will have

¹⁷ See Relicensing Study 3.5.1, at 4-1.

¹⁸ Letter from Andrew Fisk, Connecticut River Conservancy, to Bethany Card, Exec. Off. Of Env't Aff., Commonwealth of Mass. (June 13, 2022) (hereinafter "Fisk Letter"), FERC Ascension No. 20220819-5033, Attachment A, at Sect. II.

¹⁹ ¹²² See USGS Connecticut River Near Northfield, MA – 01161280 stream gage: <https://waterdata.usgs.gov/monitoring-location/01161280/>. See USGS Connecticut River Near Northfield, MA – 01161280 stream gage: <https://waterdata.usgs.gov/monitoring-location/01161280/>. 105,000 cfs recorded on 7/11/23 at 7:30 pm.

sustained flooding of over 100,000 cfs and therefore 1400 cfs would not impede their ability to live in that location.

”To be clear, CRC is not advocating against protecting rare plants generally, but context matters. Here, if the rare plants and the ALUs cannot both be protected—a premise for which the data, evidence, and analysis are currently lacking—the plants must give way to the more sensitive uses that require more water, not less.”²⁰ CRC opposes the proposed minimum flow of 500 cfs, advocating instead for FERC to mandate a flow of at least 1,400 cfs in the river during that timeframe, in particular for the one-mile section of the river between TFD and Station 1 (also known as “Reach 1”). A flow of 1,400 cfs would allow the applicable portion of river to be “maintained or restored to protect existing and designated uses,” including aquatic life and recreational uses, as required under Massachusetts surface water quality standards (“WQS”).²¹

C. Applicable Massachusetts Water Quality Standards

The Connecticut River from TFD to the Holyoke Dam is designated as a Class B water under Massachusetts WQS.²² Class B waters are Inland Waters that “are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation.”²³ DEP also requires that Class B waters maintain a “consistently good aesthetic value.”²⁴ In this context, the proposed minimum flow of 500 cfs in Reach 1 fails to maintain, restore, or protect its existing and designated Class B uses because it (1) fails to support Aquatic Life Uses (ALUs), (2) does not sufficiently support recreational activities, and (3) fails to meet the WQS’s “consistently good aesthetic value” standard.

²⁰ See Connecticut River Conservancy, Concerns About Settlement Process and Request for Ready for Environmental Analysis, Attachment A: Letter from CRC to Secretary Beth Card, MA Executive Office of Energy and Environmental Affairs.

²¹ See 314 CMR 4.03(3)(b).

²² 314 CMR 4.06 (see Table 7).

²³ 314 CMR 4.05(3)(b).

²⁴ *Id.*

All segments of Massachusetts rivers must comply with state WQS, including protecting existing and designated uses, unless a use attainability analysis has been performed, which has not occurred for this relicensing process.²⁵ Importantly, river segment MA34-03, which extends downriver 3.7 miles from TFD and includes Reach 1, is listed as impaired on Massachusetts' most recent Clean Water Act 303(d) list for, among other reasons, dewatering and flow regime modification.²⁶ Thus, it is imperative that flows below TFD are adequate and sufficient to remove this impairment and maintain existing and designated uses.

D. Proposed Flows Do Not Comply with Water Quality Standards Because They Do Not Maintain, Restore and Protect Aquatic Life Uses

As a Class B water, Reach 1 below TFD must provide essential conditions for reproduction, migration, growth, and other critical aquatic life functions.²⁷ However, according to the expert affidavit of Donald Pugh,²⁸ the proposed minimum flow of 500 cfs “is insufficient to provide a suitable amount and quality of habitat for most aquatic species inhabiting [in Reach 1].”²⁹ Specifically, Pugh’s affidavit provides that the proposed minimum flows would only allow for 10 percent of the maximum available habitat for macroinvertebrates, and less than 27 percent for several fish species.³⁰ Instead, Pugh testifies that a minimum flow of 1,400 cfs is needed to address the impairments related to ALUs.³¹

²⁵ See 314 CMR 4.03(4)(c) (“The Department may grant a variance for a specified period of time for a particular discharger and for specific pollutants so that it can be determined through a Use Attainability Analysis whether uses can be attained”).

²⁶ Rebecca L. Tepper, et al., Final Massachusetts Integrated List of Waters for the Clean Water Act 2022 Reporting Cycle, at 167 (Executive Office of Energy and Environmental Affairs, et al., 2023), <https://www.mass.gov/doc/final-massachusetts-integrated-list-of-waters-for-the-clean-water-act-2022-reporting-cycle/download> (last visited May 21, 2024).

²⁷ 314 CMR 4.05(3)(b).

²⁸ See CRC Flows & Fish Passage Comment, FERC Accession No. 20230525-5090, Pugh affidavit at ¶ 1 (Donald Pugh is independent consultant with over 20 years of experience, study and expertise in analyzing fish passage at hydroelectric projects, including projects going through licensing proceedings before FERC).

²⁹ *Id.* at ¶ 5.

³⁰ *Id.* at ¶¶ 6—7.

³¹ *Id.*

FirstLight responded to CRC's previous comments on the proposed minimum flows, which we will address below.³² CRC does not agree with FirstLight's characterization of this issue and offers the following in response. Much of FirstLight's contentions relate to CRC's "exclusive focus on Reach 1 of the bypass reach."³³ However, these arguments prove unproductive as FirstLight appears to prefer disregarding the relevant and critical segment of the river entirely. In other words, while FirstLight contends that habitats for certain fish species improve in discrete parts of the river *beyond* Reach 1,³⁴ FirstLight fails to clarify why CRC's attention to Reach 1 is unjustified. Not only does Reach 1 make up a mile of the river that has experienced extreme dewatering for decades due to TFD operations, the particular high gradient riffle run habitat present there is preferred habitat for fluvial species and is unique in Massachusetts.³⁵ So concentrating on this river segment is not only justified, it is crucial for *comprehensively* assessing the impact of dewatering on habitat below the dam.³⁶ In fact, as discussed more in-depth in CRC's Flows & Fish Passage comment, certain fluvial species (meaning these species rely on flowing water for all stages of their life cycle) like the longnose dace and tessellated darter are specialized for such environments.³⁷ Consequently, evaluating the effects on these species is more than appropriate given the species' dependency on moving water throughout their lifecycle.

FirstLight contends that CRC's focus on degraded habitat for fluvial species in Reach 1 is improper because Reach 1 "has very limited habitat for longnose dace and tessellated darter," and because "these species' optimal habitat consists of steep gradient streams with gravel or cobble rubble substrate."³⁸ Thus, FirstLight argues, the presence of fluvial species in Reach 1 "is to be expected [to be limited] regardless of flow conditions."³⁹ However, according to

³² See generally FirstLight F&FP Comment Response, FERC Accession No. 20230612-5216.

³³ *Id.*, at 4.

³⁴ *Id.*

³⁵ CRC Flows & Fish Passage Comment, FERC Accession No. 20230525-5090, Pugh affidavit at ¶ 6.; see also *id.* ¶ 12.

³⁶ See Watershed Planning Program, Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2022 Reporting Cycle, at 24 (2022) (hereinafter "MA CALM Guidance") ("In moderate to high gradient (riffle/run prevalent) streams fish community includes fluvial specialist/dependents species or at least one fluvial species in moderate abundance.").

³⁷ CRC Flows & Fish Passage Comment, FERC Accession No. 20230525-5090, Pugh affidavit at ¶ 6.

³⁸ FirstLight F&FP Comment Response at 5.

³⁹ *Id.*

FirstLight's Relicensing Study Report, Reach 1 comprises 0.16 miles of plunge pool downstream of the dam, followed by the bypass channel before narrowing upstream from Station No. 1.⁴⁰ The Study also describes the bypass channel mesohabitat as primarily consisting of a deep pool that also includes runs and riffles and substrate composed of bedrock overlain with rubble and cobble.⁴¹ FirstLight's own studies refute their contention of lack of suitable habitat for fluvial fish, revealing that the natural conditions of Reach 1 are particularly conducive to supporting longnose dace and tessellated darter. This suggests these species should be expected to be *more* abundant in this area under *higher* flow conditions leading to more consistently wetted substrate and supporting CRC's assertion that Reach 1 in particular will benefit from higher flows.

FirstLight also takes aim at CRC's assertion that the segment is not in Aquatic Life Use (ALU) attainment because the electrofishing station sampling results did not illustrate the presence of multiple fluvial species, as required for Class B Warm Water Fisheries.⁴² Although FirstLight admits that tessellated darter are in "low abundance" in that stretch,⁴³ it argues that under Massachusetts CALM guidelines, ALUs in low gradient streams "can be attained with at least one fluvial species" (emphasis added).⁴⁴ However, the pool-run stretch above Station 1 is a moderate to high gradient river reach.⁴⁵ The presence of two individual fish of a single species during the 2015 sampling survey in that reach does not meet the standards for ALU in moderate to high gradient streams as defined by the Massachusetts CALM, which states that two or more fluvial fish species or one fluvial fish species in moderate abundance must be present.⁴⁶ CRC's comments have intentionally focused on the pool-run habitat in Reach 1 given the habitat's particular suitability for fluvial fish species.⁴⁷

⁴⁰ Relicensing Study Report 3.3.1. Instream Flow Study in Bypass Reach and Below Cabot, FERC Accession No. 20161017-5012 (filed Oct. 17, 2016) (hereinafter Study 3.3.1.),

⁴¹ *Id.*

⁴² FirstLight F&FP Comment Response at 5.

⁴³ See FirstLight F&FP Comment Response at 2 & 5.

⁴⁴ *Id.* at 3.

⁴⁵ CRC Flows & Fish Passage Comment, FERC Accession No. 20230525-5090, Affidavit of Julian Burghoff ("Burghoff Affidavit"), ¶ 11.

⁴⁶ *Id.*

⁴⁷ See Mattaceunk Hydroelectric Project, FERC Project No. 2520-076 (Mar., 2018), at 24 (providing that in Massachusetts' most recent list of impaired waters, DEP stated that electrofishing at three locations in August and

Finally, FirstLight challenges CRC's use of the wetted perimeter method to assess available aquatic habitat.⁴⁸ While the wetted perimeter method was not used in the relicensing studies to determine habitat availability, it is a method that FERC has previously and appropriately used as an indicator of aquatic habitat availability in recent Environmental Assessments and therefore is a legitimate and acceptable means of measuring available habitat.⁴⁹ The Relicensing Study has provided parameters for applying the wetted perimeter method, demonstrating that flows below 1,500 cfs limit habitat for both fluvial species and macroinvertebrates.⁵⁰ Again, CRC is providing a compromise of 1,400 cfs, knowing that 1,500 cfs is better.

Notably, FirstLight did not address CRC's concerns about macroinvertebrate habitat in its response. CRC reiterates that the proposed minimum flow of 500 cfs would only provide 10 percent of maximum available habitat for macroinvertebrates between TFD and Station No. 1.⁵¹ Increasing the minimum flow to at least 1,400 cfs would result in a 26 percent increase in macroinvertebrate habitat and a total of 36.1 percent weighted usable area.⁵² In conclusion, the evident disregard for Massachusetts WQS in the proposed minimum flows below TFD results in a continued threat to aquatic life and underscores the pressing need for an increase in the minimum flow requirements in Reach 1, a portion of the river that is already listed on Massachusetts' list of impaired waterbodies for dewatering and flow regime modification.⁵³ In particular, CRC's expert testimony demonstrates that the proposed 500 cfs minimum flow is insufficient to sustain, much less restore, crucial aquatic habitats.⁵⁴ CRC's steadfast focus on Reach 1 is not only justified but imperative, given its status as a vital habitat for fluvial species,

September of 2009 just downstream of TFD and 0.5 miles downstream of the TF road Bridge found that moderately tolerant macrohabitat generalists dominated the samples).

⁴⁸ See FirstLight F&FP Comment Response at 5—6.

⁴⁹ See, e.g., Municipal Hydroelectric Project, FERC Project No. 1235-017 (Nov, 2018); See also West Buxton Hydroelectric Project, FERC Project No. 2531-075 (July, 2017); Mattaceunk Hydroelectric Project, FERC Project No. 2520-076 (Mar., 2018).

⁵⁰ See Study 3.3.1., at § 6.1.1.3.

⁵¹ See CRC Flows & Fish Passage Comment, FERC Accession No. 20230525-5090, at 4 (citing Pugh affidavit, at ¶ 7).

⁵² *Id.*, at 4—5 (citing Pugh affidavit, at ¶ 13).

⁵³ Rebecca L. Tepper, et al., Final Massachusetts Integrated List of Waters for the Clean Water Act 2022 Reporting Cycle, 167 (Executive Office of Energy and Environmental Affairs, et al., 2023), <https://www.mass.gov/doc/final-massachusetts-integrated-list-of-waters-for-the-clean-water-act-2022-reporting-cycle/download>.

⁵⁴ See CRC Flows & Fish Passage Comment, FERC Accession No. 20230525-5090, at 4--5 (citing Pugh affidavit, at ¶¶ 8, 18).

particularly with its unique high-gradient riffle run habitat. FirstLight’s attempt to downplay the significance of Reach 1 by pointing to purportedly better habitats elsewhere is both disingenuous and undermines the urgency of protecting this critical ecosystem. The evidence supports CRC’s contention that a minimum flow of 1,400 cfs is the lowest possible flow to meet ecological needs, while still allowing for reasonable energy production. CRC’s proposal strikes a fair balance between industry concerns and the long-term sustainability of the river ecosystem.

E. Proposed Flow Levels Create Unacceptable Conditions for Recreation

CRC also opposes FirstLight’s proposed minimum flows of 500 cfs due to its adverse impact on recreational activities—another violation of state WQS and federal obligations. At a state level, according to Massachusetts WQS, minimum flows below TFD must support primary and secondary contact recreational activities on the Connecticut River.⁵⁵ At the federal level, the Federal Power Act (FPA) mandates that FERC equally consider recreational purposes alongside other public interests in its licensing process.⁵⁶ Thus, because a minimum flow of 500 cfs falls short of providing recreational opportunities, CRC has consistently emphasized the legal repercussions of the inadequate flow on recreation.⁵⁷

FirstLight also has since acknowledged the navigability constraints below TFD based on the results it collected from its Boating Navigability Study.⁵⁸ FirstLight initially executed its Boating Navigability Study with the aim of understanding the impacts on paddling navigability that various flow levels presented.⁵⁹ The study focused on two areas below TFD: (1) the channels around Peskeomskut Island and (2) the channels around Rawson Island, below Station

⁵⁵ See 314 CMR 4.05(3)(b); See also 314 CMR 4.02 (under Massachusetts WQS, Primary Contact Recreation is defined as “[a]ny recreation or other water use in which there is prolonged and intimate contact with the water with a significant risk of ingestion of water. These include, but are not limited to, wading, swimming, diving, surfing and water skiing) (Secondary Contact Recreation is defined to include “[a]ny recreation or other water use in which contact with the water is either incidental or accidental. These include, but are not limited to, fishing, including human consumption of fish, boating and limited contact incident to shoreline activities. Where designated, secondary contact recreation also includes shellfishing, including human consumption of shellfish”).

⁵⁶ Federal Power Act, 16 U.S.C. §§ 797(e) & 803(a)(1) (2018).

⁵⁷ See, e.g., CRC Comments on Recreation Offer.

⁵⁸ Exhibit A: Gomez & Sullivan Engineers, Boating Navigability Study: Turners Falls Hydroelectric Project (No. 1889) (2021) (prepared for FirstLight) (hereinafter Boating Navigability Study).

⁵⁹ *Id.* (see Executive Summary).

No. 1.⁶⁰

Although the 2021 Boating Navigability Study aimed to test the navigability of the study areas at four flows ranging from 500 – 1100 cfs at the Turners Falls Dam, the highest flow that FirstLight released was 545 cfs, due to calibration errors at the dam.⁶¹ At this flow level, the left channel of Peskeomskut Island was completely unnavigable, and safety and navigation ability of the center and right channels varied for paddlers depending on their experience and comfort levels.⁶² Study participants gave the 545 cfs flow—which represents a higher number than what FirstLight is currently proposing to pass—an average navigability rating of 0.5, which did not meet the “acceptable” navigation value of 1.⁶³ Flow regimes that provide less than acceptable navigability in the height of recreation season on New England’s largest river and the country’s only national Blueway⁶⁴ are an embarrassment and certainly not sufficient to support recreational uses in that vicinity.

FirstLight claims that the proposed portage trails around Peskeomskut Island provide a solution for paddlers during low flow conditions, making the river navigable.⁶⁵ However, there is no evidence supporting the notion that paddlers prefer to walk around the island instead of paddling, especially if they lack experience to navigate the rocky center and right channels. Moreover, exiting the river to haul paddle craft and gear along a trail significantly differs from the uninhibited navigation down the river channel, completely altering the recreation experience. The “option” of portaging may end up excluding certain recreationists who lack the ability to undertake such potentially strenuous maneuvers from enjoying this section of the river.

Finally, FirstLight takes the position that it does not have an obligation to prioritize recreational activities *at any cost*.⁶⁶ As previously discussed in the context of habitat loss, FirstLight asserts that increasing the minimum flow in the bypass reach from 500 cfs to 1,400 cfs

⁶⁰ *Id.* at § 3.1 (describing the study area).

⁶¹ *Id.* at 3.3-1.

⁶² *Id.* at § 4.3.

⁶³ *Id.*

⁶⁴ U.S. Dept. of Interior, America’s Great Outdoors Rivers: Secretary Salazar Creates National Blueways System, Designates Connecticut River and Its Watershed as First National Blueway (2012).

⁶⁵ FirstLight Recreation Settlement Agreement, at § 5.1.4.

⁶⁶ See FirstLight F&FP Comment Response, at 7—8.

would cost FirstLight over \$900,000 per year and argues that the economic cost will substantially outweigh any “limited benefits” of recreation.⁶⁷ Moreover, FirstLight argues that decreasing the output of renewable energy will create an even greater harm to the environment.⁶⁸ However, both of these arguments are not supported by any evidence from FirstLight, and, in any event, would not exempt FirstLight from compliance with state WQS.

In conclusion, it is evident that the proposed minimum flows of 500 cfs not only fail to meet the recreational needs outlined by the Massachusetts WQS, but the minimal flows also disregard the significant impact on the enjoyment and accessibility of the Connecticut River for recreational users. Despite purported efforts to address navigability concerns through the Recreation Settlement Agreement and portage trails, these measures are insufficient and lack evidence of their effectiveness. Moreover, FirstLight’s prioritization of economic interests over recreational considerations is deeply concerning, especially when their arguments once again lack substantial evidence to support the claimed economic costs of increasing minimum flows and the alleged harm to renewable energy production. By neglecting the importance of recreational activities and disregarding CRC’s concerns, FirstLight is undermining both the ecological and recreational value of the river.

F. Proposed Flow Levels Diminish Aesthetic Experiences

Finally, CRC also opposes the proposed minimum flows below TFD because the minimum flows fail to safeguard aesthetic resources. Based on state WQS, the relevant segment of the Connecticut River is designated with purposes beyond providing habitat for aquatic species and supporting recreation--Class B waters are also recognized for their aesthetic value.⁶⁹ Moreover, under the FPA, non-power aspects such as recreation hold equal weight during FERC’s evaluation of hydropower project licenses.⁷⁰ In the seminal case of *Scenic Hudson Preservation Conference v. Fed. Power Commission*, the court clarified that, under FPA,

⁶⁷ See Section II(C)(1); See FirstLight F&FP Comment Response, at 7—8.

⁶⁸ See FirstLight F&FP Comment Response, at 7—8.

⁶⁹ See 314 CMR 4.05(3)(b) (“Class B waters... shall have consistently good aesthetic value”).

⁷⁰ 16 U.S.C. § 797(e).

“recreational purposes” include “the conservation of natural resources, the maintenance of natural beauty, and the preservation of historic sites.”⁷¹ Accordingly, aesthetic values must also be factored in when assessing project impacts. However, the AFLA fails to adequately address the negative impact of project operations on aesthetic quality in the project area.

A conceptual framework developed by the National Park Service and the Hydropower Reform Coalition depicts the relationship between flows and aesthetics. In this framework, flows affect the resource conditions of a given area, in turn impacting the resource outputs, such as recreational opportunities and aesthetic characteristics.⁷² Flows and the resulting resource conditions are a necessary consideration during hydroelectric project licensing proceedings, and FERC must take into account how flows will necessarily impact the aesthetic qualities of the Connecticut River.⁷³ The conceptual framework includes several recommendations for whether and how to conduct flow-aesthetics studies in the process of hydroelectric licensing proceedings.⁷⁴ Flow-aesthetics studies have been used successfully in other FERC relicensing proceedings and contribute positively to the relicensing process by directing attention towards the portions of the river that are of most value to recreational stakeholders, providing a “transparent and defensible” record of what the applicant has done to consider aesthetic values, and improving information sharing across licensing proceedings.⁷⁵

In its AFLA, FirstLight acknowledges the impact of current lower flow regimes on aesthetics and claims proposed project operations will improve aesthetic value: “The increase in bypass flows will improve aesthetics in the bypass reach for those crossing the Gill Montague Bridge and 5th Street Bridge as well as for the public that access the bypass via the formal and informal recreation sites.”⁷⁶ While CRC agrees that the increase in bypass flow will improve auditory and visual aesthetics in the bypass reach when compared to current conditions, the

⁷¹ *Scenic Hudson Preservation Conference v. Fed. Power Commission*, 354 F.2d 608, 614 (2nd Cir. 1965).

⁷² Exhibit B: Doug Whittaker & Bo Shelby, *Flows and Aesthetics: A Guide to Concepts and Methods* 6 (Nat’l Park Serv. Et al., 2017).

⁷³ *Id.* at 1 (explaining the relationship between the relevant federal laws and flow aesthetics) & 6 (discussing the concept of “resource trade-offs”).

⁷⁴ *See generally* Whittaker & Shelby.

⁷⁵ *Id.* at 15-16 (explaining the ways in which the Guide’s framework “has been applied successfully to flow-recreation studies in FERC relicensing proceedings”).

⁷⁶ AFLA, at page E-591.

proposed summertime minimum flow of 500 cfs still fails to uphold the natural aesthetic of the river because it will not provide enough water to fully cover the riverbed.⁷⁷ In other words, because dewatering below TFD has reduced the aesthetic baseline for years, a slight improvement over that baseline does not meet an acceptable or appropriate aesthetic standard.

The photos below depict the drained river channel around Peskeomskut Island and along the access trail at 545cfs. These photos are from Appendix D of the Boating Navigability Study⁷⁸ completed in December, 2021. This view of the river is not a view of a river, but merely a view of a trickle of what should be a mighty river.



Photo 3-05: Peskeomskut Island – Left Channel – North View

Figure 2: Peskeomskut Island, Left Channel

⁷⁷ See CRC Flows & Fish Passage Comment, at 5 (“500 cfs does not even fill the river such that water covers the riverbed from bank to bank”); See also CRC Flows & Fish Passage Comment, Pugh affidavit, at ¶ 16 (discussing how increasing the amount of covered riverbed with flowing water will increase fluvial habitats).

⁷⁸ Exhibit A: Gomez & Sullivan Engineers, Boating Navigability Study: Turners Falls Hydroelectric Project (No. 1889) (2021) (prepared for FirstLight) (hereinafter Boating Navigability Study).



Photo 3-07: Put-In #2 – Access Trail – Downstream View

Figure 3: Put-In #2 Access Trail – Downstream View

The Connecticut River is New England's longest river and is a unique natural resource across the five-state watershed.⁷⁹ The Connecticut River is also the only river with the National Blueway Designation, which recognizes the Connecticut River as a significant waterway, emphasizing its unique ecological importance and historical significance.⁸⁰ This recognition not only highlights the river's ecological diversity but also underscores its crucial role in supporting wildlife habitats and providing clean water resources for communities. Maintaining its aesthetic and recreational value ensures the preservation of this vital ecosystem, promoting environmental sustainability and enhancing the well-being of the surrounding communities by offering diverse recreational opportunities and preserving the natural beauty of the region.⁸¹

In summary, state water quality standards for habitat and other ALUs, recreation, and aesthetics will be violated by the proposed 500cfs minimum flow in summer months. This flow should be increased to 1,400cfs to comply with WQS.

⁷⁹ See Connecticut River, Am. Rivers, <https://www.americanrivers.org/river/connecticut-river/> (last visited May 21, 2024).

⁸⁰ *Id.*

⁸¹ See Nat'l Blueways System. Statement for the Record Before the Subcommittee of Power & Water, Dep't of Interior (July 17, 2013), https://www.doi.gov/ocl/hearings/113/natlbluewaysystem_071713.

III. The Proposed Flows Endanger Cultural Resources

A. Recommendations to protect Cultural Resources

FERC should also utilize the above recommended flow of 1400 cfs from July 1 through November 15 to protect cultural resources. CRC recommends that a new Traditional Cultural Properties Study is undertaken and included in the final license, - as the Nolumbeka comments state⁸² – the current study in the FERC docket does not include any acknowledgement of indigenous peoples or their places of cultural import occurring in the project area.

B. Higher Flows needed to Protect Cultural Resources

CRC supports the comments of the Nolumbeka Project, a nonprofit organization dedicated to the preservation of the history of the many Native American and American Indians in New England.⁸³ The Nolumbeka Projects 's comments on the proposed Recreation Settlement demonstrate the proposed minimum flow of 500 cfs below TFD is inadequate to protect important cultural resources in the river and on the riverbeds, which aligns with CRC's opposition to that flow level. Rawson Island and Peskeomskut Island are both culturally important to members of the Nolumbeka Project, and it is imperative that river flows are maintained at such a level as to impede foot access to these islands to preserve cultural artifacts. Details of these artifacts are left unpublished so that the public cannot deface them.

At the time that the Turners Falls Dam and Northfield Mountain Project were last relicensed, it was without input from indigenous groups. CRC urges FERC to consider and act on the invaluable perspective and connection to the river of indigenous peoples when assessing the new license terms.

⁸² Federal Energy Regulatory Commission, "Comments of Nolumbeka Project, Inc. re the Recreation Settlement Agreement for the Turners Falls Hydroelectric Project, et al. under P-1889 et al." FERC Accession No. 20230710-5131 (July 10, 2023).

⁸³ Nolumbeka Project, Notice to Intervene and Comments of The Nolumbeka Project Inc re the Fish and Flows Settlement Agreement and relicensing for the Turners Falls Project, et al. (filed May 25, 2023) (FERC Project Nos. P-1889 and P-2485).

IV. Northfield Pumped Storage Facility Operations Have Adverse Impacts on Erosion and Recreation.

The 20-mile stretch of the Connecticut River running from the Turners Falls Dam in Montague, MA, upriver to the Vernon Dam in Vernon, VT is known as the Turners Falls Impoundment (“TFI”). The TFI has many uses and benefits including recreation, sites of indigenous significance, and habitat for terrestrial and aquatic species. The area's human residents engage with the river through swimming, fishing, and various types of boating including but not limited to motorboats, kayaks, and canoes. The TFI has significant fluctuations of river height caused by pumping water from the river up to the storage reservoir at Northfield Mountain. Two of the consequences of these fluctuations are:

1. Access to recreation is impeded when surface water levels are dropped
2. The large fluctuation range causes erosion during the down-pull of the water against the shoreline.

A. CRC’s Northfield Mountain Erosion Mitigation Recommendations

1. Recommendations for Target Elevation and Normal Operational Range

The 20-mile stretch of the Connecticut River running from the Turners Falls Dam in Montague, MA, upriver to the Vernon Dam in Vernon, VT is known as the Turners Falls Impoundment (“TFI”). This impoundment in the river also functions as the “lower reservoir” for Northfield Mountain Pumped Storage facility. The current fluctuations in river height in the TFI are causing extreme erosion and negatively impacting recreation. Thus, any surface water elevation fluctuations from facility operations in the future must not exceed current operational fluctuations and new regulations for future fluctuations need to be put in place.

FERC should instate a target river height (ex. 181 ft) for TFI that is consistent with operational levels from the past 50 years. From that target river height, the new license should require operational measures be put in place for fluctuations to not exceed a certain elevation above or below the baseline level. The set range should be no more, and ideally less, than the

average surface water elevations from years 2000 to 2014, because the river and its ecology has already adjusted to this range. If the operating range approved in this next license is not consistent with what it has been, more erosion will be caused as a result of those changes.

FERC should also mandate how often and when FirstLight can cause the river height to be above and below the target elevation. FERC should create a “normal operational range” which would be a certain number of feet above and below the target height and outline what percentage of the time the facility is mandated to operate within this range. For example, *“From the target river height of 181 ft, FirstLight must operate between 1 foot above and below this height 90% of the time and is allowed to operate between 2 feet above and below this height 10% of the time. If and only if there is an emergency operational situation, as outlined by emergency guidelines that FERC writes, can FirstLight exceed the 2 foot range.”* It is imperative that fluctuations in river elevation are minimized; CRC recommends that base operations do not exceed 1 foot in difference from the target water surface elevation.⁸⁴

Additionally, FERC should require that 100% of the time during daylight hours, the river height must be above 179 ft to ensure safety and navigability for boats at Barton Cove. These operational measures for TFI fluctuation will help prevent further erosion as well as ensure safety and usability of the TFI for boaters.

CRC also supports the recommendations for operational range framework put forth by the Franklin Regional Council of Governments.

2. Recommendations for Data Collection and Monitoring

CRC also recommends that FERC require data collection of observed erosion and that the numbers be made public and filed with FERC. FERC should require FirstLight to report statistics in their annual compliance reports throughout the full term of the license, including the average TFI elevation for each month of the year, the average daily change, the highest

⁸⁴ Federal Energy Regulatory Commission, “Connecticut River Conservancy submits comments on Settlement Process and Request for Ready for Environmental Analysis for the Turners Falls Project. et al. under P-1889, et al.” FERC Accession No. 20220819-503 (August 18, 2022)

elevation of the month, and the lowest elevation of the month. This report should also show that they are operating under the new framework as outlined above and the Full River Reconnaissance should continue to be required.

B. Unacceptable Erosion Is Occurring as a Result of Current Operations

Landowners along the Connecticut River in the Turners Falls Impoundment (TFI) have experienced and documented erosion since the project began in 1972.⁸⁵ Michael Bathory has lived along this portion of the river for 40 years and has records that the previous landowner kept of the erosion that began with the start of the pumping project.⁸⁶ In 1991, the Army Corps published study results that reported out of 148,000 feet of shoreline covered in the study, roughly one-third was experiencing active erosion. Furthermore, it stated that since the study was conducted in 1979, the riverbank erosion had increased by almost 300%. Since then, the issue has only continued to be exacerbated by continued operation and lack of mitigation.

This erosion of the riverbanks is a serious concern that has not been adequately addressed in FirstLight's application, as they claim it is not due to their pumping. The Northfield Mountain Pumped Storage facility causes a four, sometimes five-foot variation in river level when it operates. Laura Wildman from Princeton Hydro assures that this big fluctuation in the impoundment causes the initial point in the erosion cycle⁸⁷. Expert Dr. Dethier corroborates this, proving that erosion is clearly documented in both data and images produced by FirstLight.⁸⁸ Dethier also shows that the observations and measurements included in the FirstLight Full River Reconnaissance and Erosion Causation Study point to numerous ways in which their Project operations could enhance erosion.⁸⁹

⁸⁵ Federal Energy Regulatory Commission, "Motion to Intervene of Connecticut River Conservancy under P-1889, et al." FERC Accession No. 20240522-5024 (May 21, 2024).

⁸⁶ see Michael Bathory Declaration in Federal Energy Regulatory Commission, "Motion to Intervene of Connecticut River Conservancy under P-1889, et al." FERC Accession No. 20240522-5024 (May 21, 2024).

⁸⁷ <https://www.youtube.com/watch?v=l1yiOY7SeUk&list=PLab3dcAb-SUMJCbFpVWFYQ9m0h8YS3Eoi&index=3&t=6s>

⁸⁸ Exhibit c: Dr. Evan Dethier, Review of Erosion in the Turners Falls Impoundment (2024)

⁸⁹ *Id.*

C. Proposed Operational Changes Will Exacerbate TFI Erosion

FirstLight's AFLA proposes significant operational changes, including expansion of the upper reservoir at Northfield Mountain, which will continue to accelerate erosion and impact opportunities for recreation. The accelerated erosion impacts have been amply demonstrated by the conditions created on June 12 – 13, 2021, when FirstLight operations brought the impoundment down to a water level of 177.5 msl, which was within the current and proposed allowed minimum elevation of 176 msl. This decrease in water level left boats stranded and exposed aquatic habitat. The lowered water level resulted from operational measures at Northfield Mountain responding to low or negative cost energy prices created during times of high solar energy generation. This scenario is likely to happen more often as energy generation shifts to these renewables, but the effect on the river in TFI is unacceptable. FERC must require FirstLight to minimize impacts to shoreline areas within the project reservoir and stream reaches in order to mitigate erosion.

D. Lower Water Levels in the TFI Cause Negative Recreation Impacts

Low water level in the river negatively impacts recreation. Relicensing study 3.6.6 looked at water levels at the Pauchaug Boat ramp within the TFI and concluded that water levels needed to be above 181 feet for the boat ramp to be usable for emergency motorboats.⁹⁰ Figure 4.2.2-3 indicates that water levels dip below 181 feet at Pauchaug about 20% of the time throughout the course of the recreation season.⁹¹ CRC's analysis in our comment letter on this study analyzed water level logger data and demonstrated that during summer months, it is common that water levels at Pauchaug are below 181 feet.⁹²

⁹⁰ FirstLight, Relicensing Study 3.6.6: Assessment of Effects of Project Operation on Recreation and Land Use Study Report (Oct. 2016) at 4-4, FERC Accession No. 20161014-5125 (filed Oct. 14, 2016).

⁹¹ Id. at 4-8.

⁹² Connecticut River Watershed Council comment, FERC Accession No. 20161215-5197 (filed Dec. 15, 2016), pg. 26.



Figure 4: Jonathan Trudel's photo of his unusable dock at low water.⁹³

Resident Jonathan Trudel reported in a letter filed with FERC on March 4, 2024, that his personal dock in Gill on the River is often not usable due to pumping at Northfield Mountain.⁹⁴ The photo above in Figure 4 shows that, even with a dock designed to withstand river fluctuations, recreational use of the river is still impeded during low river levels from project operations.

Recreational access at Barton's Cove is also impacted by changing water surface elevations. Relicensing Study 3.6.6 *Assessment of Effects of Project Operation on Recreation and Land Use Study Report* evaluated water levels at recreation sites. Section 4.2.6 of Study 3.6.6

⁹³ Comments of Jonathan Trudel with photos of the depict low water level re the Turners Falls Dam of the Northfield Mountain Pumped Storage Project, FERC Accession No. 20240311-5044 (filed Mar. 11, 2024).

⁹⁴ *Id.*

concluded that water level elevations need to be above 179 ft msl to adequately launch an emergency motorboat in Barton Cove. In Study 3.6.6, Figure 4.2.6-4 shows that the boat ramp elevation is at 184 ft msl, so when the TFI is above this elevation, parts of Barton Cove on the Gill side are under water.⁹⁵

Changes to operational patterns could increase erosion and have detrimental impacts on the ecological life of the banks. New license requirements should ensure that the impoundment be held at the same baseline river height that has been in place under current operations. FirstLight and previous owners of the project have received temporary license amendments to use the expanded upper reservoir during the winters of 2005-2006, 2014-2015, 2015-2016, and summers of 2001 and 2006. As noted in previous CRC comments and interventions related to these temporary amendment requests, FirstLight held the average elevation of the impoundment about a half foot higher during these temporary amendment periods than usual, based on data FirstLight was required to file regarding operations during the temporary amendment periods. Extreme high and low events seem to be getting more common, based on anecdotal reports from residents along the river. However, there is no publicly available information about recent or long term daily TFI fluctuations as measured at the dam.

V. Fish Passage and Protection not Thoroughly Addressed nor Monitored

A. CRC's Fish Barrier Net and Spillway Lift Recommendations

For the Barrier Net at Northfield Mountain, CRC recommends that FERC require Adaptive Management Measures ("AMMs") for the duration of the license – not just the first 20 years as proposed. The AMMs should monitor fish presence to see if the performance targets for migrating shad and American eel in the impoundment are met. If performance targets remain

⁹⁵ See Connecticut River Conservancy Concerns About Settlement Process and Request for Ready for Environmental Analysis, Attachment A, FERC Accession No. 20220819-5033 (filed Aug. 19, 2022).

unmet after two rounds of effectiveness testing, FERC should require operational changes that will minimize entrainment during the migratory season. In the case that the barrier net is not sufficient to protect migratory fish, the AMMs should be updated after trial period.

Additionally, the proposed installation timelines of seven and nine years for the barrier net at Northfield Mountain and the Spillway Lift at Turners Falls are far too drawn out. FERC should require the barrier net to be installed within the first two years of the license and the spillway lift to be installed within five years; there is no reason to delay the installation.

B. New Barrier Net Does Not Prevent Impingement and Entrainment of Juvenile Eel and Shad Eggs

At Northfield Mountain Pumped Storage, fish entrainment and impingement occur when water gets pumped from the river up to the holding reservoir. To attempt to mitigate for impacts from this operation, FirstLight's application includes a fish barrier net to be installed from June 1 – November 15. CRC's primary concern with the barrier net is its efficacy. The model used to assess velocities at the net did not accurately reflect expected conditions and there was no field testing.⁹⁶ In 2019, Alden Research lab conducted a study to determine forces acting on the barrier net.⁹⁷ Velocities at the net are of concern due to the potential to impinge fish. The report modelled velocities at the net including magnitudes of flow in the Connecticut River passing by the Northfield intake/tailrace including 5,000 cfs, 30,000 and 50,000 cfs.⁹⁸ The Pre-Application Document (PAD) demonstrated that for the majority of the time between June and November, 30,000 cfs and 50,000 cfs are so high that they are not even on the flow duration curves and are not representative of typical conditions. Moreover, the water elevation for the 5,000 cfs flow was modeled at 179 ft and 181.4 ft at the Northfield Mountain tailrace,⁹⁹ an elevation that is exceeded at least 95% of the time according to PAD Figures 4.3.1.3-13 through -18.¹⁰⁰ As a result, the studies did not simulate flow or elevation scenarios that accurately

⁹⁶ See CRC Fish & Flows Comment, at 16—18.

⁹⁷ See FirstLight submits the Northfield Station CFD Modeling for Fish Exclusion Net Forces Report under P-2485.etal., FERC Accession No. 20190603-5024 (filed June 3, 2019).

⁹⁸ *Id.* at viii.

⁹⁹ *Id.* at 50.

¹⁰⁰ NOI/PAD of FirstLight Generating, FERC Accession No. 20121031-5247 (filed Oct. 31, 2012).

reflect the conditions expected when the net is deployed from June through November and so it remains unclear whether fish might get impinged while pumping operations are underway.

CRC supports the installation of the barrier net; however, FirstLight has not demonstrated that the barrier net alone will be sufficiently protective of out-migrating shad. FirstLight has also failed to demonstrate through sufficient field testing that the barrier net will ensure the proposed performance targets are achieved. It is extremely reasonable, therefore, that should the barrier net not perform as expected, additional Adaptive Management Measures (AMMs) be included in the license as outlined above in the recommendations section A.

C. Not Enough AMMs for the Barrier Net

CRC is particularly concerned with the currently proposed Adaptive Management Measures (AMMs). As it stands, if FirstLight does not achieve its performance metrics, no additional AMMs would be introduced within the first 25 years of operation.¹⁰¹ This provision allows for the possibility of continued entrainment and mortality for the first 32 years of the license. FERC should foreclose this possibility by including additional AMMs if the performance targets cannot be met. FirstLight contends that, with further modeling and design, “there is no reason to believe [the barrier net] will not be effective.”¹⁰² Given FirstLight’s confidence in the imminent success of the barrier net, CRC sees no harm in requiring additional AMMs as a failsafe to make certain the performance targets are met.

As was done with the Ludington Pumped Storage Project (P-2680), which employs a similar barrier net, AMMs should include a review of entrainment abatement technologies on a periodic basis. The North Umpqua Hydroelectric Project (P-1927) is obligated, under its § 401 Water Quality Certification, to investigate modifications to its pumped storage operations to prevent violation of water quality standards.¹⁰³

¹⁰¹ Flows and Fish Passage Settlement Agreement and Explanatory Statement of FirstLight MA Hydro LLC, et al. under P-1889, et. al., FERC Accession No. 20230331-5600 (filed Mar. 31, 2023) (see page 21).

¹⁰² Technical Responses to Comments on FirstLight’s Flows and Fish Passage Settlement Agreement (see FirstLight’s Response to FF&P Comments) at 14.

¹⁰³ See 314 CMR 4.03(3)(b) & 4.05(3)(b).

The FirstLight research on how fish will interact with the barrier net, is faulty. FirstLight references a 1978 study at Northfield Mountain which examined the behavior of adult shad, indicating that the author did not report entrainment.¹⁰⁴ Given that entrainment was not the focus of this study, the conclusion that entrainment was not reported does not mean that entrainment did not occur; simply that it was not studied. In fact, a 2018 report, to which Gomez and Sullivan engineers contributed, cites the same article and states: “No published information on entrainment of adult American Shad at pumped storage facilities exists, although Layzer (1978b) reported on behavioral reactions of ultrasonic-tagged adults to the operations of the Northfield Mountain Pumped Storage Station.”¹⁰⁵ As concluded by the authors, published information on entrainment of adult shad at pumped storage facilities does not exist outside of the relicensing studies; therefore, it is fallacious to cite the 1978 study to imply that entrainment is not taking place.

CRC agrees with the 1978 study’s findings that adult shad prefer deeper sections of the river for migration. However, FirstLight goes on to make contradictory claims regarding the presence of shad in the intake. First, it claims that because shad prefer to migrate in deeper pools, this behavior limits exposure to the intake/tailrace area.¹⁰⁶ At the same time, FirstLight also claims that, as per the 1978 study, adult shad were found milling in the tailrace and that this area is used as a resting or staging area.¹⁰⁷ Adult shad were also found milling in front of the intake in Relicensing Study 3.3.2.¹⁰⁸ While shad are likely found in both areas, it is misleading to claim that a preference for deeper waters precludes time spent in the intake area.

As a part of relicensing, FirstLight conducted *Study 3.3.9 Two-Dimensional Modeling of the Northfield Mountain Pumped Storage Project Intake/Tailrace Channel and Connecticut River*

¹⁰⁴ Technical Responses to Comments on FirstLight’s Flows and Fish Passage Settlement Agreement (attached to FirstLight’s Response to F&FP Comments) at 13 (citing J.B. Layzer, Northfield Mountain Pumped Storage Hydroelectric Project anadromous fish study: Part I. behavior of ultrasonic tagged adult American Shad, *Alosa sapidissima*, in the Connecticut River with particular reference to the Northfield Mountain Pumped Storage Hydroelectric Project and the Vernon Dam 1973-1976 (1978)).

¹⁰⁵ Exhibit D: Dilip Mathur et al., *Entrainment of Juvenile and Adult American Shad at a Pumped Storage Facility*, 38 N. Am. J. Fisheries Mgmt. 56--75 (2018).

¹⁰⁶ Technical Responses to Comments on FirstLight’s Flows and Fish Passage Settlement Agreement (attached to FirstLight’s Response to FF&P Comments, FERC Accession No. 20230612-5216) at 13.

¹⁰⁷

¹⁰⁸ FirstLight files Relicensing Study Report 3.3.2 Evaluate Upstream and Downstream Passage of Adult American Shad, FERC Accession No. 20161014-5112 (filed Oct. 14, 2016), at 4-79 & 4-83.

*Upstream and Downstream of the Intake/Tailrace.*¹⁰⁹ FirstLight uses the results of this study to draw a comparison between the velocity of the river (4.5 ft/s) with the prolonged swim speeds of adult shad (7.2 ft/s),¹¹⁰ arguing that adult swim speeds exceed velocities in the tailrace area during pumping.

FirstLight selectively focuses on the impact of pumping on adult shad. In Study 3.3.9, FirstLight concludes that while adult shad can swim fast enough to avoid entrainment,

*“out-migrating adult eel and juvenile shad could be attracted to and potentially follow the flow into the intake. Given a relatively low burst speed of 2.5 ft/s, it is unlikely that a juvenile shad that was attracted to the intake structure would be able to escape if it traveled too close to the structure, particularly during pumping at full capacity. Juvenile American Eel within the tailrace area could also potentially become entrained if pumping is initiated.”*¹¹¹

The impacts on eels, resident species, and any other migratory species aside from shad have not been fully studied. The results from Study 3.3.9 are predicated on the assumption that if swim speed is greater than velocity, then entrainment is less likely to occur. FirstLight acknowledges that, given some of the uncertainties and assumptions included in the study, the results cannot stand alone and, “... definitive conclusions pertaining to actual effects on migratory fish are not possible until results from this study can be coupled with empirical fisheries data from other studies.”¹¹²

Additionally, FirstLight conducted Study 3.3.2: *Evaluate Upstream and Downstream Passage of Adult American Shad*. In that study, 145 adult shad were tagged and released into the TFI and 100 adult shad were recovered at the uppermost receiver in the TFI.¹¹³ Again, this study only analyzed the migration of adult shad in the TFI and does not provide information on the ability of juvenile shad to successfully out-migrate past the intake. FirstLight conducted

¹⁰⁹ Relicensing Study 3.3.9 Report, FERC Accession No. 20160301-5512 (filed Mar. 1, 2016) (hereinafter Study 3.3.9).

¹¹⁰ Technical Responses to Comments on FirstLight’s Flows and Fish Passage Settlement Agreement (attached to FirstLight’s Response to FF&P Comments, FERC Accession No. 20230612-5216) at 13—14.

¹¹¹ Study 3.3.9, FERC Accession No. 20160301-5512, at 7-9.

¹¹² *Id.* at 8-1.

¹¹³ Relicensing Study 3.3.2, FERC Accession No. 20161014-5112 (filed Oct. 14, 2016) (hereinafter Study 3.3.2) (see Executive Summary, page iii).

Study 3.3.20 *Ichthyoplankton Entrainment Assessment at the Northfield Mountain Project* to quantify entrainment of various life stages of shad.¹¹⁴ The study took place in 2015 and 2016 and an addendum was published in 2017 to estimate entrainment under potential future expanded Upper Reservoir storage at NFM. In its response to comments on the Fish and Flow Settlement Agreement, FirstLight chooses to only reference the impacts of current operations when arguing that only 0.1% - 1.1% of adult equivalents will be lost to entrainment.¹¹⁵ FirstLight has not proposed to maintain the same operating conditions, so it would be more appropriate to consider the percentage of adult equivalents lost to entrainment under the proposed operating regime for the next license.

The replacement of the TFD fish ladder with the proposed fish elevator is expected to increase the number of fish migrating into the impoundment. In the proposed license articles, FirstLight sets the objective of attaining 75% passage for fish arriving within 500 meters below Cabot Station into the impoundment. Considering expanded operations, 600 additional juveniles and 81 adults would be lost to entrainment.¹¹⁶ With the additional juveniles and adults, and extrapolating from the results of the 2015 and 2016 ichthyoplankton studies (Study 3.3.20), there would be 175 and 659 adult equivalents lost, representing about 2.2% of fish that passed at TFD in 2016.¹¹⁷ While this percentage seems minimal, FirstLight does not account for the expected continual increase - due to the fish lift - in fish passing at TFD. Nor does it consider the compounding effects that entrainment will have on future generations of shad.

For reference, the Connecticut River American Shad Management Plan establishes a range of achievement of 40-60% of fish to pass at each successive dam, with a goal of 58%. The plan also sets the objective of 687,000 fish passing through the Holyoke dam.¹¹⁸ Using the more conservative estimate of 42% (instead of the outlined 58% goal) of fish who pass at Holyoke

¹¹⁴ Relicensing Study 3.3.20 Report: *Ichthyoplankton Entrainment Assessment at the Northfield Mountain Pumped Storage Project*, FERC Accession No. 20160302-5041 (filed March 2, 2016) (hereinafter after Study 3.3.20).

¹¹⁵ Technical Responses to Comments on FirstLight's Flows and Fish Passage Settlement Agreement (attached to FirstLight's Response to FF&P Comments, FERC Accession No. 20230612-5216) at 14-15.

¹¹⁶ Relicensing Study 3.3.20 - Addendum 1, FERC Accession No. 20170728-5035 (filed July 28, 2017), at 5-1.

¹¹⁷ See Second Year Report - Relicensing Study Study 3.3.20, *Ichthyoplankton Entrainment Assessment*, FERC Accession No. 20161228-5079 (filed Dec. 28, 2016) (finding that 54,069 shad passed in 2016); See also Study 3.3.20 - Addendum 1, FERC Accession No. 20170728-5035, at 5-1.

¹¹⁸ Exhibit E: Connecticut River Atlantic Salmon Commission, Connecticut River American Shad Management Plan 4 (2017) (addendum approved 2020).

who would then go on to approach TFD, and 75% of those fish successfully migrating over the dam, it would mean 216,405 shad should pass at TFD.¹¹⁰

Finally, Article B220 of the Flows and Fish Passage Agreement have conditions that that NFM operations will not be altered, nor will any new AMMs be introduced, regardless of potential entrainment and mortality. This Article also proposes restriction on resource agencies to bar them from asserting any of their regulatory authority for a quarter of a century. CRC strongly opposes these conditions. *It is agency and FERC responsibility to ensure effectiveness of these fish protection measures.* This article does not even come close to equal consideration of environmental protection and must be overwritten.

VI. FirstLight Should be Required to Mitigate for Aquatic Invasive Species

A. CRC's Aquatic Invasive Species Recommendations

CRC supports the recommendations outlined by USFWS in its Invasive Plant Species Management Plan comments.¹¹⁹ CRC agrees with the suggested requirement to conduct a baseline AIS survey the first summer following license issuance and supports the methodology outlined by the USFWS. However, the new plan included in the license should also include provisions to ensure that monitoring methodology is consistent among the Great River Hydro facilities currently undergoing relicensing, as well as the monitoring methodology employed by Holyoke Gas & Electric at the Holyoke Dam. It is important that monitoring results are comparable across the watershed so that data collected are consistent. In addition to consulting with the resource agencies, CRC requests the plan also require consultation with a representative from the Northeast Aquatic Nuisance Species Panel (NEANS Panel), whose mission is to protect the marine and freshwater resources of the Northeast from invasive aquatic nuisance species through commitment and cohesive coordinated action.

¹¹⁹ Federal Energy Regulatory Commission: The U.S. Department of the Interior submits comments, recommendations, terms and conditions, and prescriptions, in response to FERC's 02/22/2024 Notice Application Ready for Environmental Analysis re the Turners Falls Project et al. under P-1889 et al. (May 16, 2024). FERC Accession No 20240516-5099.

CRC likewise agrees with USFWS' recommendation¹²⁰ that FirstLight adopt the Early Detection and Rapid Response Protocol. An annual survey for highly aggressive AIS will prevent the rapid proliferation of emergent invasive species by implementing both monitoring and control methods in consultation with the resource agencies. CRC recommends that this work be done in collaboration with a representative of the NEANS Panel so that the work is aligned with the regional approach to AIS management. Finally, CRC supports the cyclical monitoring approach proposed by USFWS.¹²¹ Targeted monitoring on a rotating basis will provide an up-to-date understanding of the status of AIS in the impoundment as well as the efficacy of management techniques. However, we suggest that every fourth year, following the individual section monitoring for three years, should include another baseline survey such that there is a comprehensive survey completed every four years.

Finally, educational materials and signs should be coordinated with the Massachusetts Department of Conservation and Recreation (DCR), which manages AIS education across the state and throughout the watershed. Maintaining consistency throughout the watershed, including at FirstLight facilities, enhances the effectiveness of awareness campaigns and ensures uniform messaging to those recreating on the river.

B. FERC should require FirstLight to Address AIS in the Project Area

FirstLight's AFLA includes the Invasive Plant Species Management Plan,¹²² which is intended to prevent the introduction and spread of aquatic invasive species ("AIS") within the NFM project boundary. During relicensing, FirstLight surveyed riparian and aquatic invasive plant species along the perimeter of the TFI downstream of Route 116 and identified nine wetland and aquatic invasive species and thirteen terrestrial invasive species.¹²³ The study also found that 38% of submerged aquatic vegetation beds were infested with an exotic species.¹²⁴ In response to these findings, FirstLight proposed limited protection measures that include

¹²⁰ *Id.*

¹²¹ *Id.*

¹²² See AFLA, Invasive Plant Species Management Plan (hereinafter "Invasive Plant Species Management Plan").

¹²³ FirstLight Hydro MA, LLC, Relicensing Study 3.5.1: Baseline Inventory of Wetland, Operational Impacts on Special Status Species at 4-6, 4-112, FERC Accession No. 20160302-5043 (filed March 2, 2016).

¹²⁴ *Id.* at 4-6; Invasive Plant Species Management Plan, at 2.

preventing the proliferation of invasive species during routine maintenance and construction activities but do nothing to address existing infestations and the threat of emerging invasive species in the watershed. The proposed invasive species plan is lacking in substance and does not fully address the threat of invasive species to fish and wildlife in the project area. As previously described in our comments,¹²⁵ the current operations of NFM and TFD create conditions that support the growth of invasive species,¹²⁶ and FERC should require an invasive species monitoring and control plan.¹²⁷

Such a plan is a requirement in the FERC license for the closest downstream facility, the Holyoke Dam (P-2004-083).¹²⁸ This plan, required under License Article 417, obligates the licensee to conduct an annual survey of the project shoreline and impoundment as well as an annual meeting with agencies to review the results. Article 417 further requires the licensee to take action to control or eliminate invasive species if the species are significantly affecting fish and wildlife populations at the project. The revised plan includes intensive monitoring reports every five years and an annual Rapid Response evaluation to better manage and respond to emergent invasive species.¹²⁹

C. AIS Presence and Negative Impacts in the Project Area

Aquatic Invasive Species have numerous impacts on the Connecticut River ecosystem within the project area. Both segment 34-02 (the segment between Route 10 Bridge and Turners Falls Dam, excluding Barton Cove) and segment MA34122 (Barton Cove) are listed as impaired, in part due to aquatic invasive plants like the curly-leaf pondweed, Eurasian water

¹²⁵ See, e.g., Connecticut River Conservancy, Concerns About Settlement Process and Request for Ready for Environmental Analysis at 2, FERC Accession No. 20220819-5033 (Aug. 18, 2022); CRC Flows & Fish Passage Comment, *supra* note 4, at 20-21.

¹²⁶ Pieter TJ Johnson et al., Dam invaders: impoundments facilitate biological invasions into freshwaters, 6 *Frontiers Ecology & Env't* 357 (2008), doi:10.1890/070156.

¹²⁷ *Rhineland Paper Co. v. Fed. Energy Regul. Comm'n*, 405 F.3d 1, 6-7 (D.C. Cir. 2005) (FERC's interpretation of the Federal Power Act as granting it the authority to require an invasive species control plan was permissible under Chevron).

¹²⁸ See FERC, Holyoke Water Power Company, Project No. 2004-083, Order Modifying and Approving Invasive Species Monitoring Plan Pursuant to License Article 417, FERC Accession No. 20010822-0499 (filed Aug. 21, 2001).

¹²⁹ Holyoke Gas & Electric, Five Year Summary Invasive Species Monitoring Report 2014 -2018 (2018), FERC Accession No. 20181219-5217 (filed Dec. 19, 2018).

milfoil, fanwort and water chestnut. For decades, stakeholders like CRC and local residents have been monitoring and removing invasive water chestnut (*Trapa natans*) from Barton's Cove and across the watershed. Water chestnut is an invasive plant that forms dense floating mats on the water surface, limiting sunlight in the water column, reducing oxygen levels in the water, displacing native species and, in some cases, prohibiting recreation. FirstLight is not protecting these sections of the River from water chestnut and CRC has stepped up in their lack of presence in the matter. To address these environmental and access concerns, CRC works to hand-remove water chestnut from Barton's Cove with volunteer assistance every year. Because water chestnut seeds can remain viable in the sediment for up to twelve years, managing this invasive species is a long-term project. Since 2020, CRC has helped remove over 190,000 pounds (about 86183 kg) of water chestnut in Massachusetts and Connecticut by providing essential resources to communities and partners, such as equipment, staff time, volunteer and outreach resources, and data management. CRC and our partners organize several volunteer water chestnut removal events annually, as well as offering presentations about water chestnut removal to organizations.

Another species of concern is hydrilla (*Hydrilla verticillata*), which was first identified in the Connecticut River in 2016 in Connecticut and within four years grew to occupy roughly 1,000 acres in the river, reaching up into Agawam, Massachusetts.¹³⁰ Like water chestnut, hydrilla proliferates rapidly and grows quickly to create dense mats of vegetation that outcompete native species for habitat, reduce light penetration, and obstruct recreation. Hydrilla can spread through fragmentation and is capable of growing up to an inch per day. While hydrilla has not yet been identified in the project area, the variety found in the Connecticut River has been intercepted in New York and Vermont. The threat of this highly aggressive species demands a monitoring and response plan that adequately addresses both the prevention and spread of AIS in the project area.

¹³⁰ Connecticut Agricultural Experiment Station, Invasive Aquatic Plants in the Connecticut River (map) (last visited May 22, 2024), <https://caes.maps.arcgis.com/apps/webappviewer/index.html?id=007f6ee203b74bcbb1d6e68a953d8baf>.

VII. Impacts on Threatened, Endangered, and Sensitive Species Not Taken Into Ample Consideration

The AFLA's proposed minimum flows can significantly impact state and federal threatened and endangered species, as well as other sensitive species, by altering their natural habitats and disrupting critical life processes. Reduced water levels can lead to the loss of essential habitats for fish species as well as aquatic-dependent species like bald eagles.

A. CRC's Species Recommendations

CRC recommends a flow of 1400 cfs from July 1 to November 15 to help protect threatened, endangered, and sensitive species. CRC also recommends that increased awareness and monitoring for hydrilla should be included in the Bald Eagle Protection Plan. Furthermore, CRC recommends that the new license includes articles ensuring safety measures to protect the state listed threatened and endangered species of burbot and longnose sucker, as well as federally endangered Cobblestone Tiger Beetle and Puritan Tiger Beetle.

B. Protected Aquatic Species

As described previously in this comment, higher flows are needed below TFD to protect aquatic life uses. Such uses include habitat for two state listed species of special concern: burbot (*Lota lota*), longnose suckers (*Catostomas catostomas*) and one federally listed endangered species: shortnose sturgeon (*Acipenser brevirostrum*). CRC has consistently raised concerns about the project's harmful effects on threatened and endangered aquatic species.

First, as detailed in CRC's June 13, 2022 letter to Secretary Bethany Card of the Massachusetts Executive Office of Energy and Environmental Affairs, burbot have been identified in a pool downstream of TFD since December 2000, when a 12-inch burbot was caught by an angler.¹³¹ Burbot are nocturnal predators, with young burbot feeding on aquatic

¹³¹ See Fisk Letter, FERC Ascension No. 20220819-5033, at Exhibit 2 ("Technical Memorandum"), at 7.

insects and crustaceans, while large adults feed on fish.¹³² Burbot spawn under ice and are generally particularly sensitive to changes in water quality and temperature.¹³³

Second, longnose suckers have historically been documented in the Connecticut River, Westfield Rivers, and at the mouth of the Chicopee River.¹³⁴ As benthic feeders, longnose suckers play an important role in their ecosystems by helping to control algae growth and contributing to the nutrient cycle.¹³⁵ However, pollution and habitat alterations along the mainstems have significantly reduced surviving populations.¹³⁶ Over recent decades, the water quality in the Connecticut River has improved greatly,¹³⁷ and the relicensing provides a once-in-a-generation opportunity to restore habitat for these at-risk species.

Third, the Shortnose sturgeon is a federally listed endangered species found in rivers and coastal waters along the eastern seaboard of North America, including in the Connecticut River.¹³⁸ The Shortnose sturgeons primarily inhabit rivers and estuaries along the Atlantic coast, favoring habitats with moderate to fast currents and sandy or gravelly bottoms. Slow-growing and long-lived, Shortnose sturgeons can live up to 60 years or more.¹³⁹

C. Protected Terrestrial Species: Beetles and Eagles

In the Flows & Fish Passage Agreement in Principle, FL mentions that it will maintain a stabilized flow regime below Cabot Station in summer, fall and spring in part to protect habitat of Cobblestone Tiger Beetle (“CTB”) and Puritan Tiger Beetle (“PTB”). CTB is state-listed and PTB is both federally and state listed. Because these species are listed, it is FERC and the state agency’s responsibility to maintain their protection under the new license.

¹³² See Fisk Letter, FERC Ascension No. 20220819-5033, at Exhibit 2 (“Technical Memorandum”).

¹³³ CITE

¹³⁴ Fisk Letter, FERC Ascension No. 20220819-5033, at Exhibit 2 (“Technical Memorandum”).

¹³⁵ *Id.*; See also Nat’l Heritage & Endangered Species Program, *Longnose Sucker*, Mass. Div. of Fisheries & Wildlife, <https://www.mass.gov/doc/longnose-sucker/download> (last updated 2015).

¹³⁶ Fisk Letter, FERC Ascension No. 20220819-5033, at Exhibit 2 (“Technical Memorandum”).

¹³⁷ See Fisk Letter, FERC Ascension No. 20220819-5033, at Exhibit 2 (“Technical Memorandum”).

¹³⁸ Nat’l Heritage & Endangered Species Program, *Shortnose Sturgeon*, Mass. Div. of Fisheries & Wildlife, <https://www.mass.gov/doc/shortnose-sturgeon/download> (last updated 2015).

¹³⁹ *Id.*

Although CRC supports FirstLight’s proffered Bald Eagle Protection Plan (BEPP),¹⁴⁰ the measures included in the BEPP are not adequate to protect bald eagles, a species of special concern in Massachusetts. As discussed in more detail in the previous section, FirstLight’s proposed low flows make it more likely that invasive aquatic species will thrive. For example, hydrilla, which we address in our comments on invasive aquatic species, are likely to infest the segment of the Connecticut River in the vicinity of the Projects.¹⁴¹ Among other problematic characteristics, hydrilla stands in the Connecticut River are known to host a cyanobacterial neurotoxin that is deadly to bald eagles.¹⁴² Notably, a study of mass bald eagle mortality in the southeast United States found that hydrilla and hydrilla treatments are a cause for these mass bald eagle mortalities.¹⁴³ Thus, in addition to its recommendation for increased minimum flows, CRC recommends that increased awareness and monitoring for hydrilla should be included in the BEPP.

VIII. Concerns Regarding the Power Canal Drawdown Procedure

A. CRC’s Canal Drawdown Procedure Recommendation

CRC supports the USFWS recommendation for the License to develop a Canal Drawdown Protection Plan¹⁴⁴. Specifically, the plan should articulate a “slow” drawdown rate of the canal described in terms of a measure of distance or vertical height per hour. The plan should also seek to increase the interconnectedness of the remaining pools during the drawdown and minimize no water conditions in areas of the canal where the substrate does not allow for burrowing. Additionally, the plan should evaluate the potential to conduct the drawdown every other year or shorten the number of days of the drawdown in order to minimize impact on aquatic species. CRC also supports the recommendation to create a Canal Drawdown Team, and

¹⁴⁰ AFLA, FERC Accession No. 20230710-5073, at Appendix A.

¹⁴¹ See above, Section VI (“FirstLight Should be Required to Mitigate for Aquatic Invasive Species”).

¹⁴² Exhibit F: Steffen Breinlinger et al., *Hunting the eagle killer: A cyanobacterial neurotoxin causes vacuolar myelinopathy*, 371 SCIENCE 1-7 (2021), <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8318203/>.

¹⁴³ *Id.*

¹⁴⁴ Federal Energy Regulatory Commission: The U.S. Department of the Interior submits comments, recommendations, terms and conditions, and prescriptions, in response to FERC's 02/22/2024 Notice Application Ready for Environmental Analysis re the Turners Falls Project et al. under P-1889 et al. (May 16, 2024). Accession Number: 20240516-5099

while the efforts of agency staff and CRC volunteers are highly valuable, there is a responsibility and a need for paid staff from FirstLight to participate in the fish rescue efforts. We also recommend that FirstLight provide in-kind support or financial assistance to support teams at these events to maximize rescue of sea lamprey and other aquatic organisms. Furthermore, CRC recommends that FERC make it mandatory for FirstLight to share the results of the surveys publicly, which will allow the next license to be informed by data collected starting now.

B. FirstLight's Proposed Canal Drawdown Procedure Causes Unacceptable Levels of Impacts to Migrating Fish and Other Aquatic Organisms

The canal drawdown is conducted annually to perform maintenance on the power canal. The mile-long canal is drained of all water, sediment is cleared out, and repairs made to uphold the integrity of the canal. This process is done to benefit Cabot Station power production. The license application lacks mitigation measures to prevent or reduce stranding and mortality of aquatic organisms during this annual power canal drawdown. Study 3.3.18, *Impacts of the Turners Falls Canal Drawdown on Fish Migration and Aquatic Organisms*,¹⁴⁵ established four objectives, two of which are addressed in the 2015 report: to evaluate the level or mortality for juvenile sea lamprey exposed during the drawdown and to survey aquatic organisms during the drawdown.¹⁴⁶ Study Objective #4 included an evaluation of measures to minimize impacts on aquatic organisms in consultation with the resource agencies. FirstLight has failed to propose sufficient measures in their application to reduce such impacts as promised in their study plans and reports.

In CRC's 2015 comments on Updated Study Report (USR) and USR meeting summary,¹⁴⁷ CRC requested that FirstLight work with stakeholders to fulfill Study Objective #4 to determine appropriate measures to reduce impacts on aquatic organisms.¹⁴⁸ FirstLight responded to this request stating that recommendations for Objective #4 were already included in the report, but

¹⁴⁵ See 2015 Updated Study Reports for the relicensing of its Turners Falls Hydroelectric Project FERC Accession No. 20150914-5188 (filed Sept. 14, 2015), at 5 (Table 1 provides information regarding updated study reports).

¹⁴⁶ *Id.* at 1-4.

¹⁴⁷ ILP Updated Study Report Comments of Connecticut River Watershed Council, Inc., FERC Accession No. 20151113-5258 (filed Nov. 13, 2015).

¹⁴⁸ *Id.* at 8.

offering no evidence that these recommendations were developed in consultation with the resource agencies.¹⁴⁹ In fact, the USFWS, an agency purportedly consulted with to develop these recommendations, commented on the two measures included in the final report saying, “these measures do not address the impacts of dewatering more than 90 percent of the canal or stranding in isolated pools.”¹⁵⁰

In addition to concerns about the minimal attention paid to mitigating the impact of the drawdown on aquatic species, CRC and several stakeholders have repeatedly expressed concern about the conclusion drawn in Study 3.3.18 that there is “little impact to organisms in the canal during the drawdown,”¹⁵¹ a conclusion that is baffling to anyone who has walked in the canal during the drawdown period. For the past four years, a group of fisheries biologists, initially started by Dr. Boyd Kynard, have worked with CRC, USFWS, and the Conte Lab to conduct a “sea lamprey rescue” during the annual canal drawdown. This rescue is made possible by the participation of volunteers, who join the efforts by collecting ammocoetes in buckets. Rescued species are transported by USFWS downstream of the dam to continue their journey.

The 2014 Initial Study Report indicated that, “A field crew of experienced biologists will systematically traverse each of the zones in a meander survey fashion recording observations of estimated number of each species encountered.”¹⁵² Despite several requests for clarification as to whether this survey took place, FirstLight has failed to provide substantive information on the results of this survey. CRC recommends that FERC make it mandatory for FirstLight to share the results of the surveys publicly, which can allow the next license to be informed by science collected starting now.

The same report also says that data on physical status (stranded, alive, dead) will be recorded to, “extrapolate counts for the entire area of suitable habitat within each zone.”¹⁵³

¹⁴⁹ FirstLight, Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Updated Study Report and Meeting Summary, FERC Accession No. 20151214-5095 (filed Dec. 14, 2015), at 9.

¹⁵⁰ U.S. Fish & Wildlife, Comments on Updated Study Report, FERC Accession No. 20160509-0208 (filed May 9, 2016), at 16.

¹⁵¹ Study 3.3.18, *supra* note 38, at 5-2.

¹⁵² Relicensing Study 3.3.18, Impacts of the Turners Falls Canal Drawdown on Fish Migration and Aquatic Organisms: Initial Study Report Summary, Appendix B, FERC Accession No. 20140916-5028 (filed Sept. 16, 2014), at 3.

¹⁵³ *Id.* at 4.

However, once the Study was concluded, FirstLight was quick to dismiss CRC's request for this information, claiming that extrapolating rates of mortality to understand the impact to populations in the canal is not possible and that "extrapolating by area is improper as well because fish congregate into the pools as the canal dewater, thus artificially increasing population densities."¹⁵⁴ Given FirstLight's inability to extrapolate these data, CRC provided a set of realistic hypotheses that could be used to roughly estimate overall mortality numbers.¹⁵⁵ When the quadrant data provided in the Study is extrapolated, we estimate that the following total number of organisms may be impacted by the drawdown: 1,668,750 elliptio; 3,125 alewife floater; 9,375 mudpuppy; and 37,500 sea lamprey. CRC does not consider this of "little impact."

To justify its conclusion of "little impact," FirstLight asserts that ammocoetes are not highly impacted due to their ability to burrow and survive in the sediment, referencing a USGS study that evaluated the effects of dewatering on larval lamprey movement and survival (Liedtke et al. 2015).¹⁵⁶ CRC has already demonstrated why this study is not an appropriate comparison to the canal drawdown; primarily, because the Liedtke study took place over just 48 hours (not seven days), was done under artificial conditions using sand as the substrate (whereas the actual substrate in the canal drawdown is more mud like), and mortality after 48 hours was very high.¹⁵⁷ The results of the Liedtke study cannot be used to justify the claims that ammocoetes burrowed in the sediment will survive a 7-day drawdown.

IX. Concerns Regarding Light Pollution

A. CRC's Light Pollution Recommendation

¹⁵⁴ FirstLight Response to Stakeholder Requests for Study Modifications, at 9.

¹⁵⁵ Comments of the Connecticut River Watershed Council on the Draft License Application (DLA) dated December 5, 2015, FERC Accession No. 20160301-5434 (filed March 1, 2016), at 10.

¹⁵⁶ FirstLight Response to Stakeholder Requests for Study Modifications, at 8.

¹⁵⁷ Comments on FirstLight's response to comments for Study 3.3.18: Impacts of the Turners Falls Canal Drawdown on Fish Migration and Aquatic Organisms, FERC Accession No. 20160106-5266 (filed Jan. 6, 2016), at 1--2.

The DarkSky Approved lighting program is designed to reduce light pollution and has been successfully implemented at major industrial sites.¹⁵⁸ Upon license issuance, CRC recommends that FERC require FirstLight to consult with a lighting designer to create a plan for DarkSky Approved lighting schemes that minimize glare and reduce light pollution by drawing on the five principles of responsible outdoor lighting.¹⁵⁹ Such a plan should include an assessment of existing lighting and a schedule for reducing the impact of light pollution within five years of license issuance. Due to the impact of light pollution on recreation, review of artificial lighting progress and recommendations should be included in the ten-year comprehensive review, as described in the proposed Recreation Management Plan.

B. The Projects Cause Significant Light Pollution

FERC describes the conditions that influence recreation at hydropower facilities, citing light pollution as a deterrent to those seeking out recreation opportunities at the site.¹⁶⁰ As previously discussed, aesthetic resources are embedded within recreation considerations when evaluating the impact of the facility and obligations to provide mitigation. Protecting dark skies is important for aesthetic resource consideration, but also has benefits for aquatic species impacted by artificial lighting.

While CRC recognizes the importance of lights at the project facilities for safety considerations, excessive lighting in riparian areas has been shown to impact the behaviors of aquatic organisms. Artificial lighting can influence fish species by altering the ways in which species forage, avoid predators, reproduce, and migrate.¹⁶¹ While there is minimal research on

¹⁵⁸ See, e.g., Sam Karas, *West Texas Oil Country is Revealing a Sky Full of Stars, reasons to be cheerful* (June 27, 2023), <https://reasonstobecheerful.world/west-texas-dark-skies-mcdonald-observatory/> (last visited May 22, 2024).

¹⁵⁹ DarkSky, *Five Principles for Responsible Outdoor Lighting* (Sept. 8, 2023), <https://darksky.org/resources/guides-and-how-tos/lighting-principles/> (last visited May 22, 2024).

¹⁶⁰ Fed. Energy Reg. Comm'n Office of Energy Projects, *Guidance for Shoreline Management Planning at Hydropower Projects* 24 (2012), <https://www.ferc.gov/sites/default/files/2020-04/smpbook.pdf> (last visited May 22, 2024).

¹⁶¹ Roger Tabor et al., *Artificial Lighting Experiments in Lake Washington (2014) and Lake Sammamish (2015)*, <https://www.govlink.org/watersheds/8/committees/15TechFrm/Artificial-Lighting-Experiments-RTabor-USFWS-2015.pdf> (last visited May 22, 2024); FishBio, *Some Like it Dark: Light Pollution and Salmon Survival* (June 4, 2018), <https://fishbio.com/like-dark-light-pollution-salmon-survival/> (last visited May 22, 2024).

the impact of lighting at hydropower facilities, several studies have explored the impact of riparian or river-adjacent lighting on aquatic ecosystems. Such studies found that artificial lighting along rivers can alter cross-ecosystem fluxes on a regional scale¹⁶² and impact ecosystem function in rivers by changing aquatic-terrestrial fluxes of invertebrates.¹⁶³ Artificial light at nighttime can impact birds, as well. Migratory birds can become confused, exhausted, and disoriented by artificial light, leading to disruptions in migration patterns and even sometimes mass mortality events.¹⁶⁴ The level of artificial lighting on a structure is a strong predictor of the number of collisions that birds will have with the structure. Reducing excessive lighting at night reduces injuries to migratory birds, especially during fall and spring migration events.¹⁶⁵ Further, “warm” colored lights (amber, orange, or red tones) have been shown to be less disruptive to migratory birds at night.

The Turners Falls Dam is very brightly illuminated at night. At some point in the past five years or so, two bright lights were installed, one above the dam on the western side and one below the dam on the eastern side. The photo below shows the light above the dam, as captured from the other side of the river. Upon installation of these lights, local residents commented on the intensity of the lights and questioned their use. While some amount of light is necessary to illuminate both the bridge and the dam, these bright lights do not seem to be directed at something specific and clearly disturb that natural night setting.

¹⁶² Alessandro Manfrin et al., *Artificial Light at Night Affects Organism Flux across Ecosystem Boundaries and Drives Community Structure in the Recipient Ecosystem*, 5 FRONTIERS ENV'TL SCI. 1, 1 (2017), <https://doi.org/10.3389/fenvs.2017.00061> (last visited May 22, 2024).

¹⁶³ Lars A. Meyer & S. Mazeika P. Sullivan, *Bright lights, big city: influences of ecological light pollution on reciprocal stream-riparian invertebrate fluxes*, 23 ECOLOGY APPLICATIONS 1322, 1322 (2013), <https://pubmed.ncbi.nlm.nih.gov/24147405/> (last visited May 22, 2024); Maja Grubisic, *Waters under Artificial Lights: Does Light Pollution Matter for Aquatic Primary Producers?*, 27 BULL. LIMNOLOGY & OCEANOGRAPHY 76, 77-79 (2018), <https://doi.org/10.1002/lob.10254> (last visited May 22, 2024).

¹⁶⁴ Amy Fraenkel, *The Growing Effects of Light Pollution on Migratory Birds*, UN Chronicle (Oct. 6, 2022), <https://www.un.org/en/un-chronicle/growing-effects-light-pollution-migratory-birds> (last visited May 22, 2024); U.S. Fish & Wildlife Service, *Threats to Birds: Collisions – Nighttime Lighting* (May 4, 2023), <https://www.fws.gov/story/threats-birds-collisions-nighttime-lighting> (last visited May 22, 2024).

¹⁶⁵ *Id.*



Figure 5: Bright lights at night at Turners Falls Dam. Kelsey Wentling, Oct. 26, 2023.

X. The Projects Are a Source of Greenhouse Gas Emissions

A. CRC's Greenhouse Gas Emissions Recommendation

Given the availability of ISO-NE fuel mix data, FirstLight should be required to report Northfield's net GHG impact on an annual basis, based on the marginal fuels used during pumping and displaced during generation.

Additionally, given the availability of inputs and the availability of the G-res tool, CRC recommends that FirstLight be required to estimate and report the GHG emissions of FirstLight's two reservoirs. In addition to the information on GHG emissions being crucial to measuring and

combatting climate change, it is likely that during the license terms of the FirstLight Projects that such reporting will become mandatory on the federal or state level.¹⁶⁶

B. FirstLight’s Claim that the Projects are “emissions free energy production and storage” operations is Unsupported

While hydropower is a source of low-emissions energy, the claim that Turners Falls Dam and Northfield Mountain are “clean, emissions free energy production and storage”¹⁶⁷ is unsupported. First, Northfield Mountain is a net energy consumer, consuming (as it acknowledges in the AFLA), about 35% more energy than it produces. Most of the time, the marginal fuel it is using and replacing on today’s New England grid is natural gas. This means the plant is inherently a net *producer* of greenhouse gas (GHG) emissions. FirstLight’s argument that the plant will increasingly be able to use variable energy sources like wind and solar to pump, effectively displacing these resources in time, to when they are needed, is far more accurate than its claim that the plant produces clean energy. As long as Northfield remains competitive with other forms of energy storage which are increasingly coming online (see section on The Future of FirstLight’s Hydropower), it may be true that Northfield might complement an energy transition. However, even when it pumps during hours when solar or wind are the marginal fuels on the regional grid, those resources are already incentivized (paid for) from state-based renewable and clean energy programs through procurements and renewable energy credits. Northfield then benefits from these ratepayer-subsidized variable energy additions to the grid because they create price volatility that the plant can take advantage of, pumping during low prices and generating during low prices.¹⁶⁸

¹⁶⁶ See, e.g., Petition for rulemaking to add dams and reservoirs as a source category under the Greenhouse Gas Reporting Program (March 21, 2022), https://earthjustice.org/wp-content/uploads/patagonia_et_al_-_petition_to_add_dams_and_reservoirs_to_the_ghgrp.pdf (last visited May 22, 2024); see also Massachusetts Global Warming Solutions Act of 2008, M.G.L. Ch. 21N (requiring GHG emissions reporting).

¹⁶⁷ Response of FirstLight MA Hydro LLC and Northfield Mountain LLC to Comments on Flows and Fish Passage Settlement Agreement at 2, FERC Accession No. 20230612-5216 (filed June 12, 2023).

¹⁶⁸ Northfield’s ability to take advantage of price volatility is suggested in AFLA Exhibit D, p. D-5 to D-6, which states that Northfield’s realized energy value in 2019 was \$45.03/MWh, far more than a simple subtraction of the reported average peak hours (\$27.63/MWh) versus nonpeak hours (\$33.79/MWh). If the plant operated all the time during peak hours at those prices it would lose money, earning $\$33.79 - (1.35)(\$27.63) = \$33.79 - \$37.30 = -\$3.50/\text{MWh}$.

Northfield operates according to price signals, not beneficence to the energy transition; and while it may respond to and complement an energy transition, it cannot bring one about. What do we know about Northfield's contribution to the grid? Following ISO-NE market prices, using the plant when it is most profitable for the company. Assuming the ISO-NE markets are structured correctly, this is at the hours Northfield's storage is most cost-effective for the grid. This does not show anything one way or another on the plant's effect on net GHGs. However, such information could be ascertained. The ISO-NE maintains data on the fuel mix and marginal fuels over time, as well as five-minute price changes. What is not public information is exactly when a given plant is operating and at what MW. FirstLight should be required to report, on an annual basis, what the marginal fuels were on the grid during its hours of pumping, the total GHGs produced in order to generate the grid power it used during those hours, what the displaced marginal fuels were on its hours of generation, and the total GHGs avoided during its hours of generation based on that displacement. This will provide objective information on its role in reducing net GHGs. As the energy transition proceeds, net carbon emissions from Northfield's energy storage should diminish.

Second, the creation of reservoirs alters the ways in which ecosystems naturally produce and release greenhouse gases. When a dam is erected in a river, the resulting impoundment creates a body of water with increased residence time, allowing for the accumulation of carbon in the reservoir, which can be released into the atmosphere, introducing new greenhouse gas emissions.¹⁶⁹

In recent years, researchers have turned their attention to the potential emissions released from the artificial reservoirs created by dams. As this body of research continues to grow, it is becoming increasingly clear that hydropower owners can no longer assume that their facilities do not directly produce greenhouse gases. A comprehensive synthesis of the existing literature reveals methane emissions to be a dominant contributor to the greenhouse gas emissions from reservoirs;¹⁷⁰ methane is twenty-five times more potent than carbon dioxide

¹⁶⁹ International Hydropower Association Ltd., The G-res Tool: Scientific basis, <https://g-res.hydropower.org/scientific-basis/> (last visited March 12, 2024).

¹⁷⁰ Bridget R. Deemer et al., Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis, 66 BioScience 949 (Oct. 2016), available at <https://doi.org/10.1093/biosci/biw117> (last visited May 22, 2024).

when it comes to trapping heat in the atmosphere.¹⁷¹ An analysis of the carbon footprint of 1,473 hydroelectric reservoirs found that emissions from hydropower facilities are far higher than previously assumed and exceed the footprint of all other renewable sources of energy.¹⁷² Additionally, a more recent study co-authored by an EPA researcher found that, out of thirty-two U.S. reservoirs studied, all of them were sources of atmospheric methane.¹⁷³ Dams and reservoirs are such a significant source of greenhouse gas emissions that the retailer Patagonia has submitted a petition for rulemaking to the EPA requesting that it adds dams and reservoirs as a source category for emissions under the Greenhouse Gas Reporting Program.¹⁷⁴ The scientific literature on reservoir emissions demonstrates that it cannot be assumed that hydropower operations are emissions-free.

The GHG Reservoir (G-res) Tool is a web-based tool developed by hydropower companies in collaboration with scientists to estimate GHG emissions from impoundments. The International Hydropower Association and UNESCO developed guidance for measuring GHG emissions from freshwater reservoirs through this free tool to better understand and communicate the impacts of hydropower projects and the need for mitigation measures.¹⁷⁵ FirstLight's projects include two large reservoirs: the impoundment created by Turners Falls Dam and the upper reservoir of Northfield Mountain. The parameters necessary for estimating the GHG emissions from these reservoirs are readily available from the relicensing studies and, rather than collecting any new data, the G-res tool is designed to employ "data that should be

¹⁷¹ U.S. Env't Prot. Agency, Importance of Methane, <https://www.epa.gov/gmi/importance-methane> (last visited March 12, 2024).

¹⁷² Laura Scherer & Stephan Pfister, Hydropower's Biogenic Carbon Footprint, 11 PLoS ONE 1, 8 (Sept. 2016), available at <https://doi.org/10.1371/journal.pone.0161947> (last visited May 22, 2024); *see also* Patagonia and Earth Justice Petition for Rule Making atagonia_et_al_-_petition_to_add_dams_and_reservoirs_to_the_ghgrp.pdf (earthjustice.org)

¹⁷³ Jake Beaulieu et al., Methane and Carbon Dioxide Emissions from Reservoirs: Controls and Upscaling, 125 J. Geophysical Rsch. Biogeosciences 1 (2020), <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019JG005474> (last visited May 22, 2024).

¹⁷⁴ *See* https://earthjustice.org/wp-content/uploads/patagonia_et_al_-_petition_to_add_dams_and_reservoirs_to_the_ghgrp.pdf

¹⁷⁵ *See* G-Res Tool; *see also* UNESCO Chair in Global Environmental Change and the International Hydropower Association, The GHG Reservoir Tool (G-res) User Guide: UNESCO/IHA research project on the GHG status of freshwater reservoirs (Dec. 19, 2022), available at <https://g-res.hydropower.org/wp-content/uploads/2022/12/G-Res-Tool-User-Guide-v3.2.pdf> (last visted May 22, 2024).

known by project developers and environmental professionals.”¹⁷⁶ FERC should require this analysis as part of the Federal license.

XI. Concerns Regarding Water Quality Impacts from the Project

A. CRC’s Water Quality Recommendations

CRC’s Dissolved Oxygen and Temperature Recommendation: FERC should require FirstLight to monitor DO and water temperature accurately by moving the loggers and by putting more water in the project area.

Oil Sheen Recommendation: FERC should mandate protocols in the license for when/if FirstLight has another oil spill that outlines how the oil needs to be dealt with and in what time frame. There should also be guidelines in place for how to solve the issue and prevent it from happening if oil spills continue to occur. FERC should incorporate Best Management Practices for Oil Spill Response as an article license.

Trash and Debris Recommendation: CRC recommends that the Recreation Management Plan require provisions for debris management procedures to determine how and when FirstLight will remove accumulated debris and trash from the boat barrier. Such a requirement is necessary to mitigate the impact on aesthetic value at this site on the river.

CRC’s Sediment Recommendation: CRC recommends that, at a minimum, the annual cross-section surveys that were used to determine net deposition be continued. Additionally, CRC recommends that if there is a significant net increase in sediment deposition over a five-year period, FirstLight be required to oversee and pay for the appropriate dredging to improve boating navigability. Any dredging should be limited to boat channels and should not include archaeologically sensitive portions of Barton Cove. FERC should also require appropriate dredge spoil disposal.

¹⁷⁶ See *id.* G-res User Guide at 3.

B. Dissolved Oxygen and Temperature Data Gaps

Dissolved oxygen (DO) measurements represent the levels of oxygen available to aquatic organisms in a particular water body. Fish and other aquatic flora and fauna need certain levels of DO to survive. When not enough DO is present, water bodies can devolve into “dead zones” with large amounts of decaying organic matter, such as algal blooms. DO levels are directly linked to water temperature. Cold water contains more DO than warm water, which is why algal blooms are commonly observed in spring and summer when water temperatures are elevated.¹⁷⁷ Because sufficient available DO is critical for aquatic organisms, DO levels are often used as indicators of the overall health of lakes and streams. Thus, accurate DO measurement is important in assessing water quality to ensure that water bodies can adequately support aquatic life.

In FirstLight’s Water Quality Monitoring Study,¹⁷⁸ Table 3.3-1 depicts the minimum, maximum, and average DO and water temperature for each of eighteen sampling locations within the project area.¹⁷⁹ In the AFLA, FirstLight relies on this study to show that baseline water quality conditions in the project area comply with Massachusetts State Water Quality Standards.¹⁸⁰ However, the DO and temperature logger at Site 7 of the study was installed at a depth of twelve feet, which is deeper than the other sampling sites.¹⁸¹ The inconsistent depths at which the loggers were placed makes it difficult to compare data across the sampling sites.

Further, the loggers at sampling sites located in the TFI (Sites 5 and 7) were placed at depths that would not have measured surface water temperature warming as a possible effect of the projects. CRC also believes that organizing the DO and water temperature data by month, as opposed to by minimum, maximum, and average, would provide a more complete picture of

¹⁷⁷ See <https://www.usgs.gov/special-topics/water-science-school/science/dissolved-oxygen-and-water> (last visited May 22, 2024).

¹⁷⁸ Relicensing Study 3.2.1: Water Quality Monitoring Study, Study Report, FERC Accession No. 20160301-5490 (filed March 1, 2016).

¹⁷⁹ *Id.* at 3-20.

¹⁸⁰ See AFLA, at E-142. For Class B waters, dissolved oxygen “[s]hall not be less than 6.0 mg/L in cold water fisheries and not less than 5.0 mg/L in warm water fisheries.” 314 CMR 4.05(b)(1). Further, “[n]atural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.” *Id.*

¹⁸¹ See Relicensing Study 3.2.1, *supra* note 23, at 3-20.

the water quality indicators at different times of the year. Finally, certain portions of the bypass reach dry up during the summer, and there would not have been loggers placed in these dry areas because the loggers must be fully submerged to record data. CRC contends that sections of the bypass where loggers could not be placed may violate water quality standards for temperature during some parts of the summer due to partial or complete dewatering. FirstLight's reliance on Study 3.2.1 in the AFLA to show existing water quality standards is insufficient.¹⁸² Study 3.2.1 does not comprise a complete and accurate data set for DO and water temperature in the TFI and portions of the bypass reach. FERC should require FirstLight to collect data that accurately depict the DO and water temperature by moving the loggers and eliminating the dry areas.

C. The Projects Have in the Past and Likely Will in the Future Cause Oil, Trash and Debris Spills into the Connecticut River

Oil spills happened in 2022 and 2023 at the Turners Falls Dam¹⁸³ from FirstLight's operations. The main issues that arose were the horrible smell, the disturbing sight of the oil on the river (pictured below) and the ecological impact on the river and its environment. Any amount of oil that FirstLight discharges into the Connecticut River has an immediate, harmful impact on the aquatic ecosystem. It is disappointing that FirstLight allowed this same story to play itself out two years in a row.

¹⁸² For Class B waters, water temperatures "[s]hall not exceed 68/F (20/C) based on the mean of the daily maximum temperature over a seven-day period in cold water fisheries, unless naturally occurring" and shall not exceed "83/F (28.3/C) in warm water fisheries." 314 CMR 4.05(3)(b)(2). Further, "[t]here shall be no changes from natural background conditions that would impair any use assigned to this Class, including those conditions necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms." *Id.*

¹⁸³ Montague Reporter Article, March 16, 2023: https://montaguereporter.org/wp-content/uploads/2023/03/March-16-2023.pdf?_ga=2.169267496.887264246.1715200835-1419377568.1715200835 (last visited May 22, 2024).



Figure 6: CRC photo taken March 17, 2023: Oil Sheen on the Connecticut River below Turners Falls Dam



Figure 7: CRC photo taken March 17, 2023: Oil Sheen absorbed onto a sponge on the Connecticut River below Turners Falls Dam

Additionally, trash and debris have accumulated behind the boat barrier upstream of Turners Falls Dam after heavy rainstorms and floods. Following the flooding event in July 2023, a

large amount of trash was held by the boat barrier and backed up along the Connecticut River.¹⁸⁴ The trash and debris behind the barrier persisted for months, as FirstLight prioritized work to repair to the bascule gates at the dam. Even so, by the end of October, the debris pile had not been cleared away, though it seemed as though some trash had floated past the barrier to continue downstream.



Figure 8: Trash and debris behind the TFD boat barrier. Kelsey Wentling, Oct. 2023



Figure 9: Trash and debris behind the TFD boat barrier. Kelsey Wentling, Oct. 2023

¹⁸⁴ Ashley Shook, Debris backup along boat barrier in Connecticut River in Turners Falls, WWLP (Aug. 23, 2023), <https://www.wwlp.com/news/local-news/franklin-county/debris-backup-along-boat-barrier-on-connecticut-river-in-turners-falls/> (last visited May 22, 2024).

By FirstLight's own admission, the trash accumulation along the boat barrier creates an "eye sore,"¹⁸⁵ for those who live in Montague and Gill, or those visiting to recreate or enjoy views of the Connecticut River. The trash accumulation is also detrimental to the health of the ecosystem as it leaves microplastics and any toxic releases into the environment. Persistent debris and trash accumulations constitute an impairment for aesthetic use, as defined in the Massachusetts CALM.¹⁸⁶ As a result of the boat barrier, trash and debris have remained in this portion of the river for months, which, unless addressed, will lead to an impairment designation.

D. Concerns Regarding Sediment Discharges into the Turners Falls Impoundment

In 2010, FirstLight drained the upper reservoir of Northfield Mountain for maintenance purposes. The process caused sediment from the upper reservoir to become entrained and inhibited the facility's operations. To address the issue, FirstLight dumped sediment directly into the Connecticut River, resulting in the deposition of 20,000 - 50,000 cubic yards of silt/sediment below the High-Water Mark and extending roughly 800 feet downstream.¹⁸⁷ The resulting Consent Order from the Environmental Protection Agency ("EPA") required that FirstLight outline measures it would adopt to prevent sediment discharges and create a plan to minimize entrainment of sediment in future drawdowns. Study 3.1.3, the Northfield Mountain Pumped Storage Project Sediment Management Plan, is a result of the EPA Consent Order and was

¹⁸⁵ See *id.*

¹⁸⁶ Mass. Dept. Env'tl Prot., Massachusetts Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2022 Reporting Cycle at 59 (Oct. 2022), <https://www.mass.gov/doc/2022-consolidated-assessment-and-listing-methodology-guidance/download>. According to the Massachusetts CALM, waters designated for Aesthetics Use under state water quality standards should be "free from pollutants in concentrations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life." *Id.* (internal quotation marks omitted).

¹⁸⁷ Exhibit G: EPA File No.: ACO-WE-10-6W003 Administrative Consent Order and Notice of Noncompliance (Aug. 4, 2010).

integrated into the relicensing process with the stated objective of understanding sediment transport between the Connecticut River and Northfield Mountain upper reservoir.¹⁸⁸

In order to determine how much sediment is present in the Northfield Mountain Upper Reservoir, FirstLight proposes to conduct a monitoring program in the upper reservoir and intake channel every two years, as well as initiating excavation activities as outlined in the FirstLight Study 3.1.3 Northfield Mountain 2017 dewatering protocols. Dredging of the upper reservoir is anticipated to occur ten times if a 50-year license is granted.¹⁸⁹

Regarding the TFI, FirstLight concludes in the AFLA that, "... although deposition may still occur on a year-to-year basis, a balance of sediment inflow and outflow likely occurs over a long period of time (i.e., years to decades)."¹⁹⁰ This conclusion is predicated on the results of cross-section surveys, specifically those conducted at four transects on Barton's Cove from 1999-2015,¹⁹¹ in which FirstLight finds that net deposition was 4,400 square feet, equal to roughly 275 square ft/year at the four survey cross-sections.¹⁹² In AFLA Figure 3.3.1.2.3-1, it is unclear where the information is sourced from and why BC4 is not included. The lack of data and clarity prevents CRC from further commenting on this section.

In recent years, boaters in Barton Cove have noted that it is increasingly difficult to navigate this area due to sediment deposition behind the Turners Falls Dam. Even if this sediment inflow and outflow balances over time – an outcome that is not at all clear from the data- on a year-to-year basis this sedimentation may inhibit recreational activities for one year or multiple years in a row.

XII. FERC Should Require FirstLight to Provide Financial Assurances for Decommissioning and Dam Removal at the end of the Projects' Useful Lives

¹⁸⁸ Northfield Mountain Pumped Storage Project Sediment Management Plan at 1-1, FERC Accession No. 20161014-5109 (filed Oct. 14, 2016).

¹⁸⁹ AFLA, at D-4, Table 4.5-1: Cost Estimate of Proposed PM&E Measures at the Northfield Mountain Project

¹⁹⁰ AFLA, at E-72.

¹⁹¹ AFLA, at E-125 ("Fig. 3.3.1.2.3-1: Transect BC1, BC2, BC3 and BC5 Sedimentation Rates (in square feet) from 2000-2015").

¹⁹² AFLA at E-72.

A. CRC's Decommissioning Funding Recommendation

CRC requests that the final licenses for TFD and NFM contain provisions requiring FirstLight to construct a decommissioning plan for when the facilities are ready for retirement and removal. Additionally, the final license should include conditions requiring FirstLight to provide financial assurances that when the time comes, it will be able to fund decommissioning. As explained below, these requirements are necessary to prevent further water quality degradation and ensure that local, state, and federal taxpayers will not end up bearing the burden of subsidizing decommissioning. Such required funding also increases the likelihood that decommissioning, and dam removal will occur in a timely manner.

B. FERC Has the Authority to Require Decommissioning and Removal Funds

As is happening with hydropower facilities throughout the country¹⁹³, at some point in the future, both the Turners Falls Dam and the Northfield Mountain Pumped Storage Project will reach the end of their useful lives as energy producers. It is quite possible that these projects will reach this point before the end of their next license. The Turners Falls project is already old, and the Northfield Mountain pumped storage station is a net energy consumer and may no longer be cost-effective in a future grid with a robust array of flexible supply, demand, transmission, and storage resources. Because a FERC license is predicated on energy and development benefits, when these projects come to the end of their useful life as energy producers, the environmental costs can no longer be justified. Then it will be time to retire and decommission one or both projects, and remove the Turners Falls Dam as an obstruction in the river. The question of who will finance their decommissioning and removal looms large and is not addressed in the AFLA. It is imperative that there are some measures in place to guarantee funding for decommissioning. The river is a public trust, and the hydropower companies use it to make money. Once the dams are no longer in use, the financial and logistical burden must not be put on the people of the area, for whom the river is a public trust and not a revenue stream. These projects and others on the river have also seen multiple sales and new ownership

¹⁹³ See generally <https://www.americanrivers.org/resource/the-practitioners-guide-to-hydropower-dam-removal/> (last visited May 22, 2024).

over the course of the last 30 years since electric restructuring; there is considerable risk that, as has happened with other hydropower projects, aging, unprofitable projects may be sold to an unscrupulous company that could leave the hazard and the bill to local and state governments.¹⁹⁴

FirstLight is responsible for maintenance and operations of TFD and NFM, and it is FirstLight that profits from them, while these segments of the Connecticut River are and will continue to be impaired due to the operation of these facilities. Accordingly, it is FirstLight's responsibility to take steps to decommission and remove its facilities when they reach the end of their useful life. The final license should include conditions for FirstLight to create a decommissioning plan and require financial assurances to ensure the ability of FirstLight to complete this work. If FirstLight does not take responsibility for decommissioning the projects, it will be left to the public to bear the costs of remediation and removal.

FERC has the authority under the Federal Power Act to require the licensee to finance project decommissioning as a condition of license renewal.¹⁹⁵ “[I]n certain situations, where supported by the record, the Commission may impose license conditions to assure that funds are available...when the time for decommissioning arrives.”¹⁹⁶ Additionally, regardless of whether the provision of decommissioning funds is actually included as a license condition, “the licensee will ultimately be responsible for meeting a reasonable level of decommissioning costs,” and thus, “[t]he licensee should plan accordingly.”¹⁹⁷ It follows that part of planning accordingly should be to include license provisions regarding financial surety so that FirstLight will be able to fund project decommissioning.

FERC solicited comments on whether and how the Commission should require additional financial assurance mechanisms in the licenses and other authorizations it issues for hydroelectric projects.¹⁹⁸ Multiple resource agencies, including the U.S. Fish and Wildlife Service

¹⁹⁴ Independent Forensic team. (2022). Final Forensic Report on 2020 Edenville and Sanford Dam Failures Released. Association of State Dam Safety. <https://damsafety.org/MI-Final-Report>

¹⁹⁵ Federal Energy Regulatory Commission, Policy Statement – Project Decommissioning at Relicensing, 60 Fed. Reg. 339 (Jan. 4, 1995).

¹⁹⁶ *Id.* at 340.

¹⁹⁷ *Id.*

¹⁹⁸ Federal Regulatory Energy Commission, Notice of Inquiry: Financial Assurance Measures for Hydroelectric Projects, 86 Fed. Reg. 7081 (Jan. 26, 2021).

(USFWS), NOAA, National Marine Fisheries Service (NMFS), Environmental Protection Agency, National Parks Service, USDA Forest Service, and many others, responded in favor of FERC requiring financial assurances, including decommissioning costs, in project licenses. In voicing its support for financial assurance provisions in all new and renewed licenses, USFWS stated, “environmental effects occur at both major and minor projects and financial assurances should be required to ensure that licensees can afford to implement the environmental mitigation measures that are required in the license.”¹⁹⁹ Decommissioning costs “reduce the risk that taxpayers and ratepayers would have to pay to remove project infrastructure and restore habitat,”²⁰⁰ and can help mitigate the environmental harm that occurs when inoperable or abandoned dams cannot be removed for lack of funds.²⁰¹

Requiring decommissioning funding also means that decommissioning will actually get done. If funding and responsibility are not pre-ordained, there will be arguments and delays that may kill decommissioning efforts. There is an entire landscape of derelict dams due in part to the idea that the operator of the hydropower project has no responsibility to take the project down when they abandon it.

Decommissioning requirements are necessary to prevent further water quality degradation and ensure that local, state, and federal taxpayers will not end up bearing the burden of subsidizing decommissioning. Such required funding also increases the likelihood that decommissioning and dam removal will occur in a timely manner.

C. The Future of FirstLight’s Hydropower

FirstLight’s application for its new license rests on its claims that Northfield Mountain Pumped Storage Facility’s (“NFM”) and Turners Falls Dam and Hydro Project’ (“TFD”) power is needed.²⁰² Further, the company argues that the particular characteristics of these two projects

¹⁹⁹ U.S. Fish and Wildlife Comments on the Federal Energy Regulatory Commission’s Notice of Inquiry on Financial Assurance Measures for Hydropower Projects, FERC Accession No. 20210329-5230 (filed March 29, 2021).

²⁰⁰ *Id.*

²⁰¹ National Marine Fisheries Service Office of Habitat Conservation Comments on Financial Assurance Mechanisms for Federal Energy Regulatory Commission Licensed Hydroelectric Projects, FERC Accession No. 20210329-5151 (filed March 29, 2021).

²⁰² AFLA, at Exhibit E, 1.2.2

will make them increasingly valuable as the grid transitions to low-carbon resources. However, there are reasons to question how much and how long these characteristics will make these projects valuable. According to the University of Massachusetts (“UMass”) Energy Policy and Rivers group, it is true that in the next 10-15 years or so, the projects’ ability to provide on-demand power and energy storage is likely to be increasingly valuable as solar energy continues to grow in New England and large volumes of off-shore wind begin to come online. After that, however, pending changes in the grid and the climate may begin to reduce their value.

To elaborate on the UMass group’s points, there are a number of ways the future value of these projects to the grid and the energy transition may diminish. First, new imports of Hydro-Quebec power via Maine’s NECEC line, and planned two-way trading, will allow Hydro-Quebec’s giant reservoirs to play much of the same role as Northfield, with even greater capacity and likely at a lower price.²⁰³ Later, new long-distance transmission lines are likely to connect New England with farther regions of both supply and demand, allowing easier integration of intermittency through geographic diversity rather than high-impact peaking and resource-intensive storage.²⁰⁴ Demand response technologies and resilience solutions like distributed energy are also growing; these will buffer future moments when supply and demand don’t match up despite these new interconnections, making TFD and NFM less valuable.²⁰⁵ New

²⁰³ Dimanchev, E., Hodge, J., & Parsons, J. (2020). *Two-Way Trade in Green Electrons: Deep Decarbonization of the Northeastern U.S. and the Role of Canadian Hydropower* (Research Brief 003; p. 4). MIT Center for Energy and Environmental Policy Research, available at <https://dspace.mit.edu/handle/1721.1/130577> (last visited May 22, 2024).

²⁰³ Lamson, J. (2023, September 19). ISO-NE Sees Little Shortfall Risk for 2032. *RTO Insider*. <https://www.rtoinsider.com/56071-iso-ne-details-2032-shortfall-risk/> (last visited May 22, 2024).

²⁰³ Lamson, J. (2024, February 25). Québec, New England See Shifting Role for Canadian Hydropower. *RTO Insider*. <https://www.rtoinsider.com/72093-quebec-new-england-shifting-role-hydropower/> (last visited May 22, 2024).

²⁰⁴ NREL (National Renewable Energy Laboratory). (n.d.). *Interconnections Seam Study*. NREL.Gov. Retrieved February 24, 2021, from <https://www.nrel.gov/analysis/seams.html> (last visited May 22, 2024).

²⁰⁴ St. John, J. (2024, May 13). Landmark transmission reform could dramatically speed US energy transition. *Canary Media: Clean Energy Journalism for a Cooler Tomorrow*. <https://www.canarymedia.com/articles/transmission/ferc-transmission-rule-clean-energy-may-2024> (last visited May 22, 2024).

²⁰⁵ ACEEE (American Council for an Energy-Efficient Economy). (n.d.). *Distributed Energy Resources*. ACEE: Smart Energy, Clean Planet, Better Lives. Retrieved May 20, 2024, available at <https://www.aceee.org/topic/distributed-energy-resources> (last visited May 22, 2024).

²⁰⁵ Gledhill, S. (2023, March 20). Understanding the Value of Distributed Energy Resources. *Yale Environment Review*, *Yale Environmental Review*. <https://environment-review.yale.edu/understanding-value-distributed-energy-resources> (last visited May 22, 2024).

kinds of storage are coming on line, including longer duration storage than pumped hydro. The 2023 Massachusetts long-duration storage study recognized the need for medium and long-duration storage but said that no procurements are needed in the immediate future, and that when they are needed, pumped storage should not be prioritized. They noted, too, that New England’s “pumped hydro operators note that their resources run little today (~25% utilization) due to low round trip efficiency and small price spreads.” These small price spreads—Northfield relies on large ones to make a profit, and therefore to operate—will become smaller under any of the above developments, and a host of planned changes in the ISO-NE markets (e.g. current capacity market review) may also alter their profitability. Finally, hydropower is also dependent on weather, though at somewhat longer timespans than solar and wind. Changing weather patterns will make TFD at least, and possibly even NFM, more variable between weeks, seasons, and years, as their fuel (i.e. water) for generation grows and diminishes with changing precipitation. Both droughts and floods are predicted to increase in strength and frequency as weather patterns produce spring freshets sooner and more acute, leading to more spill because of declining snowpack, followed by lower levels of generation in the summer and fall. The Fifteen Miles project will have limited ability to attenuate this. Additionally, over the time of the next license, TFD may degrade in its structural soundness, as all hydro projects do over time, and sediment buildup may make it less efficient.

In short, although TFD is clearly an important energy producer and NFM an important energy storage facility for the grid, both provide important need-responsive supply, and in the medium term (10-20 years) both may be important for the energy transition, both projects’ long-term usefulness is less certain. This is especially true of Northfield, which is not used or needed most of the time even now because it is not cost-effective compared to other resources and it therefore does not get the price differential it needs to operate. In the future, circumstances which make NFM cost-effective compared to other options may become much rarer, and it may be used only in the coldest or hottest days of the year or other exceptional circumstances—or it may need to shut down, or may get sold off, because of unprofitability. TFD’s future will be limited by its own aging and climate change’s future impact, which will make hydropower production less consistent over time.

D. Revenues From Hydropower Projects Prove That There is Money for Decommissioning

Looking at revenue data from the past years of operating these facilities shows that FirstLight has sufficient funding to allocate towards decommissioning. Exhibit D in the 2016 Final License Application showed revenues for Turners Falls and Northfield Mountain for the year 2019. Each final license application only provided one year of revenues and given FERC licenses will establish operational conditions for 30-50 years, CRC wished to have a better sense of many years of revenue. Due to the lack of data, CRC hired Synapse Energy Economics to provide revenue estimates using publicly available energy prices and capacity prices for the years FirstLight provided monthly energy generation data in the license applications. These estimates are not going to exactly represent revenues for FirstLight because we do not know how the company bid into the various markets, but they are a good representation. Figures below show the estimated revenues for each project individually for the years 2011-2019, followed by a combined revenue.

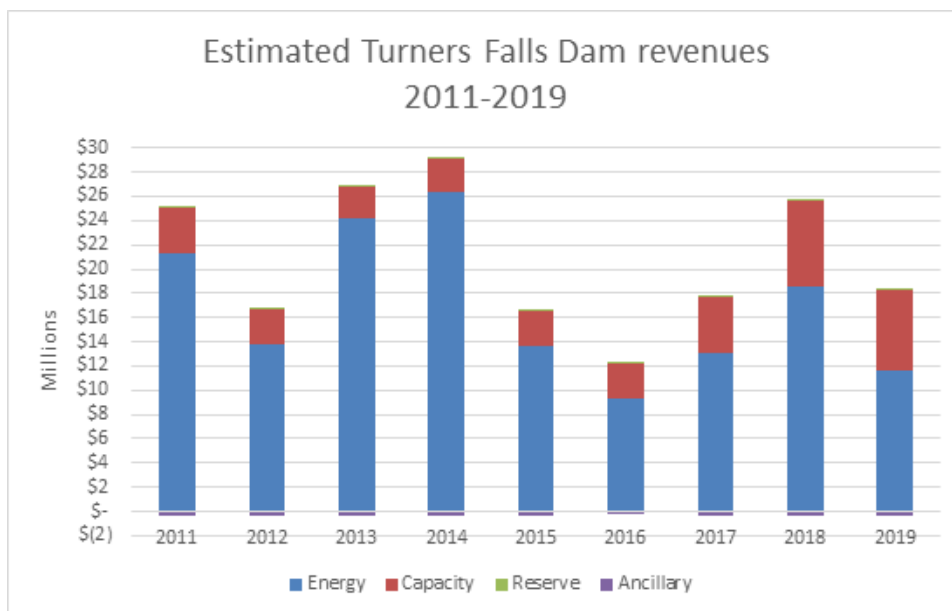


Figure 10: Estimated Turners Falls Dam revenues from 2011-2019

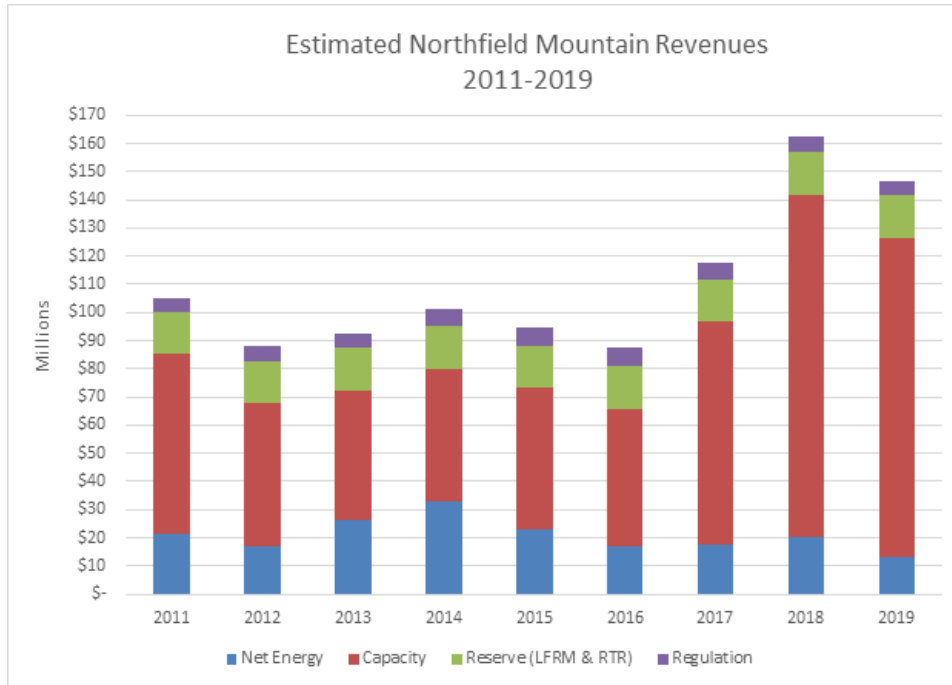


Figure 11: Estimated Northfield Mountain revenues from 2011-2019

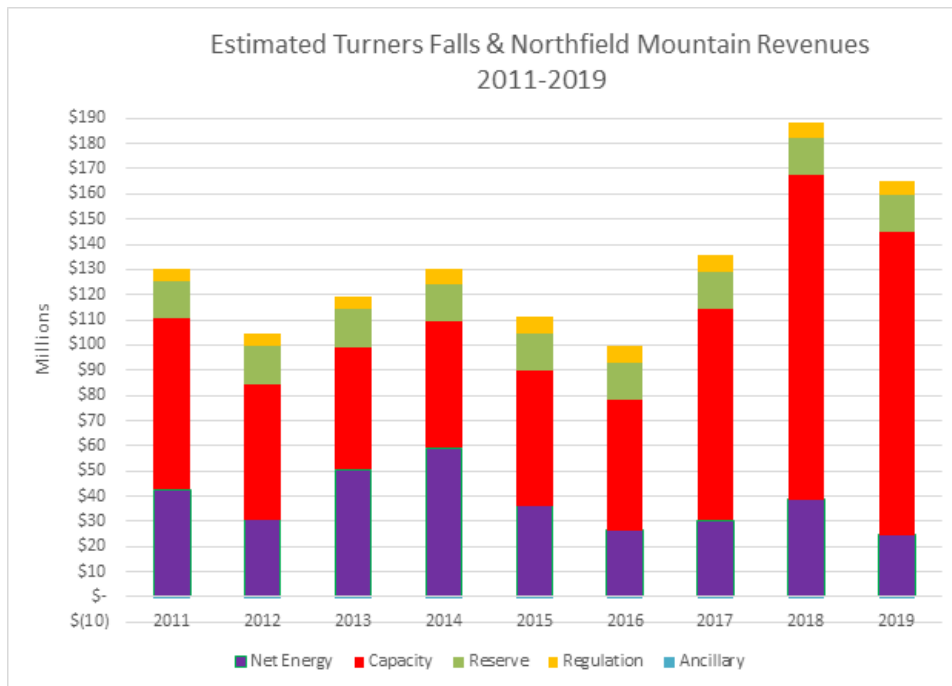


Figure 12: Estimated combined TFD and NFM revenues from 2011-2019

Further, there is strong evidence that FirstLight's revenues will go up, not down, under the proposed new license, at least for the next 20-30 years. Even at Turners Falls, where the company predicts a reduction in revenue of about \$2 million/year in its Exhibit D, the reduction is likely to be significantly less than this, for two reasons: (a) once the environmental improvements are in place, the Turners Falls project is likely to become certified as Low-Impact Hydropower, enabling it to earn Massachusetts Class II Renewable Energy Credits (RECs), which are more valuable than its current out-of-state RECs referenced in its Exhibit D revenues; and (b) FirstLight will retain a certain number of hours per month when it can peak; these will enable it also to bid into and profit from the reserves and regulation markets, which can be enormously valuable, especially during moments of grid scarcity such as December 24, 2022.²⁰⁶ But well beyond these revenue adjustments at Turners Falls, Northfield is highly likely to increase, even multiply, its revenues. In its Exhibit D for Northfield, FirstLight does not calculate predicted revenue changes with proposed operational as it does for Turners Falls Exhibit B. However, their relatively modest "sensitivity case" would suggest an average of an additional \$3 million/yr (realized energy value of energy in 2019 of \$46.03 / MWh per MWh generated (p. D-5), x 50,815 MWh/yr new generation per year (p. D-8) = \$3,134,275). This means based on their two Exhibit Ds (Northfield and Turners), FirstLight is showing a potential net revenue *gain* with the two new licenses of about \$1 million/year. This "sensitivity case" rise in generation would come from having greater storage in the upper reservoir, which would enable longer hours of pumping, and longer hours of generation (approaching 15 hours of pumping and 10 hours of generation at full capacity), enabling the plant to take advantage of extended extra low or high prices. There are at least two other reasons beyond the proposed increased storage capacity that Northfield's profits are likely to rise in the next 10-20 years or so: (a) When Massachusetts' and other New England states' predicted offshore wind comes on line (and before there is extensive other storage or extensive further transmission to bring in large volumes of distant renewables running on different-from-New England-weather timescales), there is likely to be higher price volatility in the ISO-NE energy and ancillary markets. Northfield will be able to take advantage of

²⁰⁶ <https://www.iso-ne.com/static-assets/documents/2023/01/december-2022-op4-coo-report.pdf> (see p. 12)

this price volatility to operate at more than its current 8% capacity factor²⁰⁷ (i.e. operate more hours); it will also earn more money per hour for many of these hours because of greater price differentials; and (b) FirstLight has been active in promoting state-based policies that would incentivize and subsidize its storage operations, with ratepayers paying it out-of-market extra money under a variety of circumstances, for example through Massachusetts' clean peak standard or a storage procurement. For example, if passed, Massachusetts current Omnibus Bill H. 4503 seems poised to provide significant additional revenue to FirstLight, with three mandated state procurements of medium-duration storage in the next few years.²⁰⁸ The only large-scale form of medium duration storage currently available in New England is pumped storage hydropower (PSH); two-thirds of the PSH capacity is at Northfield.

It is clear that FirstLight will have more than sufficient revenues to allocate funding towards financial assurances for decommissioning (as well as additional mitigation).

XIII. FirstLight's Proposed 50-Year License Term is Too Long

A. CRC's License Term Recommendation

CRC recommends that FERC issue a 30-year license for all five facilities undergoing relicensing on the Connecticut River. A 30-year term is in the public interest as demonstrated by overwhelming public opposition to a 50-year license term. As outlined in the above section, the energy landscape is rapidly changing, as renewable generation becomes more affordable and energy storage resources become a larger part of the market. CRC does not deny that the projects, particularly NFM, are an important renewable storage resource for New England.

²⁰⁷ Energyzt Advisors, LLC. (2020). Northfield Mountain Pumped Storage: Assessment of Contract Benefits in an Increasingly Renewable Region. Energyzt Advisors, LLC. https://firstlight.energy/wp-content/uploads/2020/07/ENERGYZT-REPORT-Northfield-Benefits_06302020_Final-for-Distribution.pdf

²⁰⁸ The 193rd General Court of the Commonwealth of Massachusetts, Bill H. 4503, An Act Relative to Clean Energy Generation, <https://malegislature.gov/Bills/193/H4503>. In the lead-up to this bill, FirstLight spend \$144,996 in 2023 alone on lobbying in the Massachusetts legislature on "Legislation, regulations, and issues related to energy, energy storage, and environmental policy." Lobbyist Public Search, FirstLight Power Resources, Inc., 2023, Lobbyist Division, Secretary of the Commonwealth of Massachusetts William Francis Galvin, <https://www.sec.state.ma.us/lobbyistpublicsearch/Summary.aspx?sysvalue=+Wk9wNbsq4xhs0Rf9HzH+kNjrNKTWhamCKOd2sWZUSA=>

However, the Northfield Mountain Pumped Storage Project was constructed beginning in 1968, and came online in 1972, making parts of its infrastructure over 50 years old.²⁰⁹ Turbines and other equipment have had to be periodically replaced over the years,²¹⁰ and presumably replacements will only become more frequent as the project ages. The cost of those replacements will primarily be passed on to ratepayers, increasing energy bills throughout New England. However, a shorter license term provides an opportunity for FERC, the state of Massachusetts, and other stakeholders to consider the value and role of aging energy infrastructure earlier and in conjunction with environmental conditions that also are changing rapidly due to climate change. For these reasons, CRC requests that FERC issues TFD and NFM 30-year licenses, consistent with its own policy and regional coordination of license terms.

B. FirstLight Has Not Provided A Sufficient Basis for the Longest License Term and Given the Changing Energy Environment a Shorter Term is Warranted

FirstLight argues that it is entitled to a 50-year license term for three primary reasons.²¹¹ First, in acknowledging FERC's policy of coordinating license terms among facilities in the same basin, FirstLight argues that all five facilities undergoing relicensing could be granted a 50-year license. Second, FirstLight argues that its proposed environmental measures, decreased revenue from the increase in minimum flow, and new development and construction, as defined in Section 36, warrant a longer license term. Third, FirstLight maintains that because settling parties have agreed upon the license term, FERC should grant a 50-year license.

While FirstLight argues that all projects undergoing relicensing could be coordinated by receiving 50-year license terms, FirstLight does not offer any explanation nor justification for why the upstream projects merit an exception to FERC's 2017 policy. In fact, in the case of coordinating license terms across five facilities, three of which, owned by Great River Hydro are silent on a preferred license term. It is reasonable to expect that the length of the license would be 30 or at most, 40 years by default for all projects being considered. FERC's 2017 policy

²⁰⁹ AFLA, at C-1.

²¹⁰ *Id.* Since 2004, the longest NFM has gone without replacing equipment is four years (between 2016 and 2020, when the AFLA was filed). *Id.*

²¹¹ FirstLight, Response of FirstLight MA Hydro LLC and Northfield Mountain LLC to Comments on Flows and Fish Passage Settlement Agreement at 23-27 (filed June 12, 2023).

emphasizes term coordination within river basins, and such coordination could be a rationale for shorter license terms for projects in the same basin.²¹² A shorter license term of 30 years for all five hydropower facilities is in the public interest given the overwhelming opposition to a 50-year license term expressed in comments submitted by numerous community members on the Flows and Fish Passage Settlement Agreement. Furthermore, as indicated previously in our comments, technology is advancing rapidly and a shorter term license allows society to continue advancing quickly with cleaner and more reliable energy sources. Similarly, a shorter license will allow for future changes and adaptability with relation to changing climate.

CRC does not object to the proposed environmental measures and costs as one factor used to determine the length of the license; however, FERC has previously determined that cost estimates provided by the company are not always reliable and that costs are not the sole determinant.²¹³ FirstLight argues that the cost of environmental measures, coupled with the loss of revenue due to the increase in minimum flows is justification for a 50-year license term. However, FERC has previously determined that losses in generation value due to environmental measures do not necessarily merit a longer license term.²¹⁴ FirstLight indicated that it would provide additional information to support its request for a longer license term, which has not yet been submitted as part of the FERC docket.²¹⁵ Further, as explained above in Section XII D, there is strong evidence that FirstLight's revenues will go up, not down, under the proposed new license.

Finally, FERC policy allows that a license term can be lengthened or shortened in the case of a "generally-supported comprehensive settlement agreement."²¹⁶ As described in CRC's comment on the recreation settlement agreement, FirstLight has not submitted a generally-

²¹² Federal Regulatory Energy Commission, Policy Statement for Establishing License Terms for Hydroelectric Projects, 82 Fed. Reg. 49501 (Oct. 26, 2017).

²¹³ Brief for Respondent Fed. Energy Reg. Comm'n at 12, *Duke Energy Carolinas, LLC v. Fed. Energy Reg. Comm'n*, 883 F.3d 923 (D. C. Cir. 2018) (No. 16-1296).

²¹⁴ *Duke Energy Carolinas, LLC*, 156 F.E.R.C. ¶ 61,010 at P 14-15 (2016).

²¹⁵ See Response of FirstLight to Comments on Flows and Fish Passage Settlement Agreement, at 27 ("FirstLight plans to submit additional information in support of its request for 50-year license terms at a time closer to license issuance."). FirstLight has had more than enough time to submit this information and therefore has waived its right to submit it now; however, CRC reserves the right to comment on any late-submitted information from FirstLight on this point.

²¹⁶ FERC, Policy Statement on Establishing License Terms for Hydroelectric Projects, 82 Fed. Reg. 49501, 49503 (Oct. 26, 2017).

supported comprehensive settlement agreement; rather, settling parties submitted two partial and contested settlement agreements.²¹⁷ The two offers of settlement do not resolve all issues that were raised during settlement negotiations and do not meet the standard for a comprehensive agreement. Additionally, as CRC has previously outlined, the settlement offers cannot be considered to be generally supported. Numerous members of the public and coalitions submitted comments in opposition to the Flows and Fish Passage settlement agreement. While FirstLight has attempted to brush off these comments, these concerns come from the local individuals and groups directly and adversely impacted by the projects. Additionally, FERC does not only consider settling parties when evaluating settlement offers: “[I]n reviewing settlements, the Commission looks not only to the wishes of the settling parties, but also at the greater public interest, and whether settlement proposals meet the comprehensive development/equal consideration standard.”²¹⁸

XIV. Conclusion

CRC sees many issues with the current AFLA and Settlement Agreements and has taken time to craft science backed recommendations for FERC to include in the updated license.

- The proposed flows below Turners Falls Dam (“TFD”) from July 1 through November 15 fail to comply with Massachusetts Surface Water Quality Standards in the one-mile stretch of river below the dam, fail to protect aquatic life uses, fail to safeguard cultural resources, fail to maintain consistently good aesthetic values, and severely limit and negatively impact recreational uses, specifically boating. CRC recommends 1,400 cfs before TFD from July 1 through November 15.
- Northfield operations cause unacceptable levels of erosion in the Turners Falls Impoundment (“TFI”) and beyond, and will result in continued environmental damage, loss of riverfront land, negative impacts on recreation, and non-compliance with state

²¹⁷ CRC, Comments on Offer of Partial Recreation Settlement; Turners Falls Hydroelectric Project (FERC No. 1889-085) and Northfield Mountain Pumped Storage Project at 4-5 (FERC No. 2485-071) (filed July 7, 2023).

²¹⁸ FERC, Policy Statement on Hydropower Licensing Settlements at 2 (Sept. 21, 2006), available at <https://www.ferc.gov/sites/default/files/2020-06/PL06-5-000.pdf> (last visited May 22, 2024).

water quality standards. CRC recommends instituting a baseline river height from which to require a “normal operational range,” with specific conditions for any deviances outside of the range.

- FirstLight’s proposed schedule of nine years and seven years for installation of the fish lift at TFD and barrier net at TFI, respectively, is far too lengthy and will result in several years of unnecessary continuation of barriers to migratory fish passage, limiting access to habitat, and failing to protect and restore aquatic life uses. CRC recommends shortened installation timelines of five years for the fish lift and two years for the barrier net. FirstLight has been allowed to continue operating under the existing license for an extra six years, which is economically advantageous for them. It will be no economic hardship for FirstLight to install these enhancements and protective measures sooner.
- While the new barrier net proposed for the Northfield Mountain Pumped Storage Project is an improvement, not enough is known about the effects of impingement and entrainment of aquatic organisms as a result of the barrier net, and the proposed schedule for installing the net is too long. CRC recommends monitoring of the barrier net for the duration of the license term and mandating further research to be done on the fate of juvenile eel and shad egg with relation to NFM pumping.
- FirstLight Projects’ operations create conditions that support the growth of invasive species, and FirstLight’s proposed invasive species plan is lacking in substance and does not fully address the threat of invasive species to fish and wildlife in the project area. CRC supports the recommendations outlined by USFWS in its Invasive Plant Species Management Plan, including requiring FirstLight to complete more monitoring, provide

more funding, and produce educational materials all for the benefit of eradicating AIS from the FirstLight project areas.

- FirstLight’s proposed license conditions do not sufficiently protect aquatic and aquatic-dependent species that are listed as threatened, endangered, or sensitive under federal and state laws, including bald eagles and sturgeon. CRC recommends FERC require the most stringent prescriptions needed to uphold the protections of the state and federally endangered, threatened and sensitive species present in the project area.
- FirstLight’s proposed annual canal drawdown procedure causes unacceptable impacts on migrating fish and other aquatic organisms. CRC supports the USFWS recommendation for FERC to develop a Canal Drawdown Protection Plan in which FirstLight would fund more support to ensure the safety of these organisms as well as scientifically document the impacts of the Canal Drawdown.
- FirstLight Tuners Falls Project cause unacceptable levels of light pollution. CRC recommends that FirstLight consult with a lighting designer to create a plan for DarkSky Approved lighting schemes that minimize glare and reduce light pollution.
- FirstLight’s Northfield Mountain is a net consumer of energy, and most of the marginal energy it consumes or displaces is gas, making it a net producer of greenhouse gas emissions (“GHGs”). FirstLight should be required to report, on an annual basis, what the marginal fuels were during its hours of pumping, the total GHGs produced in order to generate that marginal grid power that it used, what the displaced marginal fuels were on its hours of generation, and the resulting total GHGs avoided during its hours of generation. This will provide objective information on its role in reducing GHGs.

FirstLight Projects' reservoirs, both the TFI and the upper reservoir at Northfield Mountain, are likely sources of GHGs, the impacts of which on climate change must be monitored and accounted for and the licenses must be conditioned to reduce the release of GHGs to the maximum extent feasible.

- In addition to failing to comply with Massachusetts water quality standards related to insufficient flows, there are also significant questions and data gaps related to the FirstLight Projects' compliance with water quality standards for dissolved oxygen ("DO"), temperature, aesthetics related to trash and oil releases into the river, and sediment transport from draining the upper reservoir at Northfield Mountain. CRC recommends instituting requirements for FirstLight to accurately monitor DO and water temperature, mandate protocols for oil spill mitigation and prevention, develop procedures for FirstLight to manage debris and trash from the boat barrier, and require monitoring and financing of appropriate sediment deposition.
- FERC should require FirstLight to provide financial assurances for decommissioning and dam removal at the end of the Projects' useful lives.
- FirstLight has not provided a sufficient basis for the longest (50-year) license term and given the changing energy environment, a shorter term is warranted. CRC recommends a 30 year license for all projects in this relicensing.

CRC asserts that FirstLight's AFLA and proposed settlement agreements fail to provide sufficient information and solutions to issues CRC has repeatedly raised in the relicensing process including, but not limited to, the above-listed topics.

CRC appreciates the opportunity to comment on these relicensing proceedings. Please feel free to contact me, Rebecca Todd, Executive Director of the Connecticut River Conservancy, at rtodd@ctriver.org or contact Nina Gordon-Kirsch, Massachusetts River Steward and the Connecticut River Conservancy, at ngordonkirsch@ctriver.org.



Rebecca E. Todd
Executive Director

Connecticut River Conservancy Comment Exhibit List

Exhibit A	Gomez & Sullivan Engineers, Boating Navigability Study: Turners Falls Hydroelectric Project (No. 1889) (2021) (prepared for FirstLight) (“Boating Navigability Study”).
Exhibit B	Doug Whittaker & Bo Shelby, Flows and Aesthetics: A Guide to Concepts and Methods 6 (Nat’l Park Serv. Et al., 2017).
Exhibit C	Dr. Evan Dethier, Review of Erosion in the Turners Falls Impoundment (2024)
Exhibit D	Dilip Mathur et al., <i>Entrainment of Juvenile and Adult American Shad at a Pumped Storage Facility</i> , 38 N. Am. J. Fisheries Mgmt. 56--75 (2018).
Exhibit E	Connecticut River Atlantic Salmon Commission, Connecticut River American Shad Management Plan 4 (2017) (addendum approved 2020).
Exhibit F	Steffen Breinlinger et al., <i>Hunting the eagle killer: A cyanobacterial neurotoxin causes vacuolar myelinopathy</i> , 371 Science 1-7 (2021),
Exhibit G	EPA File No.: ACO-WE-10-6W003 Administrative Consent Order and Notice of Noncompliance (Aug. 4, 2010).

EXHIBIT A

Boating Navigability Study

Uploaded As A Separate File:

Ex A_Turners Falls Boating Study

Report 12-28-21

EXHIBIT B

Flows and Aesthetics

A Guide to Concepts and Methods

Doug Whittaker and Bo Shelby

May 2017



EXHIBIT B

Flows and Aesthetics: A Guide to Concepts and Methods

May 2017

Doug Whittaker and Bo Shelby

Support provided by

**National Park Service Hydropower Assistance Program
Hydropower Reform Coalition
Confluence Research and Consulting
Oregon State University**

EXHIBIT B

Foreword

River users increasingly realize that the aesthetics of rivers- the way they look and feel- provide experience as special as being on a river or physically touching the water. In the United States, federal and state laws and agency mandates recognize the aesthetic values of water, and require adequate flows and other measures to maintain and protect these values. However, state and federal agencies do not apply these laws often, and when they do, it is not always done consistently. This is due, in large part, to the absence of clear protocols for assessing and protecting aesthetic values of water.

This guide is intended to fill that gap and improve decision-making. It provides a common framework for requesting, designing, or reviewing flow-aesthetics studies, and reviews specific methods for conducting those studies. It will help participants (including regulators, applicants, agencies, tribes, and other stakeholders) involved in proceedings such as federal hydropower licensing processes or water right adjudications. The goal is to better understand, assess, and design flows to protect aesthetic resources.

This guide complements other flow-related documents produced jointly by the Hydropower Reform Coalition and the National Park Service, such as the Flows and Recreation Guide, and the Hydrokinetic Energy Projects & Recreation: A Guide to Assessing Impacts.

The authors are recognized experts in the field of flows for aesthetics and recreation and have been extensively involved in navigability litigation, water right adjudications, and hydropower licensing. Joan Harn, Cassie Thomas and Susan Rosebrough of the National Park Service, Mark Ivy and Vince Yearick of the Federal Energy Regulatory Commission, and Rich Bowers, Megan Hooker and Rupak Thapaliya of the Hydropower Reform Coalition provided reviews on an earlier draft.

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June 2017
Washington, D.C.

EXHIBIT B

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Cover Photo: Similkameen Falls, Washington was the focus of aesthetic studies and litigation described on page 48. (Photo by Tom O’Keefe, American Whitewater)

1. Introduction

*I gave my heart to the mountains the minute I stood beside this river
with its spray in my face and watched it thunder into foam, smooth to
green glass over sunken rocks, later to foam again. I was fascinated by
how it sped by and yet was always there; its roar shook both the earth
and me.*

Wallace Stegner

Rivers plunging over waterfalls are among the grandest spectacles in nature, scenic wonders that attract millions of visitors. The aesthetic qualities of flowing water have several elements, but the amount of water is among the most important. The magic of viewing waterfalls clearly depends on the sight, sound, and feel of moving water. Other activities such as hiking or picnicking along a river are less **flow-dependent**, but they are clearly **enhanced** by the beauty of water as it glides through canyons or splashes over riffles.

Federal laws and agency mandates recognize the aesthetic value of water in rivers, and protect flows or related scenic elements in the landscape. But the language is often general or abstract, and is seldom used explicitly to manage flows for aesthetics. It is often assumed that flows for other resources such as fish or recreation will protect aesthetics, but river professionals need better protocols for assessing and protecting aesthetics independent of other resource considerations.

This guide is intended to address these needs. It applies established principles and methods from flow-recreation research, a branch within the larger field of recreation management, to systematically assess how flow affects aesthetic evaluations and related recreation experiences. Designed for river professionals (including resource managers, utility staff, consultants, and advocates), it describes theory and practices agencies can use to determine whether flow regimes protect or enhance aesthetic resources.

Objectives

The overall goal of this guide is to describe the current state of flow-aesthetic research and the ways it can be integrated into a variety of decision-making settings (including hydropower licensing, water rights adjudications, and protecting scenic values of state or federally designated rivers). The hope is to provide a common framework for those conducting studies, and others who review and use that work. This includes researchers, consultants, and staff from agencies, utilities, and interest or user groups. Specific objectives include:

- Clarify and standardize terminology.
- Differentiate between descriptive and evaluative components and show why they should be considered separately.
- Describe several study options for specific situations.
- Identify study outputs that fit with decision-making processes.
- Discuss strategies for integrating aesthetic studies with those for other resources.

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- Consider ways to use study information to develop efficient and effective protection, mitigation, and enhancement measures.

In many cases, the document focuses on studies used in Federal Energy Regulatory Commission (FERC) licensing and State 401 Water Quality Certification, because these processes apply to flows on regulated rivers that can directly affect aesthetics. But similar information also can be used in decision settings such as state instream flow protection, water right adjudications, or non-FERC dam operations. In all these settings, the common need is to show how flow regimes affect aesthetics and related recreation experiences, and then integrate with findings from other resources in decision-making processes.

This document is not a cook book for conducting studies; it is designed to establish a framework for studies and review the key concepts. High quality flow-aesthetic studies require scientific, logistical, and visual media skills, as well as experience adapting social science concepts and methods to specific cases. Similarly, a growing flow-aesthetics literature offers examples of study elements such as individual survey questions or data analyses, but these often require modification to be effectively applied to other places. This document provides guidance about the issues to be considered when requesting, designing, conducting, or reviewing flow-aesthetics studies, but it is not a recipe for designing studies or navigating the scientific literature. In the same way that a guide to fish habitat methods does not replace biological expertise, this guide does not replace social science expertise.

Limitations

Research in this field is relatively young, although there is increasing consensus about issues and the ways they can be addressed. The guide is intended to catalyze additional dialog to build on this progress, with the hope that additional studies and concepts will be added to the guide in the future.

This guide recognizes that the aesthetics of rivers are affected by larger landscapes where other variables are factors. There are several visual resource management protocols for assessing landscape aesthetics, some of which focus on human modifications (such as forestry practices or construction of new facilities). This guide is not intended to summarize, duplicate, or supplant those protocols. A discussion section reviews some of the conceptual and methodological overlap in Chapter 7.

This guide focuses on the aesthetics of flows in rivers and creeks or over waterfalls, not water levels in lakes or reservoirs. But many of the principles and methods for assessing aesthetics in river settings can be adapted to lakes and reservoirs; both involve systematic evaluations of a biophysical variable that may affect scenic beauty or related resources.

Guide organization

The guide is organized into nine chapters.

- **Introduction.** Provides an overview and limitations of the document.
- **Concepts.** Defines terms, describes a conceptual perspective, and links the flow-aesthetics field to larger literature in the social sciences and philosophy of aesthetics.
- **Decision settings and process.** Reviews laws and agency policies designed to protect or enhance aesthetic flows in rivers, and presents a study process that can be adapted to different decision settings.
- **Study options.** Presents choices ranging from professional judgments to larger-scale studies with on-site assessments of multiple flows. For each, we review objectives, the typical approach, study output, additional issues, and cautions/limitations.
- **Integrating with flow studies for other purposes.** Considers efficiencies in studying flows for aesthetics along with other resources, as well as ways to integrate study findings to optimize flow regimes that provide for different resources over different time scales.
- **Example studies and projects.** Illustrates methods and findings from ten rivers, showing how studies or applications were more vs. less useful in resolving aesthetic issues.
- **Background, evaluation approaches, and classification schemes.** Collects several discussions that provide conceptual background for understanding aesthetics, or ways that scientists or resource managers have evaluated visual resources in general or waterfalls in particular.
 - Distinguishing aesthetics and recreation
 - Descriptive vs. evaluative information
 - The philosophical roots of aesthetics
 - Visual Resource Management approaches
 - Types of waterfalls and subjective waterfall evaluations
- **Conducting flow aesthetic studies.** Collects several technical discussions about conducting flow-aesthetic studies.
 - Collaboration with stakeholders and the public
 - Measuring flows and using gage information
 - Choosing Key Observation Points (KOPs) and shooting photos/video
 - Constructing successful flow-aesthetic surveys
 - Channel coverage vs. aesthetic value
- **Six flow-aesthetic principles.** Summarizes major findings from existing studies into generalizations, hypotheses, or suggestions for future research.

2. Concepts

This chapter defines terms, describes a general conceptual framework, and links flow-aesthetic issues to extensive literatures in philosophy and related social sciences.

Definitions

Several terms are commonly used in flow-aesthetic studies. Different technical meanings are sometimes intended, and common usages can add to the confusion. We offer the following definitions for clarity.

Aesthetics. This term is used broadly to refer to “the study of the mind and emotions in relation to the sense of beauty,” or to identify a branch of philosophy addressing “the principles of beauty in art and nature” (Dictionary.com, 2015). It is used in everyday language to describe objects or scenes that are “pleasurable to the senses,” or “pleasing and attractive” (Merriam-Webster, 2015).

There is an extensive literature related to the philosophical roots of aesthetics, generally focused on the question: what is beautiful? Originally used to define beauty in art, philosophers began applying aesthetic principles to nature in the 19th century. In the last 50 years, environmental aesthetics (Morton, 2007) has integrated those concepts with other ideas from environmentalism, psychology, and social psychology. A discussion section in chapter 7 provides a brief review.

Our focus is more applied, referring to ***empirical evaluations of visual (scenic) beauty or other sensory experiences in a landscape setting, including sound, touch, smell, or taste.*** When considering river settings, these empirical studies can involve experiences as diverse as the sight of a powerful cataract, the sound of a bubbling creek, the temperature of a swimming hole, the mist of a waterfall, or the smell and taste of a glacial creek.

This applied focus is also distinct from spiritual values or religious rights associated with different flows in a river or waterfall. For example, Native Americans considered sufficient waterfall mist at Snoqualmie Falls, WA to be a sacred component of their religious ceremonies, but court rulings during hydropower relicensing separated this topic from aesthetics (see discussion on Snoqualmie Falls in chapter 6 for a summary).

Recreation. Recreation refers to experiences people have while participating in goal-directed, non-work activities. It includes a long list of physical and contemplative activities, including nature-focused activities such as hiking, biking, boating, swimming, and camping. People are motivated to recreate for several reasons, including physical and psychological benefits such as enjoying nature, fitness, taking risks, developing skills, testing competency, gaining social recognition, being with friends and family, introspection, and escaping social pressures (Brown et al., 1978). Recreation research and management frameworks suggest that resource agencies manage settings to provide opportunities for high quality experiences. Aesthetics may be important parts of these experiences, involving evaluations of the environments where recreation occurs (see discussion on Recreation and Aesthetics in chapter 7).

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Scenic values or scenic beauty. These terms are commonly interchanged with aesthetics. However, we consider scenic values or scenic beauty to be more narrowly focused on visual evaluations, while aesthetics includes other senses.

Landscape and landscape scale. Dictionary definitions focus on “the visible features of land” (Merriam-Webster, 2015) or “the entire portion of territory that can be viewed from one place” (The Free Dictionary, 2015). Visual resource literature includes more narrowly defined landscape scales (see below), as well as more expansive definitions that combine a landscape’s physical features with human perceptions of them. In ecological discussions, landscape-level solutions often refer to larger regional, national, or continental scales (in contrast to smaller sites).

For our purposes, ***landscape*** generally refers to a viewshed visible from a particular location. Similarly, we adopt the Forest Service (1995) distinctions between different scales as below:

- Immediate foreground 0 to 300 feet
- Foreground 300 feet to ½ mile
- Middle ground ½ mile to 4 miles
- Background 4 miles to horizon

Given that most river channels with flow-aesthetic impacts are less than a half-mile wide, most flow-aesthetics studies will involve foreground or immediate foreground scales. These scales are similar to Litton and Tetlow’s (1973) “setting unit,” which is distinct from their larger “landscape unit.” Regardless of the label, the focus is on intimate interaction with the sights, sounds, and feel of natural features rather than the patterns and textures of larger scale landscape evaluations.



Flows are more likely to affect the sights, sounds, and feel of natural features in the foreground than patterns and textures of the larger landscape. McCoy Falls on the New River, Virginia.

A conceptual framework

A conceptual framework for flows and aesthetic resources is shown in Figure 1 (adapted from Whittaker et al., 1993; Whittaker et al., 2005). **Flow** is the variable driving the system, and it can come from natural or human-regulated sources. Flow, in turn, affects **resource conditions**, which include immediate effects such as hydraulics (depth, velocity, width, wetted perimeter, and turbulence) as well as longer-term effects related to interactions between hydraulics, channel geomorphology, and riparian vegetation. Taken together, hydraulics, channel morphology, and riparian vegetation form a dynamic system of resource conditions that define biophysical and human “habitats.”

Resource outputs are produced when different resource conditions are combined with a given flow regime. Broad categories of outputs include recreation opportunities (e.g., whitewater boating, wading-based fly fishing, swimming, and wading) and biophysical resources (e.g., quality of a sport fishery, amphibian populations, and beach size or abundance). Other possible outputs include different qualities of aesthetic characteristics. For example, lower flows may produce a shallow segmented waterfall with little mist, while higher flows produce a deeper block falls and clouds of mist.

To the extent that flow regimes can be managed to produce different outputs, the final element is **resource trade-offs**. Here the framework moves from the descriptive arena (where scientists determine how flows affect resource conditions and outputs), to the evaluative arena (where decision-makers, resource managers, and interest groups consider the desirability of different combinations of outputs). These evaluations are generally made in decision-making processes (such as FERC license proceedings, 401 water quality certifications, Wild and Scenic River water right adjudications, or land management planning) where social values (beyond monetary returns) are key considerations.

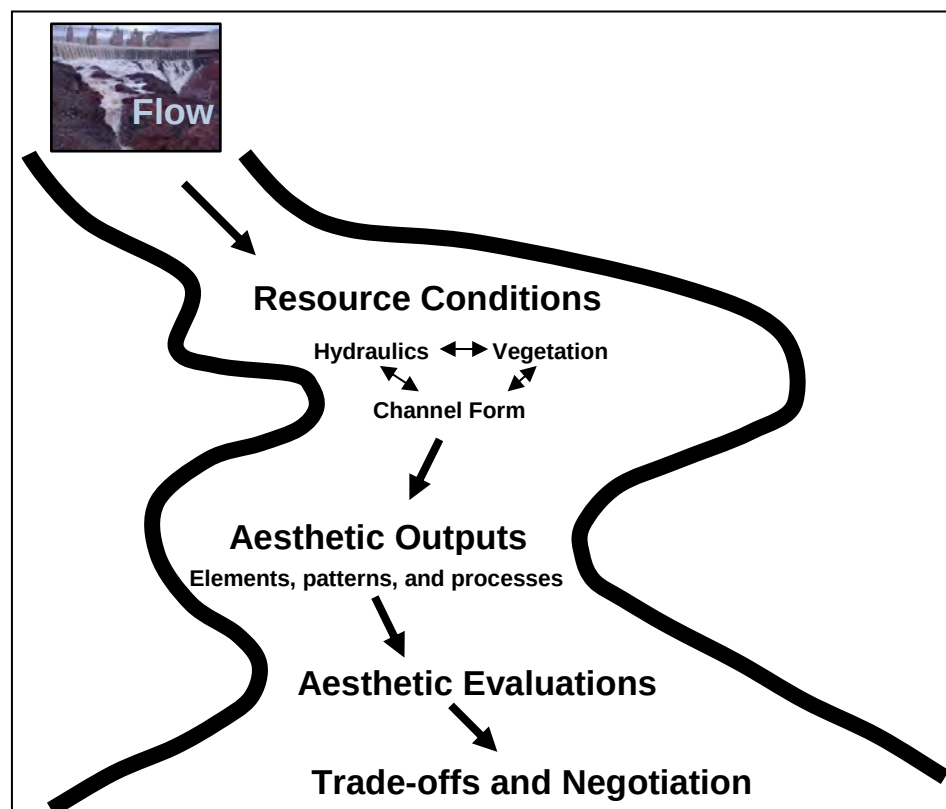


Figure 1.

A conceptual framework for assessing flows and aesthetics.

3. Decision settings and study processes

A river is more than an amenity—it is a treasure that offers a necessity of life that must be rationed among those who have the power over it.

Oliver Wendell Holmes

This chapter reviews laws or agency policies designed to protect or enhance aesthetic flows in rivers, and presents a study process that can be adapted to different decision settings.

Decision settings

Aesthetics of water in rivers or over falls can be protected through several federal or state laws (or associated regulations and decision-making processes). The following examples of flow-aesthetic decision settings describe laws or guidelines that mandate or offer opportunities for protection and how they have been used by agencies. The list is not exhaustive.

Licenses for hydropower development

The Federal Energy Regulatory Commission (FERC) regulates approximately 2,500 hydropower dams across the country, with most operated by private utilities or public utility districts. Licenses are usually granted for periods of 30 to 50 years; when those licenses expire, utilities must apply for and receive a new license to keep operating a facility. As of Jan 2017, there were 1,036 active FERC hydropower licenses for existing projects (some covering multiple dams), 629 exemptions, and 165 preliminary permits for new projects. FERC expects to review licensing applications for about 390 projects between 2017 and 2030.

The Electric Consumers Protection Act (ECPA) updated the Federal Power Act in 1986, and rewrote the rules for assessing and mitigating impacts of hydropower projects. ECPA requires “equal consideration of power and non-power values,” so a project licensed prior to 1986 may need to consider resources that previously received less attention.

Recreation and aesthetics are specified as “non-power values,” and regulations have led to a formal role for the National Park Service to provide advice to stakeholders and to represent recreation and aesthetic interests in relicensing processes. Agencies that manage land affected by hydropower projects (e.g., the U.S. Forest Service, Bureau of Land Management, U.S. Fish and Wildlife Service) have similar responsibilities to consider a variety of environmental values, including recreation and aesthetics. Although aesthetic issues in FERC processes often focus on facility/development impacts (e.g., from dams, penstocks, power houses, roads, and transmission lines), aesthetics of flows affected by project operations are also considered.

Hydropower licensing is a complex, multi-year resource planning and decision-making process. The three major phases are handled differently depending on whether the “traditional” (TLP), “alternative” (ALP), or default “integrated” (ILP) process is used. The **initial phase** assembles existing information about the project and potentially affected resources in consultation with the public. This identifies information gaps, informing which studies are needed to assess the impacts of different operation or mitigation scenarios (see below). A Preliminary Application Document (PAD) is the end product, guided by the standard of presenting “existing, relevant, and reasonably available information.” The baseline

for environmental impact assessment are “existing conditions,” but these conditions may be “less natural” for river that has had hydropower development for several decades.

The **study phase** focuses on developing **study plans**, completing the **studies**, and **integrating findings** across resource areas. This one to two year effort typically culminates in draft and final license applications that document project effects and propose future operations and protection, mitigation, and enhancement measures (PMEs). Most aesthetic studies would be conducted during this phase. Settlement discussions between utilities, agencies, and stakeholders may begin during this period.

The **final NEPA-based phase** focuses on addressing outstanding issues between the utility, agencies, and stakeholders through an impact analysis conducted by FERC using a National Environmental Policy Act (NEPA) process. NEPA requires an agency to consider a range of reasonable alternatives and assess environmental impacts for each. It also requires public involvement and decision-making by an interdisciplinary team. The result is a license to build and/or operate the project, with **license articles** that prescribe operations and mitigation. When settlement agreements between utilities, agencies, and stakeholders occur, FERC generally incorporates them into the final license.

Within each phase of this process, agencies and stakeholders have general responsibilities to help identify recreation or aesthetic issues; determine study needs; assist with study design, conduct, or evaluation; help integrate study results into application proposals; and facilitate settlements between agencies, utilities, and stakeholder groups.

The previous section is revised from the Flows and Recreation guide (Whittaker et al., 2005), with additional information from the Hydropower Reform Coalition Toolkit (HRC, 2015). Additional information about FERC licensing is available at FERC.gov.

Water quality certification

The Federal Clean Water Act’s Section 401 allows states to control water quality and instream flows related to any federal license or permit through a “Water Quality Certification” or “401 Certification.” These state-led certifications are associated with several federal permitting and licensing processes such as pollution discharge permits administered by EPA; Section 404 dredge and fill or Rivers and Harbors Act permits administered by the Corps of Engineers; and hydroelectric projects licenses administered by FERC.

Several states have developed statutes or regulations under this authority to protect recreation and aesthetic values, although other states have waived Section 401 requirements for hydropower licenses. **Examples from the State of Washington are presented below** to show the range of issues. They are excerpted from court cases, laws, hearings, or agency guidance related to 401 Certification (Washington Department of Ecology and Washington Department of Fish and Wildlife, 2003; Ecology, 2005).

- The Department of Ecology (Dept. of Ecology) can “impose flow conditions in order to protect beneficial uses of a river as identified in state water quality standards” in a 401 Certification (PUD No. 1 of Jefferson County v. Department of Ecology, 511 U.S. 700, 1994).
- Dept. of Ecology can require minimum bypass flows in a 401 Certification to ensure “the waters will not be degraded so as to interfere with or injure existing beneficial uses.” (PUD No. 1 of Pend Oreille County v. Department of Ecology, 146 Wn. 2d 778, 821, 2002).

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- “Aesthetic enjoyment, which is a characteristic use, includes enjoyment of beauty” (Snoqualmie Indian Tribe v. Ecology, PCHB No.03-156 (Final Findings of Fact, Conclusions of Law and Order, April 7, 2004)).
- Dept. of Ecology can set instream flows for any or all of the listed resources and values, and recognizes that some may “overlap” or “are often clearly related...”, for example, recreational boating flows for fishing, pleasure, and whitewater are consistent with navigational values. Scenic values likewise support both aesthetic and recreational values” (Dept. of Ecology and WDFW, 2003, p. 10).
- Instream flow statutes require instream flow “protection” RCW 90.22.010 or “preservation” (RCW 90.54.030(3)(a)) without specifically defining either term, but Ecology cites common dictionary definitions of “keeping from harm or injury” for both and requires “sufficient flows” for the “protection or preservation of fish, wildlife, scenic, recreation, navigation, water quality, and other environmental values...over the long term” (Dept. of Ecology and WDFW, 2003, p. 10).
- Dept. of Ecology has developed a “narrative standard” rather than a numerical standard for recreation and aesthetics in hydropower water quality certifications (Dept. of Ecology, 2005, p. 26). “Narrative criteria are implemented on a case-by-case basis to protect water quality and beneficial uses.”
- A two-page section from Ecology’s 401 Water Quality Certification for Existing Hydropower Dams Guidance Manual focuses on recreation and aesthetic issues (Dept. of Ecology, 2005, pp. 53-54). The section includes:
 - o “Recreation and aesthetics (sight, smell, touch, and taste) are beneficial uses specifically protected in Washington’s water quality standards.”
 - o Recognition of a “curvilinear relationship between instream flow and recreational benefits” (referred to as a “suitability curve”).
 - o Examples of recreation activities that may be affected by flow or reservoir levels, including “motor boating, fishing, swimming, wading, rafting, canoeing, kayaking, inner-tubing, and aesthetic enjoyment.”
 - o Recognition that evaluations (e.g., preferences or acceptability as assessed in surveys) may be needed to assess how flows affect aesthetics. “Water features are often valued for their aesthetic properties. Beyond the mere presence or absence of water features, however, it also is possible to determine preferences for specific attributes of water features themselves (e.g., flow quantity, water clarity).”
 - o A list of “possible causes of impairment” that includes 1) “direct dam effects such as river hydraulics, water depth, velocity, wetted perimeter, and turbulence;” and 2) indirect effects to “in-channel features such as sinuosity, sediment movement, channel movement, gravel bars, and beaches. Because of flow changes, there also may be changes to riparian vegetation, which, in turn, may affect the recreation experience.”
 - o Examples of aesthetic impairments that include “placing river flows through turbines,” and “other structural, operational, and indirect effects of dams on the senses. Growth and decay of aquatic plants; fish kills, boats, litter, and human or pet waste...and other problems contributable (*sic*) to dams or dam operations can affect taste, touch, smell, and sight.”
 - o Recognition that evaluative information from recreation users is important. “A user-based survey provides an excellent means to get qualitative responses from the user community

regarding river conditions. It also offers the opportunity to query users about other aspects of the recreational opportunity in addition to instream flow.”

- A statement that flows for recreation and aesthetics may need to be integrated with “flow needs for other values using an interdisciplinary approach. Some accommodation among uses will likely be necessary because it is unlikely that any flow can simultaneously optimize the needs of all uses.”
- The importance of public involvement for assessing “potentially visually controversial facilities.”

Wild and Scenic River designation

The federal Wild and Scenic Rivers Act (WSRA, 1968) is the nation’s primary river conservation law, designating specific river corridors for their “outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values.” The law protects such rivers in their free-flowing condition (preventing dams and similar water development), and requires Federal agencies to develop management plans that identify, protect, and enhance the specific “outstandingly remarkable values” (ORVs) for each river corridor.

Two sections of the WSRA are relevant for this guide.

First, scenery is one of the ORVs that could make a river eligible for designation. Pre-designation eligibility studies or management plans for a designated river identify the important scenic characteristics that have created that value, and describe how those characteristics will be protected and enhanced. Descriptions from a recent plan for the Merced River in Yosemite National Park (2014) illustrate the specificity that can be used to describe scenic values of the river, including some that are obviously flow-related.



The Merced River in Yosemite Valley complements and frames iconic features such as El Capitan.

Overview

Throughout its length, the Merced River flows through a scenic landscape that has few parallels. Whether these are views from the river or its banks, whether the views include El Capitan, Half Dome, Yosemite Falls, Vernal Fall, or Nevada Fall, or any of the other landmarks along the river, the Merced River provides a natural complement to Yosemite’s world-renowned scenery. Depending on the stretch of river, the Merced provides a foreground of a flat valley, a rushing and boulder-strewn river, tall waterfalls, or serene lakes.

Yosemite Valley

Crashing over Nevada and Vernal falls and then meandering quietly under 2,000 foot cliffs, the Merced forms a placid foreground to some of the world’s most iconic scenery. The river enters Yosemite Valley at Nevada Fall, flowing through Emerald Pool and then over Vernal Fall. Once

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in the flat valley, the Merced provides the foreground to many of Yosemite's most famous landmarks. From the river and its banks, views consist of Yosemite Falls, Bridalveil Fall, El Capitan, Half Dome, and other named and unnamed parts of the cliffs and hanging valleys rimming the valley. Meandering through a sequence of compound oxbows, wetlands, and meadows, the river and its related features provide broadened panoramas. Throughout the valley, views from the river and its banks encompass the lower Montane forest as it rises up to sheer rock faces of granite cliffs and talus slopes, with a flat valley bottom serving as a contrasting foreground. The juxtaposition of granite domes and waterfalls is unique, as is the concentration of river-related views found in Yosemite Valley.

The Merced Gorge

Descending 2,000 feet in 14 miles, the river is a continuous cascade under spectacular Sierra granite outcrops and domes. Descending from Yosemite Valley, the river becomes a continuous cascade in a narrow gorge littered by massive boulders. Arch and Elephant rocks and other landmarks rise above, all visible from the river and its banks. Canyon walls rise steeply and have many seasonal waterfalls cascading down to the river. Spring and fall bring special parades of colors, from redbuds and other plants warmly flowering in spring to big leaf maples and other trees turning bright colors in fall. Paternoster lakes are a series of glacial lakes connected by a single stream or braided stream system.

South Fork Merced River

Passing through an untrammelled forested wilderness, the South Fork Merced River forms the centerpiece of some of the Sierra's wildest scenery. The South Fork Merced River in these stretches is largely inaccessible, with just a few trail crossings above Wawona and none below it. The scenery from the river and its banks is that of an undeveloped Sierra Nevada river valley, with views dominated by forest-cloaked hills, distant peaks, and an untamed river. These are some of the wildest views possible in the Sierra Nevada.

Second, a river's designation establishes a federal reserved water right to fulfill the purposes of the designation (including water quality, the river's free flowing nature, and specific ORVs). Federal reserved rights generally set aside unappropriated water available at the time of designation, but Congress has the power to expand or contract water rights at that time. Federally reserved water rights are quantified through court proceedings and state-based adjudications. Adjudications generally occur through basin-wide processes organized through state courts, and may take many years (e.g., the Snake River Basin Adjudication (SRBA) in Idaho processed over 158,000 water right claims over 27 years). Aesthetics was included in the values protected as part of water rights adjudicated for five Idaho WSRs in the SRBA (including the Selway, Lochsa, Clearwater, Middle Fork Salmon, and Main Salmon). More information about federal reserved water rights is available from the Department of Justice: <https://www.justice.gov/enrd/federal-reserved-water-rights-and-state-law-claims..>

Other state laws or regulations

Several states have instream flow laws that define minimum flows for a long list of values, including aesthetics. The following describes six examples of state laws, regulations, and programs to illustrate the range. Several other states have similar laws and programs, but a comprehensive review is beyond the scope of this document.

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Alaska

Alaska has some of the most progressive instream flow laws (Alaska Water Use Act, 1966; AS 46.15.080). It is based on constitutional clauses that recognize water as a public resource, allow its common use, and define public water rights (Article VIII, Sections 3 and 13). An instream flow amendment to Alaska's Water Use Act in 1980 allows individuals and organizations to apply for instream flow reservations for specific values, and specifies information and analysis to be provided to the Department of Natural Resources (DNR) for adjudicating the request. In a list of ten values, aesthetics is grouped with recreation and parks purposes.

Despite being progressive and potentially wide-reaching, Alaska's instream flow law has not been widely implemented. Although agencies have submitted hundreds of applications for instream flows, there is a growing backlog; as of 2010, the state had granted just 30. Of those granted, most have been for fish resources, and all but two have been granted to State agencies (Fish and Game or DNR itself). The U.S. Fish and Wildlife Service has made 197 requests and had only one granted. BLM has made 13 requests and had one granted; BLM has requested reservations for flows for specifically defined fish, recreation, aesthetics, and other ecological values.



Alaska state law allows individuals, organizations, and agencies to reserve instream flows for aesthetics and other similar values. Falls on the Delta National Wild River.

Idaho

Idaho illustrates a more typical western-state approach to instream flow protection. Its laws and programs were developed from a combination of legislative actions, statewide water planning, and litigation (Beeman and Arment, 1988). Although the legislature recognized recreation and scenic beauty as beneficial uses of water in several laws, those values were not listed in the Idaho Constitution and it took a 1978 State Supreme Court case (Malad Canyon) to affirm them for public trust protection (Just, 1990). Additional laws and a state-wide program were later developed out of specific protection efforts for the Thousand Springs segment along the Snake River.

In general, Idaho instream flow reservations are made by a state water resource board, but such flows can be requested by other state agencies and non-governmental organizations. The broader purposes for protection are public health, safety, and welfare, with specific values including fish and wildlife habitat, aquatic life, navigation, transportation, recreation, water quality, or aesthetic beauty (Idaho Code Chapter 15, title 42). In general, the program has protected flows at minimum rather than optimal levels, with a focus on fisheries resources. There have been a few reservations for scenic resources such as springs and Upper Mesa Falls on the Henry's Fork of the Snake River.

Hawaii

Hawaii has instream flow laws that allow protection for fish, wildlife, recreational, aesthetic, scenic, or other beneficial uses, in balance with existing and potential water development. The application

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process for flow protection involves several local, state, federal, and university agencies and has been used to set minimum instream flow standards for 376 perennial streams in the state. Most work focuses on flows for ecological purposes, but recreation (e.g., swimming, nature study, and fishing) and aesthetics (scenic views, waterfalls, and tourism) are also listed values. Flow designations are supposed to consider the economic impacts of restricting out-of-stream use. Court challenges have invalidated “status quo” standards, and the state responded with more ambitious standard-setting in the mid-2000s. However, few rivers have received instream flow protection based on the new standards.

Vermont

Vermont is illustrative of an eastern state (which applies the riparian doctrine in allocating water) that has considered instream flow protection for recreation and aesthetics, offering a statute to protect the “natural flows of Vermont's rivers and streams in the public interest” (State of Vermont, 1993). The law requires the state to consider “all reasonable alternatives to altering stream flow and water conservation measures” before “reduction of the natural flow rate.” The law further requires “a comprehensive analysis of such measures” to help define “a reasoned and rational balance...between legitimate but competing users of the stream.” The laws recognize potential instream interests can include “fisheries, aesthetic qualities, recreational, and potable water supply uses,” but they also assert that “in general, minimum flows adequate to maintain fisheries interests are sufficient to simultaneously maintain acceptable aesthetic qualities and recreational uses.” We have not found any specific case where flows for aesthetic purposes have been calculated separately from those for fisheries.

California

California has a complicated history of instream flow protection, and its instream flow policies have been revised in recent years. It is illustrative of several western states (including Colorado and Montana) where ecological resources are the focus. In general, laws and policies (Water Code Section 85087, 2010) allow but do not require the state Department of Fish and Wildlife to identify minimum flows for selected streams for fish or related ecological purposes. The State Water Resources Control Board is responsible for reviewing and accepting those minimum flows for Public Trust resources. The law allows flows for stream-related recreation, although most flow protection has centered on endangered fish and frog species. Methods are generally limited to historic hydrology, wetted perimeter standards, and fish passage. These programs generally have not provided instream flow protection for recreation and aesthetics, even though scenic quality of Mono Lake was an issue in the landmark 1983 Public Trust case that partially led to the state’s administrative instream flow protection program.

Washington

Washington is a final example of a western state with robust instream flow protection statutes and regulations, although most have been targeted toward ecological values rather than recreation and aesthetics. The legal authority to set instream flows in Washington rivers emanate from several laws, including the Water Resources Act on 1971 and subsequent amendments, which set minimum water flows (Chapter 90.22 RCW) and direct watershed planning (RCW 90.82.080). The Department of Ecology (Dept. of Ecology) is granted exclusive authority to establish minimum flows for “the purposes of protecting fish, game, birds or other wildlife resources, or recreational or aesthetic values.” It has been systematically developing these “instream flow rules” in 62 geographically-defined watersheds in the state (29 have been completed as of 2016). In tandem with information about water availability in a

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watershed, the rules can help determine the extent of out-of-stream diversions or groundwater development in a basin.

Ecology's guidelines discuss several methods for assessing flow needs for ecological resources (especially fish), focusing on techniques such as Instream Flow Incremental Methodology (IFIM), toe-width, and wetted perimeter. In several cases, Dept. of Ecology has suggested fish resources act as an "indicator species" for stream health, and minimum flows that protect fish will therefore protect the entire stream. Critics have suggested that flows for fish may not be sufficient to meet recreation or aesthetic values (pending petition to amend Spokane River instream flow rules, 2016). Dept. of Ecology's instream flow guidance documents recognize user surveys as a viable approach to understanding recreation or aesthetic flow needs, but has only applied these in limited ways and only in rare cases (e.g., 401 Water Quality Certifications for Snoqualmie Falls and Spokane Falls).



Washington state regulations allow flow protection for aesthetics, but most minimum flows have been based on fishery values. Critics suggest these may not be sufficient to protect aesthetics on the Spokane River (shown at rare low flows about 700 cfs).

A progression of study options

There are often competing issues when considering alternative flow regimes, and it can be challenging to know how much effort to direct toward flow – aesthetic studies. The answer depends on several variables, including the importance of aesthetic features, the impact of possible flow changes, and the level of stakeholder interest. On rivers with several important flow-dependent aesthetic features (e.g., waterfalls or other in-channel features) or where larger flow changes are considered, **more intensive studies** that produce **higher resolution findings** will be needed to distinguish the tradeoffs of different flow regimes or the opinions of diverse stakeholders. On rivers with less important aesthetic features or smaller possible flow changes, lower resolution studies may be sufficient to identify consensus concerns.

Given such diverse situations, it is difficult to specify a single standard for a “sufficient” flow-aesthetic study. We recommend **a progressive approach** with phased efforts of increasing resolution. Any assessment should start with information about a river’s aesthetic features, their likely dependence on flows, and potential effects from water development projects. More intensive or detailed studies should then be prescribed in situations that merit them. To be effective, this approach needs 1) a clear sequential framework; 2) standardized terminology for study options; 3) agreement about which study options provide different levels of resolution; and 4) explicit decision criteria to help determine whether the assessment needs to move to the next level.

The following framework suggests three levels of resolution, with distinct study options associated with each level.

- Level 1 – “desk-top” options. This is the initial information collection and integration phase. It usually focuses on office-based methods using existing information, or limited interviews with people familiar with flows and aesthetics on the reach.
- Level 2 – limited reconnaissance options. This increases the degree of resolution through limited reconnaissance-based studies, more intensive analysis of existing information, or more extensive interviews.
- Level 3 – intensive studies. This substantially increases the degree of resolution through more intensive studies, which may include multiple flow reconnaissance, flow comparison surveys, or controlled flow studies.

This framework has been applied successfully to flow-recreation studies in FERC relicensing proceedings, and it improves studies or applications in several ways. First, it focuses resources on those river reaches with greater interest to stakeholders or with greater impacts from project operations, while reducing workloads on other reaches. This streamlines costs, and is especially useful at projects with multiple dams, powerhouses, and reaches.

Second, it provides a transparent and defensible record for all entities (e.g., licensees, stakeholder groups, and agencies) regarding the sufficiency of effort. This should lead to more efficient licensing or adjudication proceedings, and limit legal and administrative challenges.

Third, it standardizes methods and improves comparability across situations. This should improve the quality of study products and allow them to be more efficiently used in license proceedings or other decision-settings.

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Fourth, the transparency of the phased approach allows information to be shared earlier in the process, particularly across disciplines. This encourages earlier discussion of flow needs for different resources (e.g., fish, geomorphology, recreation, and aesthetics), which may help researchers design studies that address conflicts. Integrating information across resources is a major challenge in licensing proceedings; the earlier that potential conflicts are articulated, the more likely researchers can provide information about trade-offs or possible solutions.

Finally, there are efficiencies in conducting coordinated studies, particularly if controlled flow releases are part of the study design. Although it is beyond the scope of this report, there are benefits of using this progressive approach with recreation, fisheries, or other resource studies too, with parallel work at the desk-top, initial reconnaissance, and intensive study levels. It is common for such work to occur during similar time frames in FERC processes, but explicit coordination to reduce costs and encourage inter-disciplinary exchanges is less likely.

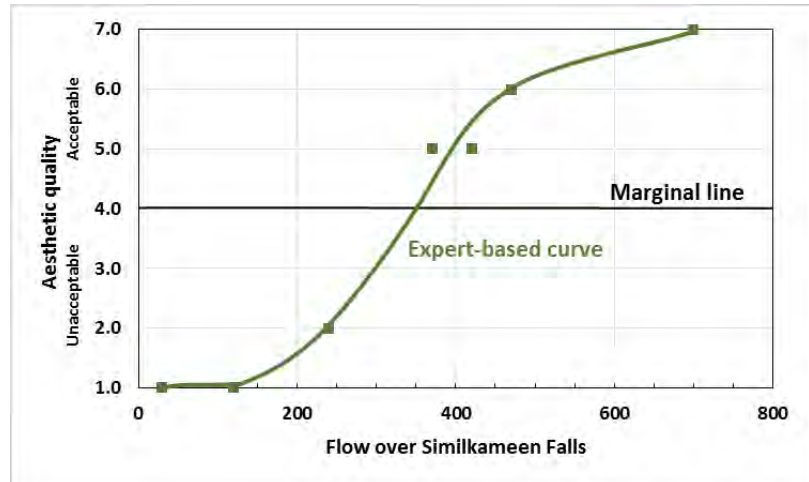
4. A review of study methods

This chapter reviews seven methods that can be used to evaluate the aesthetics of flows in rivers or waterfalls. For each, we review the objective, the typical approach, the output, and keys to success. Some assessments involve more than one method to verify or triangulate results.

Regardless of the method, the goal is to develop flow evaluation curves showing the overall effect on aesthetics through a range of flows (as discussed on page 52). These curves make evaluations explicit and transparent, and become a focal point for discussions about agreement, disagreement, and enhancement or mitigation actions.

They also help identify tradeoffs between aesthetics and other resources such as fish habitat and power generation.

Flow evaluation curves are based on several kinds of information, and many assessments use more than one method. For example, a curve may be calculated from quantitative survey data collected from different groups, or developed from experts' ratings that considered historical photos, photos taken systematically through the natural flow range, simulations of unobservable flows, and site visits (as in the example at the right).



Flow evaluation curves for Similkameen Falls, Washington from expert evaluations pieced together from historical photos, recent photos, simulations of lower-than-natural flows, and limited site visits.

The seven methods are distinguished by findings based on:

- Historical photos
- Systematic photography through a range of flows
- Physical characteristics in cross-sections
- Simulating “unobservable” flows
- Expert evaluations
- Survey-based evaluations
- Hydrologic modeling and other desktop methods

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Historical photos

Water resource development (e.g., dams, reservoirs, or diversions) may have substantially modified flows in a river or over a falls, and operational constraints may limit the ability to provide a range of flows to evaluate. In these cases, a review of historical photos may help show how a river looked before development. For new project proposals, developing a series of historical and current photos should be a standard step to document the range of existing conditions.

Objective:	Describe aesthetic features in a river segment or waterfall through a range of flows.
Typical approach	• Assemble photos of the river or waterfall with different amounts of flow. • Search for hydrology information to associate flows with the photos. • Array photos from lower to higher flows; identify features that change. • Summarize descriptive changes for consideration in making evaluations about aesthetic differences. • An array of photos may offer opportunities for public or stakeholder evaluations.
Product	Array of photos, descriptions of features that change through the flow range, (possibly) evaluations by experts, stakeholders, etc.
Keys to success	• Matching present-day photos from key observation points (KOPs) to historical photos can make both more relevant. • Historical photos may help develop simulations of flows for which photos are unavailable (such as very low or high flows). Cropping and Photoshop corrections that control extraneous factors (e.g., adjust tint, saturation, or contrast) may aid comparisons. • This method is important for documentation; developing a complete set of photos of aesthetic features through the full range of flows is a fundamental study need. • Historical photos sometimes provide little more than general descriptive information, may be taken from the “wrong” angles for study purposes, and may be difficult to associate with specific dates (and flows).
Examples	Similkameen River, WA 401 water quality certification hearing, where historical photos of a dam and waterfall from an earlier project provided the only evidence of near-dry conditions (that no longer occur).

Systematic photography through a range of flows

Visual information (still photos or video) about river features through a range of flows is central to most flow-aesthetic studies. In many cases, flows vary throughout a year, so it is possible to take visuals at appropriate intervals. The system may be natural or regulated and more or less predictable, but the goal is to capitalize on existing variation in flows to document the range of conditions. A discussion section on “Choosing key observation points and taking photos/video” is included in chapter 8.

Objective:	Develop visual media of aesthetic features through a range of flows.
Typical approach	• Determine key aesthetic features (e.g., waterfalls, rapids, in-channel geologic features). • Identify a limited number of key observation points (KOPs) and develop instructions for taking repeatable photos or video from each KOP. • Identify range of flow variation and assess predictability of flows throughout a year (or shorter time period). • Identify target flows to document, usually at evenly-spaced increments through a defined flow range (such as the typical natural range or a constrained range based on Project parameters). • Set up a schedule to take photos at the target flows. This might be calendar-based for rivers with predictable hydrology, but more opportunistic otherwise. • Array photos/video from lower to higher flows, and identify features that change. • Summarize descriptive changes for evaluating aesthetic differences. • An appropriate array of photos may offer opportunities for expert or panel-based evaluations (see below).
Product	Descriptions of features that change through the flow range, with a corresponding set of visual media.
Keys to success	• Choosing the appropriate number and locations of KOPs is critical (see discussion on KOPS in chapter 8). It generally makes sense to document from a surplus of KOPs, because some may not be usable for a variety of reasons (e.g., lack of differentiated features, challenging photographic problems, poor coverage, etc.). • Target flows are usually evenly-spaced through the flow range, although closer attention to a subset of flows is sometimes warranted (e.g., specific flows from a hydropower operating regime). • Increments between flows should be large enough to present noticeable differences in aesthetics. As a rule of thumb, we have found that changes of less than 20% may be difficult to distinguish, although

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the low end of the range or waterfalls with complex features may require smaller increments.

- The number of target flows depends on the range and increments; there are tradeoffs between more complete coverage vs. respondent burden and data costs. In general, 4 to 7 photos per KOP is sufficient.
- Photos taken at similar times of the day help minimize effects of extraneous variables such as lighting, weather, etc. Morning and evening are generally better times for images.
- Adjustments using photo-shop may help control extraneous variables (such as tint, saturation, or contrast) when it is impossible to duplicate weather and lighting conditions through the range.
- If a river is in cold-weather climates, winter photos with ice formations may be important.
- Taking photos is more expensive and logistically challenging in remote settings.
- Taking photos from known KOPs at target flows sounds simple, but can be surprisingly challenging. A river's typical flow range may not occur in a given study year, or can be infrequent and challenging to predict. Flows during a declining limb of the hydrograph may drop slowly, but ends of the range and flashy systems are less predictable, and photographers need to be opportunistic.
- In remote settings, high resolution automated field cameras may be employed to take photos at specified intervals (e.g., the same time every morning) to ensure coverage. Maintenance and vandalism are common challenges.
- A single photographer is more likely to collect photographs using the same techniques, from the same locations, capturing the same scenic frame. If you use two or more photographers, a sample "template" photo to bring on site is helpful.
- Photographers sometimes have other duties (e.g., a ranger with law enforcement or maintenance responsibilities) that may interfere with the objective of a high-quality record.

Examples

- On the Similkameen River (WA) for a 401 water quality certification hearing, environmental groups engaged a local resident to take photos and video of two falls from five KOPs through a year, documenting eight flows from 365 cfs to 2,300 cfs.
- For a study of Upper Spokane Falls, a utility staff person photographed several falls and rapids from 26 different KOPs; the study formally evaluated 10 of these. Flows included 30 cfs (leakage) and 8 flows from 500 to 1,200 cfs. Spring flows are as high as to 20,000+ cfs, but the Project focused on effects between leakage and about 800 cfs.

Physical characteristics in cross sections

Hydrology studies show consistent relationships between flow and physical characteristics such as depth, width, velocity, or wetted channel (Leopold and Maddock, 1953; Castro and Jackson, 2001). These hydraulic geometry relationships are used to measure flow (see discussion on “Measuring flows” in chapter 8) and to understand how it affects conditions for aquatic life (e.g., certain species and life stages prefer specific depths and velocities) or recreation (e.g., depths and widths for certain craft to pass a critical riffle).

Relationships between aesthetics and physical characteristics have not received the same level of attention. But hydraulic geometry shows how flows affect depths or cover a proportion of the channel, two important aesthetic considerations. These relationships can also help with accurate channel widths at different flows for simulations (see discussion on “Simulating unobservable flows” below). Over the long term, systematic data about physical characteristics and aesthetic evaluations may lead to rule-of-thumb “standards” (e.g., “X percent coverage of a channel produces acceptable aesthetics”).

These techniques not needed if natural or regulated regimes provide opportunities to study aesthetics at the full range of flows. But for a variety of reasons, some projects require information from beyond the existing flow range.

Objective	Model relationships between flow and physical characteristics (e.g., depth, width, and velocity) in a cross section of the river.
Typical approach	• Choose a representative cross section in a river or for a waterfall. • Measure or model flows (using hydraulic geometry equations) vs. physical characteristics of the channel (e.g., depths, widths, velocities, and wetted perimeter). • Develop graphs or tables that show these relationships. • Use relationships to describe or help simulate aesthetics at the site through a range of flows (when photos are not available). • Determine if there are breakpoints in relationships (i.e., when changes in flows have large effects on characteristics). • Over the long term, associate aesthetic evaluations (using other methods) with physical characteristics to develop “rule of thumb” standards for those characteristics.
Product	Graphs/tables of flow vs. physical characteristics and associated aesthetic evaluations for specific locations (see discussion of “Channel coverage vs. aesthetic value” for several European waterfalls in chapter 8).

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Keys to success

- Little work has identified specific physical characteristics that define acceptable aesthetics, but studies suggest percent of inundated channel is likely to be important (see Example studies in chapter 7, and Channel coverage vs. aesthetic value in chapter 8).
 - Depth may be important in smaller rivers with low turbidity.
 - A measure of turbulence (such as the Froude number; see Magril et al., 2009) could be related to aesthetic judgments in cascades and deserves research attention.
 - When available, studies should report physical characteristics at flows that provide acceptable and optimal aesthetics to allow analysis of these relationships.
 - This method is currently most useful for descriptive information, or as input for other methods (e.g., simulations).
-

Simulating “unobservable” flows

Aesthetics are visual, and the best ways to assess aesthetics involve “taking a look.” But for a variety of reasons (ranging from project limitations to an imposed time frame for decision-making), sometimes that’s not possible. To assess “unobservable” flows, photographic simulations are an excellent tool. Photo simulations (sometimes labeled montages or composites) involve a variety of techniques to re-touch, combine, recompose, or edit existing visual materials (usually still images) to show more or less water than in the originals. Since the advent of computer-generated imagery (CGI) programs such as Photoshop and Photopaint, most of this work is done on computers. But a computer doesn’t magically do a good job. Useful simulations require an accurate assessment of the decision space, good visual source information, knowledge of rivers and riverbeds, technical expertise with computer programs, and artistic skill.

Objective	Represent aesthetic features in a river segment or waterfall at flows that do not occur naturally (or cannot be provided through Project manipulations).
Typical approach	• Assemble existing historical or other systematic collections of photos with different flows. • Identify the flows depicted in the existing photos. • Array photos from lower to higher flows and identify features that change. • Choose a base photo (usually the lowest-flow photo from the most important KOP) that will be manipulated for simulations. • Choose the target flows to simulate. Consider intervals similar to those between existing photos, to cover the range under consideration, and to represent the most critical decision-points. • If possible, use on-site measurements or cross-section modeling (see discussion on physical characteristics) at known flows to identify the dimensions of water surfaces and riverbed features in existing photos and estimate such widths at other flows in simulations. A grid over-lay may help with measurements and object placement in simulations. More information about software options and simulation capabilities is available from the National Agroforestry Center (http://nac.unl.edu/simulation/index.htm). • Add simulations into the array of existing photos to validate appearance of the new, bigger array. This may be an opportunity for public or stakeholder evaluations or buy-in.
Product	An array that covers the relevant range of flows from important KOPs, as needed for evaluation. The array includes one or more simulated images, along with existing photos.

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Keys to success

- Some KOP(s) are better candidates for simulations than others. For example, it is easier to simulate sites that have cross-section measurements that affect wetted channel widths or waterfall form.
- Simulations are challenging technical efforts that can be expensive. Challenges include learning and using state-of-the-art software, applying on-site or modeled measurements, and adding artistic details to realistically portray moving water. There are trade-offs between simulation quality and developing larger numbers of simulations (from more KOPs, or showing more flows).
- The array to be evaluated should show meaningful differences, given the decision setting and technical limitations. Smaller flow differences are more challenging to depict in simulations.
- The number of flows depicted in the array depends on the quality of information available, resources for collecting more, the decision environment, the feasible range of project flows, and the simulation budget. More depictions also generate costs going forward, including respondent burden and the costs of collecting, analyzing, and reporting data.
- It is more challenging to simulate flows substantially higher or lower than flows in existing photos.
- Consider collaborating with stakeholders while developing simulations to include their expertise or concerns and reduce the risk of conflict over simulation representativeness.

Examples

Photos below show simulations of 30 cfs and 120 cfs flows over a 54-foot dam and a 20-foot natural falls on the Similkameen River, WA for a 401 water quality certification hearing. The base photo was a frontal view at 360 cfs, although simulations were informed by photos from other KOPs at 265 cfs. The proposed project would produce flows of 10 to 30 cfs. The natural falls had side channels with flows of 50 cfs during fieldwork, which helped simulate 30 cfs over the main falls.



Simulated photos of 0 cfs over Enloe Dam and 365 cfs in Similkameen Falls (left) and 30 cfs over the dam and falls (right), based on historical photos, fieldwork, and limited cross-section modeling.

Expert evaluations

Daniel (2000) describes the “history of landscape quality assessment...as a contest between expert and survey/perception approaches.” Both approaches recognize that aesthetic quality involves visible (or other sensory) characteristics of the site and human evaluations of those characteristics. The expert approach assumes that a trained individual can apply universal criteria from classical models of human aesthetic judgment. Survey approaches empirically measure evaluations of relevant groups and describe statistical characteristics such as averages or levels of agreement (Lothian, 1999). It is beyond the scope of this guide to adjudicate the issues underlying these fundamentally different approaches (see Lothian, 1999; Daniel, 2000; and discussions in this guide about the Philosophical roots of aesthetics in chapter 7). For projects where aesthetics are more important or controversial, it makes sense to consider methods that go beyond the opinion of a single expert.

In general, expert approaches have been developed by governmental agencies that need to assess infrastructure or other landscape modification projects (e.g., powerlines, subdivisions, or forest harvests). Prominent systems appear to build from descriptions of landscape attributes (Litton, 1968; 1972) that became codified in specific assessment protocols developed for the BLM (1984) Forest Service (1974; 1995), and National Park Service (anticipated in 2017).

These frameworks are based on the premise that trained observers, following systematic guidelines for assessing specific elements, will produce valid and reliable evaluations of landscapes with and without a proposed project. A discussion on visual resource management approaches in chapter 7 reviews some of the common elements in these systems, which could be applied to riverscapes where flow is the independent variable.

These frameworks tend to be complex, but one could have experts apply simpler criteria to predict evaluations of the public or other user groups. For example, an expert could focus on visible channel coverage, based on an empirical principle such as “aesthetics improve the most as flows fill the bottom of the channel” (see discussion in chapter 8). An expert could also rate other correlates with aesthetics (e.g., number of plumes, sound levels, or presence of mist). Ratings could be used to produce flow evaluation curves for that expert.

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Objective(s)	Apply rating systems to landscape elements through a range of flows to develop a flow evaluation curve. Suggest flow or channel modifications that may reduce adverse impacts.
Typical approach	• Choose key observation points (KOPs) to represent important landscape perspectives. • View landscapes from KOPs on-site, or using representative photographic media through a range of flows. • Rate specific landscape elements or the overall view. Several frameworks and associated worksheets are available to help develop elements and response scales (see discussion on VRM approaches in chapter 7). • Develop qualitative descriptions of ratings and how views change through the flow range. • Develop graphs (e.g., flow evaluation curves) or tables to show changes in evaluations through the flow range.
Product	A report summarizing methods and findings. Methods should explain expert qualifications, evaluation criteria, and KOP and flow range choices. Findings should include flow evaluation curves and text explaining ratings.
Keys to success	• Several empirical studies have found substantial differences between aesthetic judgments of experts and the general public for human-built environments (Kaplan, 1982; Robinson et al., 1976), and those differences are also likely in evaluations of natural settings (Brunson and Shelby, 1992). • Few studies have assessed reliability of experts applying visual assessment systems, either across experts or for the same expert in different situations. One review suggests this is a major concern and recommends comparing experts' ratings (by calculating a reliability coefficient) when evaluations are used in litigation settings (Palmer and Hoffman, 2001). • With a single expert judgment, there is no way to assess agreement with others, so bias can be a concern. Qualitative explanations help others evaluate the expert's thinking. • It is important to establish how well field conditions or photographic media represent the landscape being assessed. • Frameworks that ask respondents to review detailed elements (e.g., color, form, line, and texture) may put too much attention on abstract cognitive assessments. Zajonc (1980) suggests that "preferences need no inferences," and recommends focusing on overall evaluations.

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Examples

- Before about 2005, FERC relicensing projects generally illustrated aesthetics at different flows, but systematic evaluations were rare. Examples include Superior Falls on the Montreal River and Bond Falls on the Middle Fork Ontonagon River, both in Michigan.
 - More recently, utilities have developed simulations of proposed infrastructure. Those have occasionally been used to develop expert-based visual assessments, or consider protection, mitigation, or enhancement choices. But these approaches typically have not been applied to flows.
 - Whittaker and Shelby developed expert judgments for aesthetics on the Shepaug River in Connecticut and waterfalls on the Similkameen River, WA as part of court cases for water rights and a water quality certificate, respectively (see examples in chapter 6 for more information).
-

Panels and survey-based evaluations

In a low-controversy situation, a single expert's opinion may be sufficient. For example, Washington Dept. of Ecology instream flow staff have routinely developed "minimum flow rules" for aesthetics based solely on their expert judgment. But in more contentious settings it makes sense to involve stakeholders, user groups, or the general public in order to represent evaluations of all relevant groups. This can take the form of smaller panels representing specific stakeholders, or larger surveys of target groups. In any case, these approaches are distinguished from expert-based methods because they collect quantitative evaluations from representative panels or samples, allowing empirical analysis of characteristics such as acceptability of or agreement about managed flow regimes.

Objective:	Evaluate aesthetics of a range of flows using representative panels or samples to produce empirical flow evaluation curves and assess the acceptability of flow regimes or mitigation options.
Typical approach	• Choose key observation points (KOPs) to represent important landscape perspectives. • Assemble panels to represent stakeholders, users groups, or the general public. • View a range of flows from KOPs on-site, or through representative photographic media. • Develop numeric ratings of specific elements or the overall view. • Develop graphs or tables that illustrate the change in evaluations through the flow range (e.g., flow evaluation curves), and support for management options. • Develop qualitative descriptions of changes and explanations through the range.
Product	A report summarizing methods and findings. Methods should discuss panel/sample development, evaluation criteria and rating items, KOP and flow range choices, and prompts for qualitative discussions. Findings should include graphs/tables of flow ratings, and text explaining ratings.
Keys to success	• Representativeness is a major issue, and studies should explicitly identify target populations such as stakeholder groups, residents, recreation users, visiting tourists, or the general public. • The precision of statistics depends on participant numbers for panels or samples as well as the homogeneity of the evaluations. • Question formats, order, and analysis strategies are important; see the extended discussion on "Conducting effective flow-aesthetic surveys" in chapter 8 for a list of considerations.

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- Panelists should evaluate flows independently before focus group discussion to reduce the potential for “group effects.”
- A good facilitator is critical to the success of post-evaluation focus groups and the collection of qualitative information.
- Differences (within or between panels) require explanations. They do not necessarily mean only one group is correct or that lack of agreement precludes conclusions about findings. Different groups may have different judgments about acceptable aesthetics. The task is to understand those differences and reconcile them with protection or mitigation objectives for a given setting.

Example

- The Upper Spokane Falls study (CH2MHill, 2010) evolved from a settlement of litigation about 401 certification. The evaluation panel of 22 stakeholders represented the utility, state and federal agencies, non-governmental organizations, and consultants for various “sides” and the utility. Based on quantitative evaluations and focus groups, there was considerable agreement about aesthetic evaluations for different flows. Focus group discussions created transparency as ratings were explained.
-

Hydrologic modeling and other desktop methods

Several modeling-based approaches use summary hydrologic characteristics of a river (such as average annual flow or average minimum flow) to estimate flow needs. These methods were developed to protect water quality or ecological values, but they were more common in the early years of instream flow protection (before about 1990). Although they have substantial shortcomings, we have included them because they are still used in some states, are often referenced in histories of flow protection, and it is usually simple to consider such “rule-of-thumb” estimates before more intensive studies are conducted.

7 Q 10 method. This is a simplified hydrologic record method defined by the lowest seven-day average flow that occurs every ten years (a historically low flow for the period of record). It is an important flow from a water quality perspective, and is used to help set EPA Clean Water Act standards (e.g., pollutants cannot exceed certain concentrations during a given 7Q10 flow). In early instream flow protection schemes, several states (e.g., Georgia, Mississippi, and Alabama) allowed water withdrawals up to this easily-calculated minimum flow. More intensive fisheries work has shown this flow rarely protects the diversity of aquatic species and life stages. As the Instream Flow Council (2004) has noted, “making such a low flow the norm is like recommending the sickest day of your life as a satisfactory level for future well-being.” However, many dam-regulated rivers provide flows lower than the natural 7Q10 flow, and this natural historic low is at least a useful benchmark. These 7Q10 flows do not specifically reference recreation or aesthetic values, but there is some intuitive utility in identifying this hydrologic minimum.

Tennant or Montana method. This instream flow protection technique was pioneered by fish biologist Don Tennant of the USFWS in the 1960s and 70s (Tennant 1973). In his travels around Montana, Wyoming, and Nebraska, Tennant systematically photographed river reaches at bridge crossings, assessed ecological health at that time, and later used gage data to calculate the percentage of mean annual flow shown in the photos. Sorting the photos into piles, he developed rule of thumb estimates for “good” (30% of mean annual flow) and “excellent to outstanding” (60%) fish habitat, and noted that flows about 10% of mean annual flow rarely covered more than half the river channel and provided only short-term survival habitat. He also claimed that the 30% and 60% estimates provide for “general recreation” and “the majority of recreation uses,” respectively.

Like the 7Q10 method, additional work has shown the Tennant method oversimplifies the relationship between flows and ecological protection, and no work has closely examined Tennant estimates of aesthetic or recreation quality. However, refinements have improved the utility of Tennant ecological estimates by addressing different types of streams, aquatic species, and life stages. In addition, many recognize the value of using simple hydrology statistics as a starting point for estimating flow needs or identifying streams needing more vs. less attention.

Variations on the Tennant Method for recreation. Adaptations of Tennant’s approach have been used to identify rule of thumb recreation flow needs. Corbett (1985) used professional judgments on several southern and mid-west rivers to develop relationships between minimum boatability in open canoes (“canoe-zero”) and mean annual flow, while researchers in South Carolina did the same for motorized jon boats on Piedmont streams. These efforts have shortcomings in their execution and focus (see Shelby and Jackson, 1991 and Whittaker et al., 1993 for details). But they show conceptual connections between hydrology, resource characteristics, and evaluations for specific purposes, and these may extend to flow-aesthetic evaluations. We expect to learn more as more intensive flow-aesthetic studies are completed.

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Objective	Apply models using existing hydrology information to develop “rule-of-thumb” estimates of minimum or optimum flows for aesthetics.
Typical approach	• Formula-based models have not been developed, but variations of Tennant’s methods might show relationships between hydrology variables (e.g., mean annual flow) and aesthetic evaluations. • Initial aesthetic evaluations used to develop these relationships might use professional judgments through more rigorous methods described in this chapter. • Regression or similar statistical analyses might be used to fit a curve to the hydrology-evaluation relationship. • Resulting formulae might be applied to other rivers of similar types or with similar features. Like Tennant’s work, these are likely to be rule-of-thumb estimates that don’t replace more detailed studies.
Product	Formula-based outputs that identify acceptable or optimal aesthetic flows from hydrology data.
Additional issues	• Little work has identified specific hydrologic variables that are related to aesthetic judgments. Mean annual flow (as used in Tennant and modified Tennant approaches) is one option, but other variables more closely related to channel size (e.g., median flow in the lowest-flow month) might be more useful. • Relationships between hydrology variables and aesthetic quality probably vary for different types of streams or aesthetic features. • Aesthetic-hydrology relationships may vary considerably for waterfalls of different types, and may need distinct formulae (similar to Corbett’s canoe-zero estimates, which varied for whitewater vs. flat water and different types of rivers).
Cautions and limitations	This approach is unlikely to replace more intensive studies on complex rivers with higher levels of controversy. But it may eventually provide rule-of-thumb estimates in simple situations where aesthetic study resources are limited, or threats to aesthetic flows are minimal.

5. Integrating aesthetics with other resource values

Aesthetics are typically one component of multi-faceted decision-making about managing flows in rivers, so it is important to consider how aesthetic studies are integrated with findings for other resources. The following adapts discussion from Whittaker et al. (2005).

True integration is not always designed into hydropower licensing or instream flow protection programs. Many flow decision-making processes include centralized tracking of diverse studies. But this generally focuses on progress in terms of schedule and budgets rather than sharing findings, discussing implications across disciplinary boundaries, or considering implications for overall decision-making.

It is possible to design specific cross-disciplinary sessions to explore how findings from one resource might fit with those from other areas. By encouraging cross-discipline terminology and comparable core data, earlier information-sharing provides opportunities for researchers to consider similar sets of outcomes. In an ideal world, each resource area has sufficient information about the effects of any flow regime; in reality, studies can address only a limited number of alternative scenarios. The challenge is developing relevant alternatives early in the process.

Early discussion among work groups also encourages a less adversarial search for “elegant solutions” that provide for multiple resources, before positions become hardened. The sooner everyone learns about the range of potential proposals, the easier it is to design studies to address the issues and clarify advantages and disadvantages.

Effective decision-making benefits from distinct roles among participants, where scientific information is developed by researchers who are not advocates. While utilities are responsible for collecting flow-aesthetic information or hiring consultants to conduct associated studies, it is important that all parties perceive those studies as unbiased. Utilities, agencies, or stakeholders then use that information to develop their interests, which may be competing or adversarial, before becoming “locked into” positions. It makes sense for utilities, agencies, and stakeholders to participate in the study process, and it is more difficult and expensive to address flaws discovered after studies are completed.

In some situations, aesthetics are compatible with other resources. Flow regimes that provide for healthy fish, riparian ecology, and high quality recreation are likely to be aesthetic too. Conversely, flows for aesthetics (e.g., weekend high flows during spring run-off over the Snake River’s Shoshone Falls) are unlikely to adversely affect fish or recreation, and may provide dynamic higher flows (if only for short periods). But such assumptions should be treated as hypotheses for research, not simply presumed.

Like some recreation flows for boating or fishing, aesthetic flows do not need to be available 24-7 or in all seasons to benefit visitors, so there may be creative ways to minimize lost power or avoid other impacts from a regulated flow regime. Studies that assess seasonal, day of week, and time of day preferences allow decision-makers to consider the tradeoffs. If aesthetic flows are provided on a short-term or irregular basis, there are creative opportunities to notify the public of their availability. USGS and National Weather Service gage information is often available in real-time, and other web-based tools such as webcams are feasible where there is power and telecommunication. The goal is to help the public experience aesthetic resources.

6. Example flow-aesthetic studies and projects

This chapter provides summaries of several flow-aesthetics studies or projects. Some are short and cover limited issues, while others offer more detailed information about the river, study, or how information was used. Collectively, they are designed to highlight interesting methods, concepts, findings, or applications of results to protect, mitigate, or enhance impacts from hydropower or other flow-changing projects. The examples are roughly ordered by the date of their earliest flow-aesthetic study or project.

Niagara Falls

Niagara River between U.S. and Canada

- Niagara Falls is the most famous falls in North America, visited by 15 million people per year. Dropping 160 to 190 feet (depending on the segment and flow), the falls has three named segments: American Falls (850 feet wide), Bridal Veil Falls (55 feet), and Horseshoe or Canadian Falls (2,200 feet).
- More than half of the natural flow is diverted around the falls. Diversions for mills began in 1853, for power in 1877. Hydropower diversions increased in the early 1900s until firm limits were set in 1950. The U.S. hydropower project licensed by FERC at Niagara is P-2216.
- Aesthetic concerns were evident to critics in the early 1900s. Geologists were commissioned to investigate “the recession of the falls” from erosion and “how far the falls could be diverted without bringing about unforeseen disasters” (Spencer, 1908). Spencer argued that “preservation of the falls is now a question of inches” and showed how small changes in stage from proposed diversions could dramatically reduce the crest line (Horseshoe Falls by about 40% and American Falls by half). He also showed that diversions from either the U.S. or Canadian side affected both falls (contrary to popular opinion) and suggested that economic benefits from tourism might outweigh those from power.
- Niagara probably had the first flow-aesthetics study. Studying photos from several locations between 155,000 and 245,000 cfs, Jones reported low flow impacts for both American Falls (a “thinly covered” crest) and Horseshoe Falls (a “broken crest line and separated streams” and a shorter crest line overall), but that mist obscured the falls at higher flows. In summary, Jones asserted “the excess of river flow above 180,000 cfs contributes little or nothing to the scenic beauty of the Falls,” and such high flows may “add materially to its destructive erosion,” the rate of recession that was occurring at the time.
- Water diverted from the falls has been regulated by international treaties since 1910, but the 1950 Niagara Treaty currently in place only requires 100,000 cfs over the falls during daylight hours in the tourist season (April 1 to September 15), and only 50,000 cfs at all other times. The excess can be used for hydroelectric power (equally split between the two countries). This is about half of the river’s natural flow (long-term hydrology suggest it averages 202,000 cfs per year, with peaks as high as 300,000 cfs). The most common amount tourists see is half the flow; in the evenings and winter, they see (or hear) about one quarter of the natural flow, both much less than Jones’ 180,000 cfs.



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- A weir used to divert water for power further exposed the channel on the flanks of Horseshoe Falls and made it less aesthetic to visitors in 1953. Subsequent improvements more evenly distributed water to the American Falls side, and removed debris from the flanks of Horseshoe Falls while building up a viewing area that reduced the crest line by 330 feet. This is probably the first major example of channel modification to improve flow-related aesthetics in a river, and illustrates a recurring generalization: “cover the bottom of the channel to provide the greatest aesthetic benefit.” In combination with reduced flows, channel modifications have reduced the length of the falls’ crest line by about 750 feet since 1900. The current situation is a more compact but evenly distributed plume.
- In 1968-69, all flow was diverted from the American Falls side to assess erosion rates and the feasibility of “cleaning up” the jumble of eroded rocks at the base of the falls. A public survey indicated that most people did not want the rocks removed, and the costs would far outweigh the benefits. But engineers decided that it was feasible and beneficial to shore-up the crest of the falls to reduce natural erosion rates.
- The Niagara hydropower plants are about five miles downstream of the falls. When hydropower removes its maximum diversion, the elevation of the “Maid of the Mist” pool below the falls drops about 15 feet.
- Hydropower generation, by removing a substantial proportion of flows over the falls, has reduced the level of erosion (currently under 1 foot per year). Even so, erosive changes in the river’s channel are likely to dry up American Falls in about 2,000 years without channel modifications (Niagara Parks, 2016).
- In June 1971, a second flow-aesthetics demonstration study increased the flow over American Falls from 8,000 cfs to about 15,000 cfs (right). A report noted “there was no doubt that the increased flow...greatly enriched the appearance, deepening the green water plunging over the crest and adding considerably to the turbulence of whitewater pouring over talus rocks” (Niagara Falls Preservation and Enhancement Report, 1971).
- The report recognized that “the beauty and the drama of the Falls depend upon the interplay and relative proportions of these [three] elements:” 1) the volume of water; 2) the “sculptural form of the talus and bedrock;” and 3) the water surface level and water’s edge of the downstream pool. Scientists considered removing talus to increase the height of the water fall, raising the downstream pool level to restore an earlier natural condition, or increasing the flow to create a deeper and more turbulent water course.



Engineers dried up the American Falls in 1969 to study erosion rates. Photo by Edwin H Schroeder.

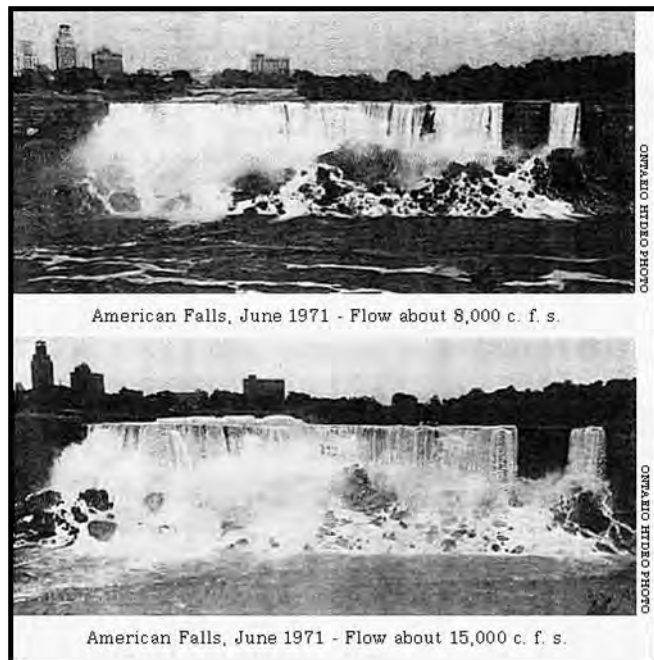


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- Scientists made a working model of the falls at a 1:50 scale, which created a falls about 22 feet wide and four feet high. To enhance the realism of the model, they used dry ice in the water to simulate blowing spray, and carefully illuminated the features for photographs at nine different levels of talus in the falls. But they couldn't duplicate the water's characteristics as well, especially opacity and level of aeration. A full set of photos were taken of each level, accompanied by narrative appraisals by experts (apparently landscape architects). In the end, the study decided not to remove any of the talus or change flows on the American side.

Kootenai Falls, Montana

Kootenai River near Libby, Montana

- This falls and associated cascades drop about 90 feet in less than a mile, with the largest drop about 30 feet high. The river is about 700 to 800 feet wide.
- The falls is one of the largest free-flowing waterfalls in the northwest with an average annual flow of about 11,000 cfs, annual peaks about 50,000 cfs, and historical peaks over 120,000 cfs.
- As described by Allen (1985) and Hooker (2014), a proposed hydropower project on the river was rejected by FERC in 1984 and affirmed in 1987 after hearings before an Administrative Law Judge (FERC, 1987). The project would have reduced late summer and fall flows in the falls to 750 cfs, "significantly reducing the amount of white water, changing and reducing the decibel level of the roar of the water, eliminating the spray, mist and rainbows permanently, exposing to view considerably more rock, eliminating the daily flow fluctuations, introducing man-made structures into an otherwise natural waterway, and, generally, making the falls less attractive to visitors."



Lower flows about 4,000 cfs in October 2007 cover much less of the falls and only the river right side of the channel.



Higher flows about 14,000 cfs in July 2013 covers most of the falls, creates a mid-channel island, and shows greater spray and power.

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Saint Anthony Falls

Mississippi River in Minneapolis, Minnesota



- Saint Anthony Falls was the only natural waterfall on the Mississippi River, but partially collapsed from erosion in 1869. Recognizing that further erosion would eventually turn the 60+ foot falls into a rapid that could not be used for water power, engineers “capped” the falls with a concrete spillway in 1870 that was incorporated in several locks and dams in the 1950s and 60s.
- With most of the water diverted into locks and penstocks for 10 months of the year, minimum flows passed over the spillway and algae growth reduced aesthetic quality of the dam face. A 1986 study explored whether “deflectors” attached to the spillway surface could create a “waterfall-like effect” and reduce algae growth.
- Experiments with the deflectors (curved metal plates about 4 inches long) were assessed at 100, 200 and 300 cfs over the 34-foot tall x 100-foot wide spillway. Observers preferred deflectors in cluster patterns (rather than evenly spaced), and aesthetics were similar at all three flows. Concern about erosion due to cavitation from the deflectors led to their removal from steeper parts of the spillway. Base flows were ultimately set at 100 cfs (shown in photo above). Since 2003, NPS has advocated for minimum flows of 200 cfs, and local advocates (including the Minneapolis Park and Recreation Board), have recommend flows as high as 2,000 cfs.
- There have been several complex plans to re-license hydropower on the river in recent years, including projects on both sides of the river. A Draft License Application was filed in fall 2016 for P-11175, with many comments about potential impacts. An aesthetic study of flows over the spillway (in response to an additional information request) was recently completed (Excel, 2016).
- The study asked respondents to rate seven flows from 100 to 2,000 cfs from three KOPs; the photos were arranged on a poster board (see right for an example from one KOP). Response options were on a four-point scale: unacceptable, marginal, acceptable, and optimum.
- The highest flow (2,000 cfs) was rated the highest, with 56% rating it the optimum flow, and another 27% reporting it acceptable.
- Majorities rated all the flows from 300 to 2,000 cfs either acceptable or optimum, and differences between 300 and 1,000 cfs were small. The uniform surface of the dam spillway may minimize differences in aesthetics through this range.
- At the low end of the flow range, 100 cfs (see photo at top of the page) was unacceptable for 41% and marginal for 15%. This flow did not produce as much whitewater, and had more algae visible.

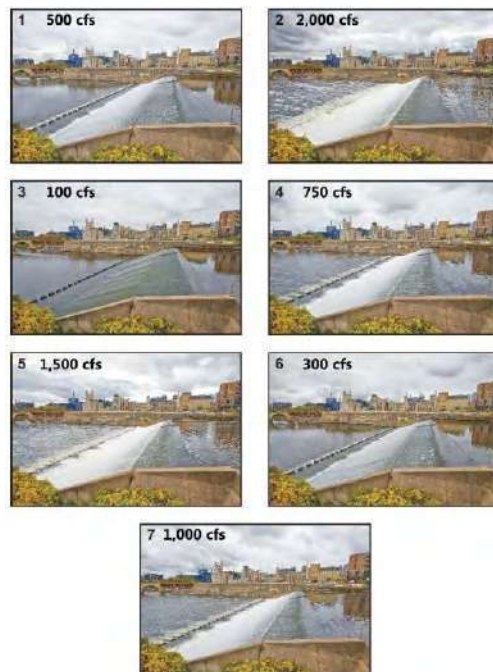


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Bond Falls

Ontonagon River near Ironwood, Michigan

- Bond Falls (50 feet, shown at 110 cfs) and Agate Falls (40 feet) are located on the Middle Branch of the Ontonagon River in Michigan's Upper Peninsula. Created by terraced sandstone, they are two of Michigan's most scenic falls.
- The Bond Falls Hydropower Project (P-1864) was built in 1952 and its initial license expired in 1988. Dam safety issues, designations in the National Wild and Scenic River System, additional studies, and settlement discussions delayed the new license until 2003.
- Minimal aesthetic studies videotaped flows in both falls at 40, 55, and 180 cfs, but did not make evaluations.
- Documentation of flows in Bond Falls included a decibel meter in the foreground quantifying sound, although the video did not record actual sound. Viewers were left to imagine the sound based on the decibel levels shown on the meter.
- Minimum flows were established at 80 to 110 cfs in different months, primarily for fisheries (Fedora, 2004). Typical natural flows were about 400 in spring and 150 during low flow periods. The license limits diversions to 175 cfs, which was less than the project had traditionally removed in order to maintain springtime flows and provide for channel maintenance.



Superior Falls

Montreal River on the Michigan/Wisconsin border

- Superior Falls is a series of drops in Montreal Canyon near the outlet of the Montreal River, which forms the border between Wisconsin and Michigan. The entire falls is over 100 feet tall, while the largest drop is 60-foot Lower Falls (shown at about 180 cfs).
- Two hydropower projects (Superior Falls P-2587 and Saxon Falls P-2610) remove most of the water in summer and fall, but in spring or after rainstorms, flows range from 500 to 2,000 cfs.
- Aesthetic flows were documented during relicensing studies in 1991; they included video of 7, 35, and 50 cfs, but did not make aesthetic evaluations. The license set minimum flows at 20 cfs.
- Current licenses that affect flows in this canyon expire in 2019 (Saxon Falls) and 2024 (Superior Falls). NPS has urged FERC to relicense both together on the 2019 timeline given interest in whitewater boating and re-consideration of aesthetic flows.



Yantic Falls

Yantic River, Connecticut



Upper Yantic Falls at approximately 20 cfs, 90 cfs, and 250 cfs.

- As described in Hooker (2014), Yantic Falls are natural and human-built falls on the 15-mile Yantic River in Connecticut. The Upper Falls flows over a 15 foot dam; the Lower Falls drops about 55 feet over natural obstacles in a 100-yard gorge. The falls are a major attraction in the city of Norwich (population 40,000).
- The gorge is an historic site where a Native American tribal leader made a great “Indian Leap” to escape a pursuing tribe.
- An historical hydroelectric project had lapsed, but a new utility applied to redevelop it in the early 1990s. The proposed Project (P-7334) would have reduced “intermediate flows” in winter and spring (usually 60 to 100 cfs) to 20 cfs. FERC initially approved the license with aesthetic flows of 100 cfs on weekends and holidays.
- During a requested rehearing, the City of Norwich argued that the small amount of power provided by the project (about one megawatt) did not justify the loss of aesthetics provided by the falls. Aesthetic features included the falls’ visual, auditory, and sensual values, as well as recognition of the river’s winter ice formations and summer mist-based rainbows at higher flows, which attracted visitors throughout the day, week, and year because of the location near the center of town. Project critics also showed that the utility’s aesthetics study failed to document preferred flows or show visitation was limited to weekends and holidays.
- FERC reversed its decision by acknowledging Norwich’s claims and further arguing that this was “one of the prime waterfall gorge combinations in the state” that had received recreation facility grants from the National Park Service, the State, and private donors (FERC, 1992).
- The case implicitly recognizes that an aesthetic feature (Upper Falls) was produced by water flowing over the human-built dam (similar to the Enloe Dam falls on Washington’s Similkameen River, described below).

Snoqualmie Falls

Snoqualmie River, Washington

- Snoqualmie Falls is 268 feet high and one of the most famous falls in the Pacific Northwest, with over 1.5 million people visiting per year.
- The river naturally averages 2,000 to 4,000 cfs most of the year, with flows under 1,000 cfs in summer and early fall. Annual peaks are typically 15,000 to 40,000 cfs, although flows have occasionally exceeded 60,000 cfs.
- The Snoqualmie Falls Hydropower Project (P- 2493), the world's first underground plant, was built in 1899, and expanded in 1919 and 1957. The current 54 megawatt project can divert 2,700 cfs through two power plants.
- A Puget Sound study in 1991 considered sound, mist, and visual evaluations of the falls at different flows, documented with still photos and video at 25, 100, 200, 450, 1,000, 1,450, 3,350 and 11,200 cfs.
- The study suggested that sound changes between 100 and 450 cfs were about 3 db and “barely perceptible.” In contrast, spray increased from “light” levels at 100 cfs to “moderate” at 200 and 300 cfs, and “heavy” at 1,000 cfs and higher.
- The study documented changes in the waterfall's form, with a single thin plume at 25 cfs, two plumes at 100 cfs, four plumes at 450 cfs, five plumes at 1,000 cfs, and six at 3,350 cfs. The plumes merge into a larger block falls at higher flows.
- The study did not include a public preference survey, although Washington Department of Ecology asked public meeting attendees to rank photos from the study, and the EIS described higher rankings for higher flows.
- A new FERC license in 2004 included minimum day time aesthetic flows from 100 to 450 cfs in different lower-flow times, with as little as 25 cfs during some night times. In general, higher flows were required for weekends and in summer high-visitation periods.
- The Snoqualmie Indian Tribe considers the falls a sacred site and asked FERC to increase flows, noting that higher natural flows create mist and spray that are central to the practice of their religion. FERC revised the license to require 1,000 cfs 24 hours per day during May and June, arguing this would provide greater mist and spray to meet the Tribe's spiritual requirements, along with general aesthetics benefits. The Tribe filed suit to get higher flows more often, but FERC eventually prevailed in the 9th Circuit Court (Snoqualmie Tribe vs. FERC, 2008).



Snoqualmie Falls at 1,200 cfs (left) and 11,000 cfs (right) before and after a major storm in fall 2016.

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Virgin River

BLM-managed segments in Utah, Arizona, and Nevada

- The Virgin River, with headwaters near Zion National Park, flows for 150 miles through Utah, Arizona, and Nevada into Lake Mead near Las Vegas.
- BLM studied flow needs for recreation and aesthetics as part of a state water rights claim in the early 1990s.
- Aesthetic video footage was collected at eight KOPs on 14 days through a season's natural flow range in 1993. Sites with channel and water visible were chosen based on access, visitation levels, aesthetic quality, and repeatability of data collection. At each KOP, video (including sound) was taken for one minute per flow. For evaluations, footage was edited into 10-second segments, with the order of flows randomized for each location.
- The study surveyed a total of 104 people in two samples, an Oregon State University forestry class (n=59) and BLM staff (n=45). They received an introduction about aesthetics and a description of the river, then evaluated river scenes using a seven-point acceptable-unacceptable scale at flows of 18, 81, 236, 697, 770, 894, 1,510 and 1,930 cfs (although not all flows were available for all KOPs).
- Findings show high ratings at all but the lowest flow (see flow evaluation curves for two KOPs, right). After the channel was covered (about 80 cfs), higher flows did not improve ratings. This was an early example of a finding that has since been seen in other places and is offered as a principle of flow-aesthetic studies (see Chapter 9).
- Findings also show differences between ratings at pools and rapids. Both improve rapidly as the channel is covered, but rapids receive slightly higher ratings at medium flows as water movement and turbulence add to aesthetic quality.
- Ratings from a clear water tributary (North Creek) were a little higher than ratings of the main stem through the entire range, suggesting that turbidity may play a part.
- The study recommended relatively low minimum aesthetic flows designed to ensure water covers the bottom of the channel at each location.



Virgin River Gorge south of St. George, Utah, at 160 cfs.

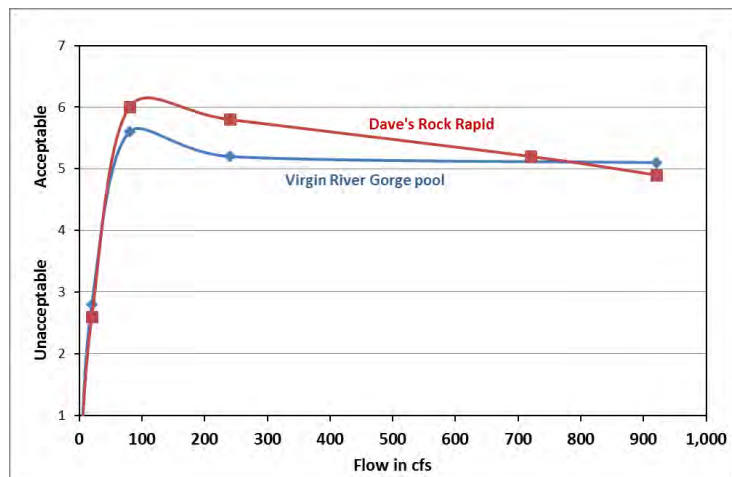


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Barberville Falls

Poesten Kill, New York



Barberville Falls at low fall flows (about 50 cfs) and higher winter flows (over 150 cfs).

- Barberville Falls is a 90-foot waterfall over slate and limestone outcroppings on the Poesten Kill, east of Albany, New York. Average flows range from 15 to 90 cfs in different months, with higher peaks.
- A utility proposed a 335 kw hydro project that would divert all but 15 cfs year-round. It did not conduct a flow-aesthetics study.
- The nearby town of Poestenkill, the Rensselaer County Environmental Council, and other non-governmental environmental organizations argued the falls were important to the identity of the village and a significant regional recreation attraction requiring higher flows that naturally vary through the year.
- FERC agreed by rejecting the utility's proposal, stating the reduction in "quality, duration, and variability of flow would affect the visual and auditory character of the falls and would degrade the quality of the vibrations generated by the naturally cascading waterfall and the mist and ice formations" (FERC, 1995).

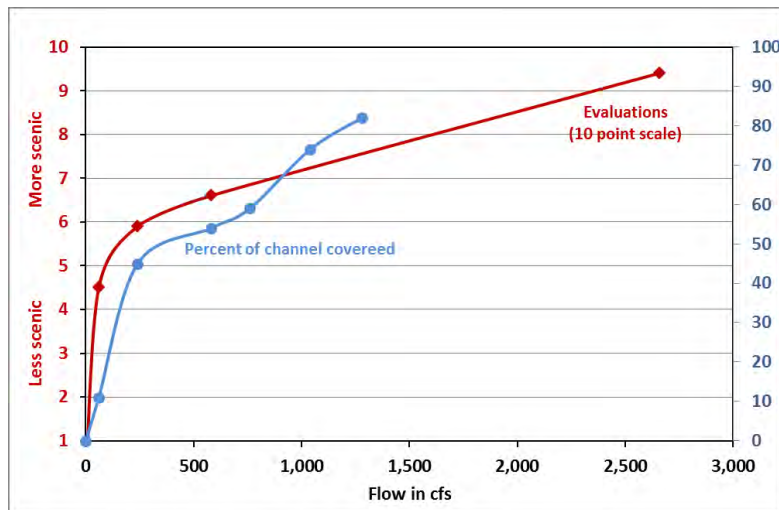
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Shoshone Falls

Snake River near Twin Falls, Idaho

- Shoshone Falls on Idaho's Snake River is 212 feet high and 950 feet wide. It has been called the "Niagara of the West."
- A tourist attraction as early as the 1860s, irrigation and hydropower development in the early 1900s reduced total river volume by about two-thirds, leaving the falls dry during low flow periods.
- Base flows after irrigation withdrawals range from about 6,000 in spring to 1,000 cfs in late summer, with runoff peaks about 20,000 cfs and record high flows about 32,000 cfs (about 10% of Niagara Falls' peak).
- There are four distinct segments at lower flows (upper right) and a block falls at higher flows (lower right).
- Idaho Power's project removes up to 950 cfs. Studies during relicensing (Idaho Power, 1996) documented aesthetics with a national sample evaluating color photos of the falls at 50, 250, 578, and 2,660 cfs using a 10-point scenic beauty scale. The study also showed the percent of channel covered from 50 to 1,200 cfs. Results are given in the figure below.
- Stakeholders requested summer flows of 750 to 1,200 cfs, while the utility recommended 300 cfs. FERC required 300 cfs during daylight hours from April through Labor Day (9 am to 8 pm).
- In 2006, Idaho Power asked FERC to increase maximum diversions from 950 to 4,800 cfs, while offering to keep aesthetic flows of 300 cfs with higher flows on holiday weekends. In 2010, discussions with local, state, and federal agencies led to a more complex regime provided higher aesthetic flows more often.
- Ultimately, Idaho Power plans a more modest diversion increase of 1,050 cfs rather than 4,800 cfs. Stakeholders and FERC are considering the impacts of this proposal in spring 2017.



Tallulah Gorge

Tallulah River, Georgia

- Tallulah Gorge is about two miles long and nearly 1,000 feet deep. Six drops collectively known as Tallulah Falls plummet 490 total feet in a mile. The gorge is a major tourist attraction, viewable from several trails and overlooks.
- Railroad access and resort hotels were developed in the late 1800s to serve tourists visiting the “Niagara of the South,” but a 1913 hydroelectric project removed most of the water from the river and tourism declined. Natural flows would be about 350 cfs in dry times of year and up to 900 cfs in spring or after storms. Typical post-dam flows were 0 to 15 cfs, except after substantial rains.
- The hydro project (P-2354) was relicensed in the mid-1990s, and aesthetic flows were a major issue. The utility documented aesthetics in the gorge at 35, 75, 100, 200, and 300 cfs from five KOPs (on the rim and in the gorge). FERC staff also reviewed aesthetics at three boating flow releases (400, 600, and 800 cfs). The aesthetics study did not develop numeric ratings, but provided qualitative descriptions of attributes, including visibility of river from the rim, apparent volume of water, width of river, exposed rock in riverbed, auditory effects, and presence of spray.
- Findings suggested that the lowest flows (35 and 75 cfs) produced minimal sound or spray, and the largest falls (Hurricane) has a single plume at 35 cfs but two at 75 cfs. Flows greater than 100 cfs begin to create falls that are more “significant features in the gorge..., with visible plunge pools and spray,” and greater coverage of the bedrock channel (FERC, 1996). Most of the falls cover the full width of the channel by 200 cfs, and attributes like spray become more noticeable. Flows at 200 and 300 cfs also appear more “dense” and covered most of the larger boulders in the channel, but flows from 400 to 800 cfs are needed to produce “explosive, powerful...and turbulent” rapids. Higher flows reduce some aesthetic features as “some rocks are drowned” and there is a “loss of contrast between riffles and pools.”
- The final license requires releases of 35 to 50 cfs base flows, with 200 cfs “aesthetic releases” during daylight hours on 18 weekend days and 9 weekdays in the spring and fall. There are 10 days of higher flows for whitewater boating and aesthetics on weekends in April and November. Georgia DNR estimates the gorge now attracts 300,000 to 600,000 visitors per year.



Shepaug River

Washington and Roxbury, Connecticut

- The Shepaug is a 26-mile tributary of the Housatonic River in Northwest Connecticut, popular for hiking, swimming, angling, and canoeing. Public access occurs at road crossings, parks, and on large properties managed by two land trusts.
- Mean annual flow is 236 cfs, with spring peaks from 500 to 800 cfs, and summer low flows of 10 to 50 cfs.
- The City of Waterbury (about 25 miles away), had a 1921 contract to divert up to 20 cfs for domestic and industrial uses when other water supplies were inadequate.
- By the mid-1990s, land trust users and residents objected to the increasing frequency of low summer flows. They argued that Waterbury's diversions diminished the river's natural beauty, harmed habitat, and decreased the quality of recreation resources, all values protected by the 1971 Connecticut Environmental Protection Act (CEPA). The ensuing controversy led to litigation, focusing on whether the river was "unreasonably impaired" and whether Waterbury was taking more water than the 1921 contract allowed. A trial in Connecticut Superior Court occurred in 1999-2000.
- Research conducted for litigation included a review of resource documents, interviews with recreation users, and fieldwork at flows of 10, 60, and 250 cfs. Findings examined effects on boating, fishing, and swimming, and photography documented changes in aesthetics at several sites. At pool and glide locations, flows as low as 10 cfs fill the bottom of the channel, so diversions would not substantially diminish aesthetics. In shallower riffles and a few rapids locations, small flow reductions had substantial effects on the width of the covered channel, and therefore diminished aesthetics.
- The judge ruled for the plaintiffs in favor of higher flows for aesthetics, noting the choices were between public interest "in the natural condition of a beautiful and nearly pristine river" and "an abundant and low cost supply of potable water." She ordered Waterbury to reduce its diversions due to "substantial diminishment" of several resources, including aesthetics. In support of her decision, she referenced expert studies (Shelby and Whittaker, 1999) that showed how the "width of the wet portion of the river" is the primary issue, and that lower flows due to Waterbury's diversions "...appreciably diminish...the appearance of the river."
- Waterbury appealed the decision to the State Supreme Court, which ruled on several issues and sent it back to the lower court for a new trial. With the cost and uncertainty of that trial looming, the two sides settled in 2006. Waterbury agreed to provide minimum flows (at 19 cfs), contingent on state funding for water system improvements. Over 3.5 million in State funds were applied to implement the agreement in 2008, and higher summer flows have occurred since 2009. A more detailed review of the case and its implications is in Whittaker and Shelby, 2010.



Shepaug River near Roxbury, Connecticut about 90 cfs.

Spokane Falls

Spokane, Washington

- The Spokane River is a major feature in the middle of Spokane, Washington. The river drops over two falls (60 feet total) and other cascades through a half mile-long park in the heart of the city.
- Historians have chronicled the city's growth in relation to the river, which provided fish resources, hydropower, recreation, and scenic quality (Olmstead and Olmstead, 1913; Young, 1996; Stratton 2005).
- The downtown river park was the site of the first environmentally-themed World's Fair in 1974. About 2.5 million visit the area each year (Avista, 2004).
- The river's natural flows range from 2,000 to 10,000 cfs in winter and spring, but drop as low as 800 to 1,000 cfs in summer and early fall. Peak flows in late spring are typically 15,000 to 35,000 cfs, occasionally exceeding 45,000 cfs.
- A private utility (Avista) operates several hydroelectric projects on the river (under one license, P-2545). Prior to 2009, hydropower diversions removed up to 2,500 cfs from the falls, dewatering the falls except for "leakage" flows (about 30 cfs) during low flow periods. Stakeholders were interested in higher minimum flows for aesthetics in the 2009 license.
- An Upper Falls flow-aesthetic study (Berger 2003) used a focus group to rank video of flows at about 30, 100, 200, 300, 400, and 500 cfs through the short bypass reach. Results showed the highest rankings for the highest flows, but recommended 200 cfs as the minimum flow.
- A review of this study (Whittaker and Shelby, 2007) suggested several methodological shortcomings, including ranking rather than Likert-scale acceptability ratings, lack of representation of user groups among the evaluators, and selective use of qualitative information to justify the lower minimum flow recommendation. The initial study did not investigate flows higher than 500 cfs, even though natural flows range from 2,000 to 8,000 much of the winter and spring (and 2,500 cfs diversions could affect them).
- After the FERC license adopted the utility's proposed 200 cfs minimum in the Upper Falls, environmental groups litigated to reverse a concurrent 401 Water Quality certification by the state Department of Ecology. Following settlement talks, a second Upper Falls flow-aesthetic study (CH2MHill, 2010) was developed as a cooperative project between the utility, environmental groups, and their consultants. It focused on low flows of 300 to 500 cfs, but also analyzed whether channel modifications could improve aesthetics by redistributing water concentrated in human-made ditches.
- A panel representing diverse stakeholders (n=22) evaluated flows and channel modifications on-site in July 2010, along with still photos of higher flows taken in spring 2010. Flows were manipulated using the diversion dam, channel modifications were manipulated with temporary sandbag weirs,

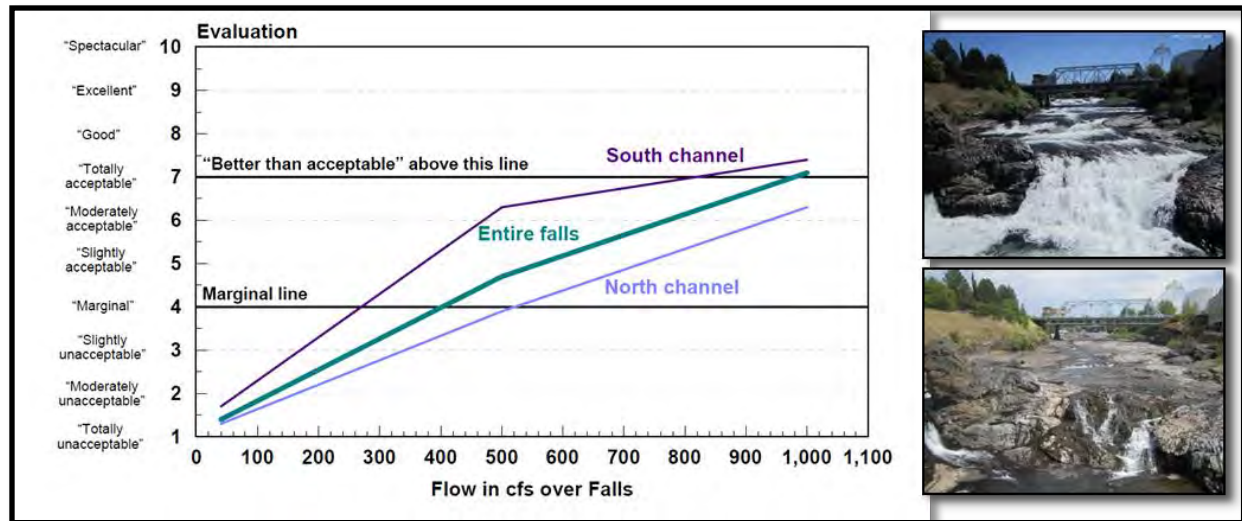


The largest drop in the South Channel of the Upper Spokane falls in downtown Spokane at 500 cfs.

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and evaluations were made with a quantitative survey from 10 key observation points. Follow-up focus group discussions provided qualitative information.



Flow evaluations in Spokane Falls from photos; example photos show 400 cfs (top) and 30 cfs (bottom) in the roughly 105 foot wide South Channel.

- Results showed that 320 cfs flows **with** channel modifications were aesthetically similar to 500 cfs **without** modifications, confirming the principle that “covering the bottom of the channel” is a major objective for improving aesthetics. Data also showed that 1,000 cfs (the highest flow evaluated) produced even higher ratings.
- Avista, state agencies, and environmental groups agreed to channel modifications in an amendment to the FERC license. The channel restoration project occurred in 2012, including several concrete weirs resembling the color and texture of natural bedrock. The weirs distributed water more evenly across the bottom of the channel, and new lower minimums of 300 cfs provide better aesthetics than 500 cfs with no modifications. Informal surveys suggest few visitors were able to identify the channel modification weirs (Avista, 2013).

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Middle Spokane River

Spokane, Washington

- Downstream of Spokane Falls, the river cuts through a 12 mile gorge with additional rapids, pools, and parks. In 2015, the Washington Department of Ecology adopted minimum instream flows for fisheries, recreation, and aesthetics (1,700 cfs October through March; 6,500 cfs April through mid-June; and 850 cfs mid-June through September). As of February 2017, environmental groups have appealed to have these minimum flows increased for fish, recreation, and aesthetics.
- Stakeholders assembled a flow-aesthetics database of photos for 37 KOPs at a range of flows in 2014-2015. Although no quantified analysis has been conducted, a review (Whittaker and Shelby, 2015) suggests they illustrate two flow-aesthetic principles:
 1. Changes in flow are more noticeable at sites with steeper gradients and boulders, and in shallow reaches with gravel bars or riffles. This is less true in pools or glides.
 2. Flows that cover the bottom of the channel are likely to be more acceptable than those which expose channel features or a “bathtub ring.”
- The report concluded that the Dept. of Ecology’s recommendation of 850 cfs in mid-to late-summer is near historic low flows, and public comments suggest this is lower than user preferences. Quantitative analysis could address these issues.



Four flows in Bowl and Pitcher rapid on the Spokane River. Photos of different flows were systematically collected at 37 locations along the river.

Similkameen Falls

Similkameen River near Oroville, WA

- The 122-mile Similkameen River runs south through British Columbia, crossing into the United States for 25 miles, before joining the Okanogan River, a tributary to the Columbia.
- Mean annual flow is 2,300 cfs, but runoff from March to June averages 8,000 cfs and peaks between 15,000 and 30,000 cfs. Late summer to early winter flows are 500 to 1,000 cfs.
- Enloe Dam was built about nine miles above the Okanogan. The dam diverted up to 1,000 cfs into a 3 megawatt powerhouse from 1922 to 1958. But for the last 58 years, the entire flow of the river has passed over the 54-foot Dam Falls and the natural 20-foot Similkameen Falls downstream.
- Public Utility District No. 1 of Okanogan County (the District) proposed a new hydroelectric project to divert up to 1,600 cfs to a new 9 megawatt powerhouse. This would reduce flows over both Dam Falls and Similkameen Falls to 10 or 30 cfs for about 8.5 months per year. The natural median flow over the two falls in the lowest flow month (September) is 506 cfs.
- The District filed a draft FERC license application for this new project in 2008. Its proposed operations plan did not include aesthetic flows or a discussion of aesthetic impacts, prompting NPS, BLM, and state agencies to request additional information about the issue. However, the District argued against the need for these studies and FERC did not require them. By 2012, settlement discussions between the District and State agencies focused on flows for fish rather than aesthetics, and by the end of the year the State had agreed to a proposed flow regime without aesthetic flows and granted the District a 401 Water Quality Certification.
- Several environmental groups filed litigation to block 401 certification, citing failure to adequately assess flow options for recreation and aesthetics. The trial-like hearing before a three judge panel representing the State of Washington Pollution Control Hearing Board (the Board) was held in April 2013.
- For the trial, aesthetic experts were asked to assess whether the District or Ecology developed sufficient information to justify the proposed Project's aesthetic flow regime under Washington's water certification guidelines, to suggest other information or studies that could have helped with aesthetic or recreation flow decision-making, and determine if the District's minimum flow proposal would provide "reasonable assurance" that recreation and aesthetic values were protected.
- The plaintiffs' expert witness report contained several aesthetic findings that were accepted by the court in its ruling, including:
 - Flows over the dam have produced a 54-foot tall by 280-foot wide "visually impressive 'block falls' that generates considerable sound and mist at higher flows."

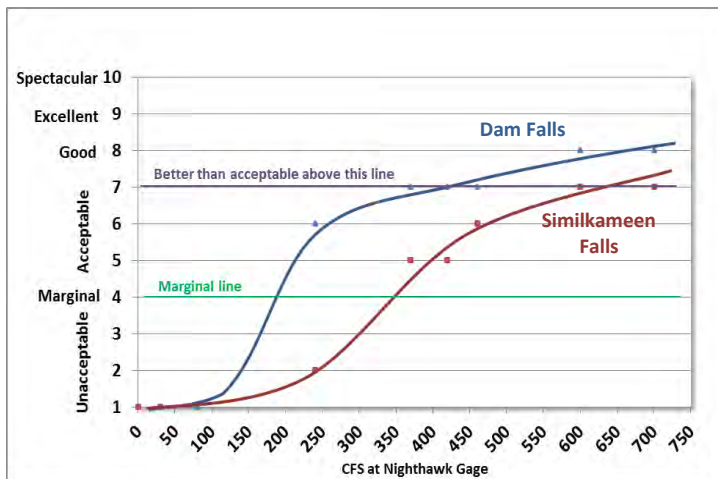


The Similkameen River flows over a 54 foot dam and 20 foot natural falls at about 700 cfs. A proposed hydro project would reduce flows to 10 to 30 cfs.

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- The proposed 10/30 cfs minimum flows would eliminate the Dam Falls and “reduce Similkameen Falls to a relative trickle, 6% or less of median dry season flows,” although it would have few aesthetic effects in the pool between the two falls.
- Both falls enhance recreation opportunities in the area, which had higher use than the District or Ecology acknowledged. Recreation investment in the region and specific recreation infrastructure in the area would induce greater recreation use.
- The District did not conduct sufficient aesthetic studies. They did not assemble photos of the falls through a range of flows, conduct direct evaluations of actual or simulated conditions, or produce a flow evaluation curve. Their modeling of proposed minimum flows was rudimentary and was not relied on by the Dept. of Ecology (which never saw it). The only District work on aesthetics produced simulations of proposed project infrastructure, which included factually incorrect depictions of flows in the spillway.
- Based on photos and simulations of different flows (developed from several sources), it was possible to develop an expert judgment curve for both falls; the District or Dept. of Ecology could have had panels of stakeholders or the general public conduct similar evaluations.
- Expert judgment curves (shown below) suggest 10 to 30 cfs flows were rated unacceptable for both falls, because they would cover only a small proportion of the bottom of the channel, provide little depth or power, and were unlikely to produce much sound or mist.
- For the Dam Falls, evaluations improve substantially through 240 cfs, where a 2006 photo shows good coverage across the entire dam and some power in the falls. Above this point, the Dam Falls does not improve as dramatically through 700 cfs (the highest flow observed during fieldwork).
- For Similkameen Falls, flows are concentrated in deeper channels and it takes more water to cover horseshoe-shaped brink. The curve shows that flows over the Falls become marginally acceptable at 350 cfs, and moderately acceptable at 450 cfs.
- The panel of judges ruled in August 2013 that aesthetic values are a “designated and beneficial use,” both falls were aesthetic features, the District had not conducted adequate aesthetic studies, and there was little evidence that the 10 – 30 cfs regime would protect aesthetics. They also recognized the District’s complaint about challenges conducting a study before the project is built (because natural flows rarely drop below 300 cfs).
- Without sufficient evidence to define minimum aesthetics flows (and assess complicated impacts on fish), the Board affirmed the state’s 401 certification, but required the District to study aesthetics of the 10 / 30 cfs regime within three years of the project’s construction. This would then be used by the Dept. of Ecology to set new minimum flows. The Board did not prescribe specific study



Expert judgment flow evaluation curves for Dam Falls and Similkameen Falls based on photos and simulations.

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methods, but suggested that it could assess actual or simulated flows and use focus group evaluations.

- The concept of a post-licensing study, as ruled in this case, is unusual and illustrates the importance of conducting flow-aesthetic studies earlier in the licensing process. Studies conducted only after the project is built may constrain the ability to provide aesthetic flows, or have impacts on other resources that cannot be mitigated. In this case, study findings are likely to suggest increased post-project low flows, which could further affect the project's overall economics. This possibility has led the District to hold meetings with agencies, stakeholders, and Tribes about abandoning the proposed project and removing the dam. However, liability and polluted sediment behind the dam are major impediments, and as of February 2017, the District still planned to construct the project.

7. Background, evaluation approaches, and classification schemes

The following discussions cover several supplemental topics that are important but tangential to the specific methods and concepts discussed earlier in this guide.

- *Distinguishing aesthetics and recreation*
- *Descriptive vs. evaluative information*
- *The philosophical roots of aesthetics*
- *Visual Resource Management (VRM) approaches*
- *Types of waterfalls and subjective waterfall evaluations*

Distinguishing aesthetics and recreation

Recreation and aesthetics are closely related concepts. People recreate outdoors to obtain psychological benefits that may include “being in nature” and “appreciating the beauty of nature.” These require settings with attractive natural features, or high quality aesthetics. For some people viewing scenery is recreation, while for others something like “scenic driving” or “scenic rafting” combines aesthetics with other activities. Aesthetics and recreation are sometimes juxtaposed in place names (e.g., Opal Creek Scenic Recreation Area); in language for protected area laws (e.g., the Wild and Scenic Rivers Act); and in research objectives (e.g., economic studies assessing recreation and aesthetic values of a park).

In this guide, ***recreation is a broader construct***. Recreation encompasses the activities people do, as well as people’s thoughts about those activities and the settings where they occur (e.g. their motivations, attitudes, and evaluations). In contrast, ***aesthetics are more narrowly focused on some of the physical attributes of the recreation setting, and people’s evaluations of those attributes***.

Both recreation experiences and aesthetic experiences are intangible, sometimes labeled “amenities,” and they are often measured by preference, acceptability, or quality scales rather than quantity or monetary scales. In recent decades, social scientists increasingly recognize complex hierarchies of human needs (e.g., Maslow, 1943; Rokeach, 1973), and recreation, aesthetics, and related values are considered central components of human life.

The fields of recreation management and leisure studies are applied disciplines within the social sciences. These fields have helped describe, evaluate, and improve recreation or aesthetic experiences for individuals and communities. They offer terminology, theoretical frameworks, and methods that organize and measure concepts such as values, value orientations, attitudes, norms, and behavior in recreation settings. Work in these disciplines also shows how resource management actions such as education programs, regulations, or facility development affect conditions, behaviors, or evaluations, creating opportunities for high quality recreation and aesthetic experiences.

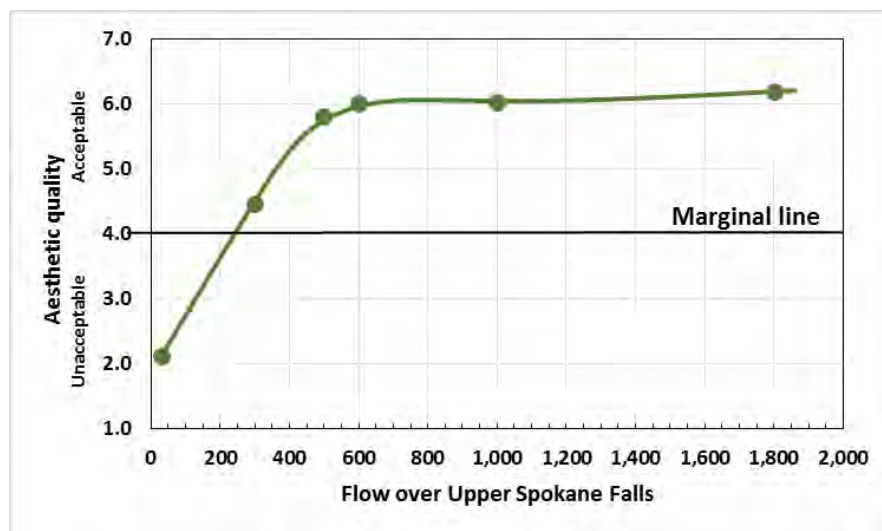
Descriptive vs. evaluative information

Considerable work has focused on how the amount and type of recreation use affects social conditions (e.g., crowding, carrying capacity, and conflict). Much of that work is based on well-established social research on values, attitudes, and norms (Manning, 2011; Shelby et al, 1996; Vaske, 2008), and it has been applied to environmental conditions such as forest practices, recreation site impacts, or flows.

This research tradition distinguishes between **descriptive** and **evaluative** components (Shelby and Heberlein, 1986). The descriptive component focuses on how management actions affect conditions (e.g., how a diversion changes flows in a river) and related attributes (e.g., channel widths, depths, or the number of plumes in a waterfall). The evaluative component focuses on specific characteristics of attributes, which attributes matter more, and preferences for different flows. This work often involves focus group or survey research, where individual evaluations are quantified and can be analyzed for different groups (e.g., statistics can describe the range of acceptable conditions, levels of agreement, or differences between groups). The same research concepts and methods can be applied to aesthetics in recreation settings.

The framework recognizes that most challenging resource decisions include value judgments. For example, **evaluative standards** (a defined level of acceptable impact) may differ for different rivers – a heavily-regulated urban river may be managed for minimally-acceptable aesthetics, while a more remote river with “outstandingly remarkable” scenery may be managed for higher quality conditions. Chapter 3 includes examples of different decision settings and associated aesthetic standards.

Considerable research suggests there are curvilinear relationships between recreation/aesthetic quality and flow, with lower flows rated less acceptable (Whittaker et al., 1993; Whittaker and Shelby, 2002). Many studies produce **flow evaluation curves** (see example below), based on quantitative data or professional judgments (Whittaker et al., 1993; Whittaker et al., 2005). Chapter 4 reviews several methods that can be used to develop flow evaluation curves, while Chapter 7 provides several examples.



Example of a flow evaluation curve for the South Channel in Upper Spokane Falls. The curve is based on average ratings of six photos from 30 to 1,800 cfs.

The philosophical roots of aesthetics

Humans have complex relationships with nature. Traditionally seen as a source of food, shelter, and commodities, natural areas also have spiritual values, and in the past 150 years have been recognized as important settings for recreation and aesthetic appreciation (Parsons, 2008). The topic of aesthetics has been studied within many disciplines, including art history, geography, sociology, and psychology, but it is particularly prominent in philosophy, which has long focused on defining beauty in art and nature. It is beyond the scope of this guide to review the entire literature on aesthetics, but several concepts provide context for this guide.

- Aesthetics is a branch of philosophy focused on the appreciation of art and beauty. The term has Greek roots that translate to "I perceive" or "I sense," and modern use dates back to German philosophers in the mid-1700s.
- Among philosophers, aesthetic judgments focus on what is beautiful vs. ugly, transcendent vs. inferior, remarkable vs. mediocre, or acceptable vs. unacceptable. The idea is to systematically assess aesthetic qualities based on recognizable dimensions. More recently, social scientists operationalize these concepts by having people rate objects on scales with descriptive labels.
- Aesthetic judgments initially considered art and architecture rather than nature, and pre-1700s art-based aesthetic principles tended to focus on proportion and symmetry. During that era, formal gardens were the only setting where natural elements received aesthetic consideration, and people generally did not tour natural areas or contemplate aesthetics in nature.
- Aesthetic conceptualizations began to change in European culture in the 18th century as part of Enlightenment-era trends, including increasing access to wild areas (e.g., the Alps), the growing popularity of landscape painting, and scientific advances revealing the complexities of nature.
- Moving beyond the classical focus on beauty defined by symmetry and proportion, philosophers identified other aesthetic concepts in nature, including the "sublime" and "picturesque." Burke (1757) distinguished characteristics of *beauty* such as smoothness, smallness, lightness, and delicacy, from the *sublime*, which he associated with vast, rugged, massive, and potentially dangerous features. Others defined the *picturesque* in terms of textures and arrangements of features, especially when irregularities, unexpected contrasts, or partially concealed features invite curiosity (Gilpin, 1782; Price, 1796). Particular settings possess one or more of these aesthetic qualities, encouraging aestheticians to extend their judgments to more dynamic natural scenes.
- Aestheticians have debated whether aesthetic judgments are objective (true for all) vs. subjective (individual to a person). Kant (1790) argued that beauty is objective and universal, and could be distinguished from "taste" that is subjective and varies according to class and culture.
- Considerable work suggests that some aesthetic principles appear stable across cultures and time periods, although others clearly vary. Dutton (2009) offered a modern theory for "universal signatures" in aesthetics based on evolutionary origins. Noting ubiquitous cross-cultural interest in idealized "postcard" landscapes that mimic environments where humans first developed (e.g., open savannahs with low grasses, broad trees, evidence of water, indications of animal life, and paths that extend into distance, beckoning exploration), he concluded that aesthetic judgments are deeply held echoes of the environments and tools that humans needed for survival.

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- Some philosophers (e.g., Burke and Hogarth) suggest that natural beauty can be reduced to lists of attributes. Others (e.g., Mill and Spencer) suggest that aesthetics should be linked to broader contexts in developing fields of biology and psychology.
- Philosophers debate whether aesthetics should reflect an understanding of the process that created the landscape. For example, does knowledge of geologic history enhance appreciation for the beauty of the canyon or the river running through it? Dewey (1934) suggests that understanding can bring value to the viewing experience, while others argue that the experience of seeing an object, not understanding the process of making it, is the aesthetic phenomenon.
- Functionalists argue that context matters, and aesthetics cannot be divorced from larger natural or human processes occurring in the landscape. They view aesthetic evaluation as a cognitive process that engages the intellect, not just sensory or emotional responses to a scene or piece of art.
- Some philosophers suggest aesthetic appreciation may follow from economic, political, or moral values (e.g., some may appreciate a golf course in a desert because it implies human mastery over nature, while others may be offended at the scale of consumption). Saito (2009) argues that such intellectual considerations (embedded in one's beliefs and attitudes) are integral to understanding modern aesthetic evaluations.
- The discipline of environmental aesthetics arose in the late 1900s as a reaction to the over-application of art-based judgments to nature appreciation. The scope of this field is wider than just natural settings; it has included the "aesthetics of ordinary life," or how humans arrange daily tasks and environments to accentuate beautiful features.
- Saito (1998) argues that information about a scene or object can be central to aesthetics. This is a partial rejection of the importance of "picturesque" scenes, suggesting appreciation of a mountain or waterfall also depends on its natural history and ecological context. Similar ideas have been expressed under Carlson's "natural environmental model" (1979) or Parson's "scientific cognitivism" (2002), where one appreciates natural scenes because they also engage the senses and intellect.
- Potential contradictions between environmentalism and environmental aesthetics have received some philosophic attention (Carlson 2010). For example, environments such as wetlands do not fit conventional definitions of scenic beauty, and aesthetic judgments may not support moral obligations to protect wetlands (Rolston, 2000; Saito, 2009). These researchers encourage an "aesthetic appreciation norm" that recognizes the order, balance, unity, and harmony of ecological communities beyond postcard scenes. Others suggest that context may allow aesthetic distinctions between "traditional scenic beauty" and ecological notions associated with "perceived care, attachment, and identity" (Gobster et al., 2007).
- Some psychologists recognize aesthetic evaluations within the framework of a "cognitive hierarchy," from the general (values and value orientations) to the specific (attitudes and norms). Rokeach (1973) recognizes "a world of beauty" as one of 36 fundamental **human values**, under which there are a hierarchy of more specific scenic beauty evaluations such as **attitudes** (Daniel and Boster, 1976) or **norms** (Jackson, 1965; Shelby et al., 1996). These constructs have cognitive and affective components (fitting with philosophy's recognition of intellectual and emotional reactions to a scene), and can be measured with psychometric scales (e.g., through survey research).
- Economists also recognize different kinds of value for intangible goods such as aesthetics. They distinguish **use value** (from experiencing aesthetic environments), **option value** (the chance to experience the scene in the future), **bequest value** (passing that chance to future generations), and **existence value** (knowing aesthetics are protected for their intrinsic value, even if no one

experiences them). Economists attach monetary metrics to these values, usually through survey-based contingent valuation methods (Mitchell and Carson, 1989; Walsh, Loomis, and Gillman, 1984).

Visual Resource Management approaches

The Bureau of Land Management (BLM) and Forest Service (FS) have established visual resource management programs, used since the mid-1980s to help protect scenic vistas from human activities. The National Park Service has recently begun developing a parallel program to address issues on its lands. It is beyond the scope of this guide to summarize these programs, but some key concepts and steps are described below for the BLM system (which is reasonably representative of the others). Additional details (including agency differences) are available in linked webpages developed by BLM at <http://blmwyomingvisual.anl.gov/vr-overview/>.

Visual Resource Management or VRM (BLM)

The VRM process is summarized below (for more information, see BLM Manual 8400).

- Inventory scenic values (Visual Resource Inventory or VRI)
- Classify visual management objectives (VRM classes)
- Evaluate proposed activities' impacts and consistency with objectives (Visual Contrast Rating or VCR)
- Mitigate to "avoid, reduce, or compensate for impacts" (Visual Impact Mitigation or VIM)
- Monitor visual impacts
- Update VRI as necessary

VRIs have three major elements:

- **Scenic Quality Rating.** Raters assess texture, color, line and form in the landscape and develop a 1 to 5 rating for landform, vegetation, water, color, adjacent scenery, and cultural modifications. Total scores are delineated by three grades (A, B, or C) associated with a map (dividing the landscape into Scenic Quality Rating Units).
- **Sensitivity Level Analysis.** Raters choose between low, medium, and high scores for the type of users, amount of use, public interest, adjacent land uses, and special area designations.
- **Distance Zones.** Classify distances from which the landscape will be viewed. Foreground/middle ground is 0 to 5 miles; background is 5 to 15 miles; "seldom seen" is beyond 15 miles.

VRM classes range from I to IV. Class I is most pristine and requires greater protection. Class IV allows more human-caused change in the landscape.

VCRs assess visual impacts and determine whether they conform to VRM class objectives. Allowing unacceptable impact requires mitigation.

VIM is the process of altering a project to reduce, eliminate or compensate for visual impacts.

Types of waterfalls and subjective waterfall evaluations

Waterfall guidebook authors have developed classification or evaluation systems to categorize waterfalls or quantify their characteristics. It is beyond the scope of this document to review each system, but it is useful to describe some common characteristics.

Geometric classifications

Classification systems are generally based on geometric shapes of waterfalls; Plumb's (1993) system is a good example, and variations have been adopted by "waterfall database" websites. The shapes are listed below; many falls have different shapes in different parts of the falls. Knowing a waterfall's type helps describe what is there and what it could be. Some waterfalls transform with different flows, and increments of flow may affect them differently. Because of these complexities, flow effects are difficult to predict and should be assessed on a case-by-case basis.



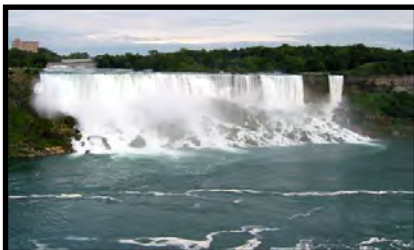
Plunge falls. Falls that drop vertically without touching an underlying cliff face, perhaps allowing visitors to walk behind the plume. Snoqualmie Falls is an example (left).

Horsetail falls. Falls that spread out from wind or contact with a steep slope, creating a shape that resembles a horse's tail. Upper Yosemite Falls is an example (right).



Fan falls. Similar to a horsetail falls, but with a wider distribution of flow across a cliff face. Smith Falls near Nebraska's Niobrara River is an example (left).

Punchbowl falls. Narrower plunge falls that drop into a larger, usually circular pool. Punchbowl Falls on Oregon's Eagle Creek is an example (right).

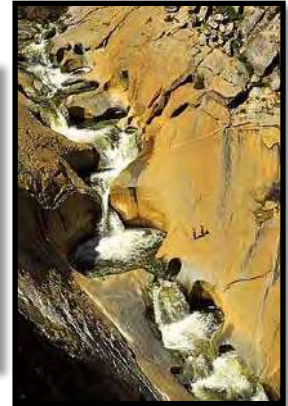


Block falls. Largely rectangular shape, with width often greater than height. The American Falls side of Niagara Falls is an example (left).

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Tiered or stair-step falls. Falls with multiple vertical steps. They are common in limestone (Pha Charoen waterfall in northwest Thailand, right), but may occur in other geologic settings (Seven Teacups in Sequoia National Forest, far right).



Segmented falls. Falls with multiple plumes or threads down the face of a cliff, usually split by protruding rocks or vegetation. Fan, block, or stair-step falls may be segmented; conversely, the different plumes in a segmented falls can have diverse shapes, like these in Plitvice Lake National Park, Croatia (left).

Cascades. Falls that descend along a slope rather than in vertical drops. Cascades along a smooth slope are sometimes further categorized as slides. Firehole Cascades in Yellowstone National Park is an example (right).



Ribbon falls. Very narrow falls, these are the converse of block falls with much greater heights than widths. Oneonta Falls in Columbia Gorge is an example (left).

Evaluation / classification systems

Several metrics can be used to compare waterfalls, including total height, tallest single drop, number of drops, average flow, maximum flow, or visible volume. Rather than rely on a single metric, some guidebook authors develop equations combining several variables into one score, or combine those scores with other evaluative ratings to represent overall “visual impact.” Three prominent rating systems are described below.

- **Visual magnitude and absolute magnitude.** Plumb (1993) was the first to combine several variables into a single score. His “visual magnitude” score is calculated by the log-scaled product of a waterfall’s height and width, multiplied by the waterfall’s slope and average flow. Logarithmic scores are non-linear (e.g., 90 is ten times greater than 80), and this formula rates height and width more favorably than flow. An alternative version he calls “absolute magnitude” uses maximum width and flow rather than averages. Both scores are reported for many waterfalls in the “world waterfall database” (2016); examples include Niagara Falls (238), Shoshone Falls (132), Snoqualmie Falls (80), and Yosemite Falls (70).
- **International Waterfall Classification System (IWC).** Beisel (2006) developed a 10-point scale where ratings are rounded up to the nearest integer. The rating is the natural logarithm of water volume present at a given time (which is the product of flow and the time it takes for water to travel from the top to the bottom). The system rates high-volume, sloped waterfalls more favorably than low-volume, vertical waterfalls. The world waterfall database includes these scores for many falls.
- **World Waterfall Database System (WWD).** This web-based rating system combines magnitude and IWC ratings with other variables, creating a single score between 1 and 100. Magnitude provides 50% of the potential points and IWC ratings 10% more; remaining points are awarded for “visibility” (10%); “surrounding development” (10%); and “subjective rating” (evaluations from the database authors, 20%). The database also compares resulting scores to others for the state, country, and world (e.g., Shoshone Falls is rated 100% in Idaho, 94% in the USA, and 48% in the world). See worldwaterfalldatabase.com for examples.
- **Other subjective ratings.** Several other websites or guidebooks have developed their own subjective ratings (e.g., assigning 1 to 5 stars). These are generally region-specific and provide less detail. Hudson’s (2000) essay on “the experience of waterfalls” reviews several other qualitative ways of describing or assessing waterfalls, including 1) distinctions between “beautiful,” “sublime,” and “picturesque;” 2) “arousal theory” assessments that contrast low and high stimuli from landscape elements; 3) “prospect-refuge theory” assessments that consider whether a landscape appears capable of providing food or shelter for primitive humans; and 4) “tourist gaze” assessments that consider how the falls and surrounding landscape may attract tourism.

These systems include measurements and calculations that give the appearance of objectivity, precision, and scientific expertise. But all of them make assumptions about the relative importance of different dimensions, and differences between systems suggest there is little consensus about which dimensions are most important. Ratings that combine outputs from several systems, or add subjective variables to create new scores, further complicate these issues. Results are broad indicators rather than precise measures of a waterfall’s overall scenic quality or importance, although they may help a waterfall viewer choose among alternative destinations, or add to discussions comparing one falls to another.

8. Conducting flow-aesthetic studies

The following discussions cover additional topics related to technical aspects of conducting flow-aesthetic studies, including:

- *Collaboration with stakeholders and the public*
- *Measuring flows and using gage information*
- *Choosing key observation points*
- *Conducting successful surveys*
- *Channel coverage vs. aesthetic values*

Collaboration with stakeholders and the public

Aesthetic flow studies generally mean that stakeholders (agencies, NGOs, user or interest groups, visitors, or the general public) are concerned about the effects of flow changes on aesthetic features. In some cases, researchers or other experts may be able to incorporate these concerns into a study without direct consultation. In most cases, however, stakeholders may encourage a collaborative approach where diverse stakeholders can help develop studies, participate in them, and review findings. These higher-involvement processes are more complex, but they give all parties more confidence in a study, and provide opportunities to discuss and possibly resolve operational or mitigation choices.

It is beyond the scope of this discussion to review all the benefits of collaboration during a study or subsequent settlement discussions, but they may include the following.

- Developing or reviewing study objectives
- Suggesting or reviewing study protocols (e.g., sample goals, Key Observation Points (KOPs), flow targets)
- Pre-testing survey instruments
- Participating on study evaluation panels or in survey samples
- Reviewing study results and draft report conclusions
- Considering project operation or mitigation choices

Collaboration can help improve the quality of studies by ensuring that diverse viewpoints are represented. It also helps establish working relationships among diverse stakeholders that will consider study results and the protection, mitigation, or enhancement options that might address impacts.

There are several things to consider during collaboration. Stakeholders usually do not possess research skills or experience, which limits their suggestions regarding study objectives or methods, and may require education or other assistance to make their contributions more successful. Care is needed to address the representativeness of panels or samples that include advocates from stakeholder groups, and collaboration usually requires more time and effort as suggestions are solicited, considered, and addressed.

Measuring flows and using gage information

Flow (in a river or waterfall) is a central issue in flow-aesthetics research, and practitioners should understand how it is measured and represented. We have summarized basic principles and potential issues below. More information about this complex topic is available in Herschy (1995) and the USGS website <http://water.usgs.gov/edu/measureflow.html>.

- Flow (also known as discharge and often represented by the letter Q) is the quantity of water passing a specific location on a river.
- Flow is calculated at a given location by measuring a cross-section. Measurements of width (in feet) and depth (also in feet) are used to calculate the area of water through the cross-section (in square feet). This is multiplied by the water velocity (in feet per second), resulting in a volume of water passing that location (in cubic feet per second, or cfs). Metric measurement uses the same strategy but produces results in cubic meters per second, or cumecs.
- Measurements have traditionally been conducted roughly as described below, although variations occur depending on locations and available equipment.
 - A cross section is established by a line across the river, perpendicular to the current. The river should be relatively straight and clear of mid-channel obstacles that might create eddies.
 - Traditionally, widths are measured with a tape or marked line, depths with surveying equipment such as a stadia rod and transit level (increasingly assisted by electronic instruments).
 - Velocities can be measured with mechanical current meters (e.g., Price AA meter) that count rotations of a propeller or wheel of cups, or by electro-magnetic meters (e.g., a Marsh-McBirney meter) that measure voltage from particles in the river as they pass by the meter's magnetic field. Velocities are typically measured at about 60% of the total depth (roughly an average, velocities are higher on the surface and lower close to the bottom).
 - Mechanical discharge methods are more challenging in deeper rivers with fast velocities because they require holding stadia rods and meters against the current while wading or using a boat.
- Flows are increasingly measured using a new technology, an Acoustic Doppler Current Profiler (ADCP), which uses GPS and sound pulses to measure widths, depths, and velocities. These measurements are usually quicker and more accurate (Hirsch and Costa, 2004), although there are some limitations in shallow or high sediment streams.
- Cross sectional measurements provide an instantaneous flow for a given location, and that flow can be associated with a stage height (depth read from a staff gage fastened in the water, or the water surface elevation relative to a benchmark measured with survey equipment).
- With enough flows and stage heights measured for a location, a ***stage-discharge relationship*** (also called a rating table) can be developed to allow easy conversions.
- Stage heights are indexed to a specific staff gage or benchmark for a specific location, and are not directly comparable to stages at other locations. For example, 2.0 feet on the Middle Fork Salmon at Middle Fork Lodge is not equivalent to 2.0 feet at Corn Creek on the Main Salmon. Similarly, 2.0 feet on the Middle Fork Salmon is not twice as much water as 4.0 feet at the same gage. To maximize comparability, we encourage reporting flows in cfs rather than stage height.

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- Stage-discharge relationships are important for most gaging stations, where stage is measured more frequently (because it is easier) and then converted into estimated flow (based on the rating table for the gage at that location). The USGS operates over 7,000 gages in U.S. rivers; most are available in real-time through the National Water Information Service at <http://waterdata.usgs.gov/nwis/>. The National Weather Service (NWS) River Forecast Center operates about 8,000 gages (some may overlap with USGS sites), with greater focus on stage heights and flood hazards.
- The USGS and NWS provide **historical data** and statistics for most of their gages. This allows characterizing the river at that site in terms such as mean, median, and exceedance flows during specified periods. Accuracy depends on the period of record (which can range from a few years to over a hundred years, and may be continuous or interrupted by lapses for a variety of reasons).
- Gaging stations are typically located at places good for measuring flows, either because of access, or proximity to important locations such as towns or important tributaries. Bridges are common gage sites, especially on larger rivers where the bridge obviates wading or using a boat. The increasing use of ADCPs and automated uploading of data to satellites will probably give greater flexibility in choosing gage sites in the future.
- There may be few gages on a river, and existing gages may be distant from the location of a flow-aesthetic study. Hydrologists can usually “adjust” flows from a gage site to flows at the study site by accounting for basin area contributions from groundwater, runoff, or tributaries. These analyses have larger margins of error when the gage is distant and the system is less stable.

Choosing key observation points and taking photos/video

Choosing key observation points (KOPs) and composing photographs are critical steps in a flow-aesthetic study. The overall goal is to choose a manageable number of views to evaluate, while ensuring they reasonably represent the landscapes people see when visiting a river or falls. This process includes both art and science, but we have identified several considerations.

Number of KOPs. The number of KOPs depends on the diversity of features affected by flow and the number of views accessible to visitors. More complex places generally require more KOPs. The tradeoff is that too many KOPs will increase cost of documentation, respondent burden, analysis effort, and complexity of findings. In general, it is better to err on the side of “too many” KOPs until all the photos have been collected; one can then choose a smaller “best of” set to be evaluated. For the Spokane Falls study, which has two channels, a dozen cascades, and several overlooks, we developed 25 KOPs but eventually evaluated only 10.

Labeling KOPs. More than one view may be taken from some KOPs (e.g., framing different elements from different perspectives). To avoid confusion, assign each view a distinct KOP number and label.

Perspectives. Rivers bend and waterfalls often have multiple elements that look different from different perspectives. In choosing KOPs, identify “classic” views that highlight landscape elements that attract the visitor’s eye. This may be an oblique view from an overlook or a canyon rim, or a view from river level, looking upstream, downstream, or directly across a cascade or pool.

In general, oblique views show the depth and dynamism of riverscapes, and frontal views taken from river level may appear flat. However, frontal views are useful as base flows for simulations because they allow use of hydraulic geometry measurements (which are harder to apply to an oblique perspective).

Zoom vs. wide angle. A major decision is whether to use telephoto or wide angle framing from the KOP. Some urge use of 50 mm lenses, the focal length they argue is “closest to the human eye.” Our experiences suggest greater flexibility; the human eye mimics different focal lengths, and the human brain can concentrate on specific features in the landscape. A 28 to 35 mm wide angle lens may help represent close-up details (e.g., an oblique angle of a falls from the water’s edge that includes more foreground). In contrast, a telephoto lens can compress several features such as a tiered cascade. In general, the principle is to represent the features that draw a visitor’s eye.

Designated, popular, vs. unique viewing areas. In general, KOPs should be located at viewpoints that people can use in a landscape, often identified by facilities (e.g., the middle of a footbridge, the end of a designated trail). But sometimes there are important views from less commonly-used areas. On Washington’s Similkameen River, a diagonal view from a point across the river from the most popular access best showed the falls’ segmented horseshoe-shape.

Choosing KOPs cooperatively. There are benefits to developing KOPs in cooperation with stakeholders or representatives from different agencies because this fosters agreement about important views and related study protocols. This may be less efficient in the short run due to the larger number of opinions to consider (see discussion about collaboration).

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Repeatability. Choose KOPs that have reasonable access and space to set up equipment. The goal is the same photo composition at each flow.

Still photos vs. video. Video captures movement and sound that may be important parts of dynamic environments like river cascades. However, collecting, editing, and presenting video clips for evaluations is more labor-intensive, expensive, and complicated than using still photos. Video is also difficult to convey in written reports, which are still the standard for most environmental impact analyses. If you use video, documentation with high quality still photos is a good idea for reports.

Sound. Some researchers consider sound an important component of waterfalls, and video can capture acoustic variation at different flows (Hetherington, Daniel, and Brown, 1993). However, weather and onsite conditions (e.g., wind) can have dramatic effects on the volume and clarity of sound from a water feature. If sound is to be accurately represented, sophisticated recording and reproduction tools (e.g., directional microphones and a full sound reproduction system) may be needed.

Composition. This is a complex topic, but frequently repeated landscape photography principles include the following.

- The “rule of thirds” suggests that more interesting photos consider arrangement around lines that divide the frame into nine roughly equal parts.
- Water generally appears more dynamic in photos where it travels diagonally across the frame, or disappears into a horizon line.
- Consider having at least one focal point in the photo.
- Consider including an interesting foreground or framing element (e.g., riparian vegetation, large wood, or dramatic rocks).
- Pay attention to horizon lines (e.g., bends may not produce horizontal lines, but the photo may look “off” if they are not horizontal).

Other technical issues. There are several commonly-discussed technical suggestions for photographing moving water.

- Use a tripod for a steady camera and to enhance repeatability of framing.
- Slow shutter speeds (e.g. 1/10 to 5 seconds) can blur or smooth falls and produce a “ghosting” effect that indicates motion. But this can be challenging to execute, and may give a misleading impression of actual current velocities.
- Slower speeds are good for artistic depictions, while scientific depictions benefit from higher shutter speeds (usually 1/250 or faster) that stop the action and show details of moving water.
- A smaller aperture (higher f-stop) provides greater depth of field (background and foreground both in focus).
- A camera’s base ISO (the sensitivity of a camera’s image sensor, usually 100 or 200) retains the most detail and produces the highest quality images. Higher ISO settings can be used in low light situations or to get slower shutter speeds (to show moving water), but will add grain to the image.
- Consider polarizing or UV filters to maintain color saturation in challenging light conditions.
- Overexposure is a common problem with photos/video of water. Water bounces a lot of light which can challenge camera metering devices, especially with contrasting dark features such as rocks, vegetation, or shadows in the photo.
- Morning and evening “magic light” produces dramatic low-angle shadows and reflections with less opportunity for overexposure. However, it can be challenging to take all the photos in a series of flows with the same low-angle light.

Conducting successful flow-aesthetic surveys

Survey research is a complex social science specialty, with many issues that have received considerable research attention. It is beyond the scope of this document to provide a review, but a good summary is available in Vaske (2008). Common issues in flow-aesthetic studies are highlighted below; these are not guidelines for conducting studies, but can help with reviews of study plans or studies. As in any field, it takes trained and experienced scientists to effectively address all the issues.

Survey modes. Surveys can be conducted in-person, by mail, online, or by phone. In-person contacts allow presentations of visuals or other information, more options for evaluations, and facilitated group discussion. Mail or online surveys allow distribution to larger samples, often at lower per-respondent cost. Phone surveys are impractical for presenting visuals.

High quality photography. It seems obvious that an aesthetics study should use high quality visual media, but many have settled for less-than-stellar photos or video. Composition and exposure are common problems with original images (see previous discussion). Reproducing visuals (in paper or online surveys) or presenting them in-person are also important. For example, poor projection equipment or a room that can't be darkened will degrade even the best photos or video.

Sizes of panels or survey samples. How many evaluators do you need? This perennially challenging research question can be answered with great certainty: "it depends." Small panels of 5 to 10 participants may be sufficient if the situation is simple, stakeholders are well-represented, and evaluations show high levels of agreement. But panels of 20 to 40 may be needed to represent complex situations, contentious issues, or diverse stakeholders. Typical survey sample sizes exceed 30 for basic statistics and 100-200 for more complex analyses or greater precision. Sample sizes around 400 typically produce a margin of error of +5% at the 95% confidence level, a commonly-cited sampling goal (Vaske, 2008).

Respondent burden. Surveys with complicated instructions, uninteresting issues, long completion times, or questions respondents can't answer increase "respondent burden" (also known as "response burden," due to effects on response rates). Too much burden leads people to answer incorrectly, skip questions, or terminate the survey. For aesthetics studies, evaluating photo after photo can become tedious, particularly with several evaluative dimensions (e.g., multiple flows and KOPs) or fine distinctions within dimensions. In general, 30 to 60 views in a session do not appear to cause substantial problems, but Daniel and Boster (1976) suggest that only very committed panels will take on 100 evaluations per session.

Opening questions. First impressions are important in surveys, so opening questions should be interesting and easy to answer. For example, experience visiting the river/falls in question and recreation activity preferences are good "ice-breakers" before starting the formal photo evaluations. Less interesting socio-demographic questions, if necessary, are best left to the end.

Evaluation formats. There are several options for evaluating photos/video of flows. The most common approach is to rate each item using response scales, but other approaches have respondents rank photos, or choose preferred views in a series of side-by-side comparisons. We advocate Likert-type scales (where people choose from a symmetric, evenly-spaced range of responses) using "acceptable-unacceptable" response labels; these have a long history of success in flow-recreation studies. Side-by-side comparisons increase respondent burden and involve more complicated analyses. Rankings are

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similarly problematic. Both of these options show which flows are rated better, but not “by how much,” and neither specifies the point when ratings go from acceptable to unacceptable, an important reference point for management.

Representing flow evaluation curves. Graphic representations of evaluations using flow evaluation curves are helpful for understanding flow-aesthetics relationships. Flow is shown along the x-or horizontal axis, and evaluations (using the Likert-type scales described above) along the y or vertical axis. Curves are usually drawn to connect mean evaluations for each flow, although other techniques can be used to mathematically fit a curve. “Specified flow questions” may ask respondents to identify acceptable, optimal, or other flows, providing further information about the curve. Medians (50% of the sample report higher values and 50% lower) are sometimes more useful measures of central tendency because means are more affected by outliers.

Order effects. Common choices for presenting flow images include random order, low-to-high, or high-to-low. Order effects in other research arenas are known to be important (Vaske, 2008), but little work has addressed aesthetic evaluations. Absent better research, random order seems preferable, although this may depend on other variables (e.g., the sophistication of evaluators or the ability to train them). If views are from more than one KOP, keeping each location’s views together reduces respondent burden and focuses on comparisons from like photos. If flows are provided in random order, there are benefits of a “pre-view” of two to four photos (including the lowest and highest). This allows respondents to recognize a range and identify the two ends before focusing on specific flow differences.

Labeled flow information. Should flow information (in cfs) appear on photos as they are evaluated? When conducting controlled flow field studies for boating, participants usually are told the flow to improve safety, allow them to interpolate/extrapolate beyond limited study flows, and because boaters are usually calibrated to the metric on many rivers. These reasons probably apply less to aesthetic judges. Absent more research or a judgement call regarding sophistication of the panel, it might make sense to omit flow labels.

Previewing photos, context-setting, and revising. It is common to start with a few introductory photos to help evaluators with the context of their evaluations. Some studies show the full range of photos before asking respondents to evaluate them, while other studies repeat the photos to allow revisions, or collect a second set of “close-out” evaluations. There is little research on this, but boater panels like close-outs, and attendees at an aesthetics workshop supported using one or more of these practices (RMS, Boise 2016). The goal is to make sure respondents are comfortable with their “final ratings.”

Length of evaluation time. To be efficient and keep evaluators engaged, photos or video clips should not be displayed for too long. Daniel and Boster (1976) suggest that 5 to 8 seconds is usually enough for an aesthetic evaluation.

Importance of a pretest. Many problems can be addressed with a careful pre-test. This helps researchers assess issues such as question content and formatting, respondent burden, and length of evaluation time.

Social desirability bias. This refers to responses influenced by perceived viewpoints of the survey administrator, other evaluators, or some more generalized public. It is a larger issue with in-person interviews than self-administered or mail surveys. Facilitators should be trained to avoid pressuring respondents, expressing preferences, or otherwise cueing responses.

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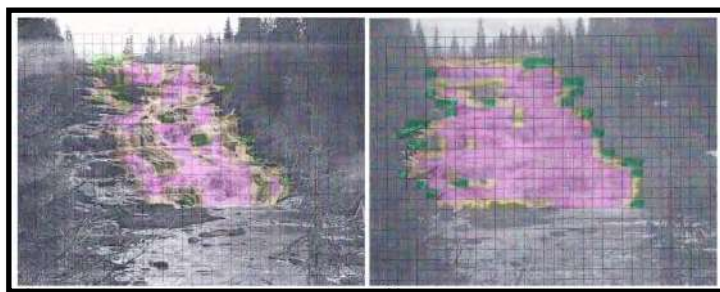
Strategic bias. This refers to answers altered by a respondent who anticipates how the data will be used, and wants to influence results in a certain direction. This issue is often raised in contingent valuation surveys where respondents indicate their “willingness to pay” on a survey but don’t actually have to spend any money. We have seen little evidence of strategic bias in our years of conducting flow studies, although in the Spokane Falls study we identified two individuals’ evaluations that were consistently out of step with others in the panel. Focus group discussion identified the issues, and analysis showed distributions of responses (including outliers).

Evaluations of importance vs. evaluations of flows. Flow-aesthetic research focuses on flow effects for a specific feature or reach, and not the “importance” of that feature or reach relative to others. Both are good questions when deciding how to provide flows from a hydropower project, but the two issues should be considered separately. Importance might be measured by several different metrics, including “willingness to pay,” “willingness to travel” (in miles or travel time), or general preference/importance scales. Features that rate higher on such scales might deserve more frequent flows, but this requires comparative data or some large assumptions, and is seldom the deciding factor in FERC licensing. Some utilities have addressed the issue empirically by providing boating flows in response to phone requests (Idaho Power on the remote Milner reach of the Snake River) or numbers of boaters who show up (Pacific Gas and Electric on the Feather River).

Channel coverage vs. aesthetic value

In earlier studies (Shelby et al., 1992; Shelby and Whittaker, 2002) and elsewhere in this guide, findings show the greatest increases in aesthetic benefits come from flows that cover the bottom of the channel, and subsequent flow increases have less effect. This suggests that aesthetic quality is related to the percent of the river channel covered by water, and that the relationship is probably not linear. In a study of several European waterfalls, Boes et al. (2011) demonstrate the concept empirically, as summarized below.

- The study included seven tall but low-volume waterfalls, six in Norway and one in Austria. Heights ranged from 50 to 460 feet, with widths from 6 to 125 feet; average flows were between 8 and 116 cfs, but peak flows were considerably higher.
- For each falls, data describing height, width, and average flow were used to calculate “visual magnitude” scores (see discussion on waterfall classification systems above), using formulae from Plumb (1993) and Beisel (2006). Boes et al., (2011) suggest that both scores indicate “waterfall importance,” but the two scores “do not closely correspond,” and other criteria (e.g., surrounding landscape, tourist value, or seasonal flow variability) might need to be included.
- At a frontal view KOP for each falls, automated cameras recorded photos for a range of flows through a season.
- Applying a fine grid over each photo (see examples at right), researchers used the percent of each square covered by water to estimate wetted area. Flows (Q) and wetted area (A) were normalized with respect to median discharge (Q_{50}) and median wetted area (A_{50}).
- Plotting wetted area (A/A_{50}) vs. flow (Q/Q_{50}), coverage increases more from the lowest to median flows, and considerably less from median to five times the median flow.
- The authors examined effects from hydro development for the falls with projects. They developed an equation accounting for the size, timing, and duration of diversions, operationalizing the concept that diversions leaving flows at or above the median have smaller effects on coverage than diversions to below-median flow.
- The study also suggests that aesthetic impacts depend on changes to both visible channel coverage **and** visual magnitude scores. Developing a conceptual “consequences matrix” that plots visual magnitude vs. the extent of hydropower impacts (with variables for coverage and flow relative to its median), the authors provide a system for assessing aesthetic impacts for diversion proposals. Larger diversions during lower flow periods for higher visual magnitude falls produce more negative impacts, compared to smaller diversions during higher flow periods for lower magnitude falls. While we disagree with using visual magnitude as a measure of a waterfall’s importance or aesthetic value, illustrating the tradeoffs among these variables is useful.
- Another contribution is the paper’s focus on median flows as a point below which decreases in flow produce greater negative aesthetic impacts. Future studies should test this concept empirically.



Estimated percent of each square covered by water at two different flows in Prestfossen Falls, Norway (25 cfs at left; 280 cfs at right).

9. Conclusion: Six flow-aesthetic principles

Flow-aesthetic research has been conducted sporadically over the years, and it has not received the same systematic attention as the aesthetics of infrastructure (e.g., hydro power plants or transmission lines) or forest practices. There has been no attempt to assemble diverse and often “fugitive” literature (such as agency or project reports), nor to summarize “principles” for the field. This guide proposes six principles that are supported across the studies reviewed here. While these have been labeled principles, they might also be characterized as concepts, generalizations, or broad hypotheses that deserve attention in future research.

1. ***Aesthetics improve the most at the low end of the flow range.*** The negative aesthetic effects of very low flows include stagnant pools, poor water quality, stranded features, exposed algae and trash, and the loss of contrast between pools and moving water (Whittaker et al., 1993). Studies show that small flow increments reduce such effects, and increases at the low end of the hydrograph are likely to provide more aesthetic improvement than similar increases at higher flows.
2. ***Flows that “fill the bottom of the channel” are likely to provide acceptable aesthetics.*** This effect was identified on the Virgin River in Utah/Arizona/Nevada (Shelby et al., 1994), but has been verified in subsequent studies. It is sometimes challenging to specify “the bottom of the channel” (channel coverage) across a diversity of channel shapes (e.g. pools, glides, rapids, bedrock vs. cobbles, different types of waterfalls). It appears these flows are often lower than a river’s median annual flow, but this finding deserves research attention.
3. ***Flows that provide optimum aesthetic ratings are less clear.*** Some studies suggest that high quality aesthetics occur at relatively low flows (e.g., average flows in the lowest flow month). Other studies show the highest ratings at median or greater flows. More research is needed to compare findings across rivers and waterfalls, identify physical characteristics or other types of features that distinguish rivers, and consider which flow metrics (e.g., medians, averages in the lowest flow month) provide certain aesthetic benefits.
4. ***Increases in flows may change the shape, type, or other characteristics of waterfalls, with substantial effects on aesthetics.*** Increasing flows may change features, plumes, mist, power, or sound. They may also connect previously separate segments, for example, changing separate horsetail falls into a single segment, or separated segments into a block falls. Research has not yet documented such changes or their effects on aesthetic ratings.
5. ***Very high flows may be rated lower, although some enjoy the novelty and raw power of these sometimes awe-inspiring events.*** This idea was proposed in Whittaker et al. (1993), and is supported by a review of guidebook descriptions and literary works mentioning waterfalls (Hudson, 2000; 2002). No study has explicitly examined this effect, probably because very high flows are rare, they are seldom provided intentionally by regulated systems, and flows labeled as “floods” are often considered destructive.
6. ***Diverse flows may produce multiple aesthetic benefits.*** Natural flow regimes in rivers and waterfalls generally have different amounts of water at different times, producing a diversity of aesthetic conditions. Several studies suggest boaters and anglers value such diversity (Whittaker and Shelby, 2000; 2002), and this may apply to aesthetics too. Determining preferences for varied flows that mimic natural conditions and assessing the tradeoffs of providing diversity are topics for future research.

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EXHIBIT C

Review of Erosion in the Turners Falls Impoundment

Prepared 19 May 2024 by Dr. Evan Dethier for the Connecticut River Conservancy and Franklin Regional Council of Governments

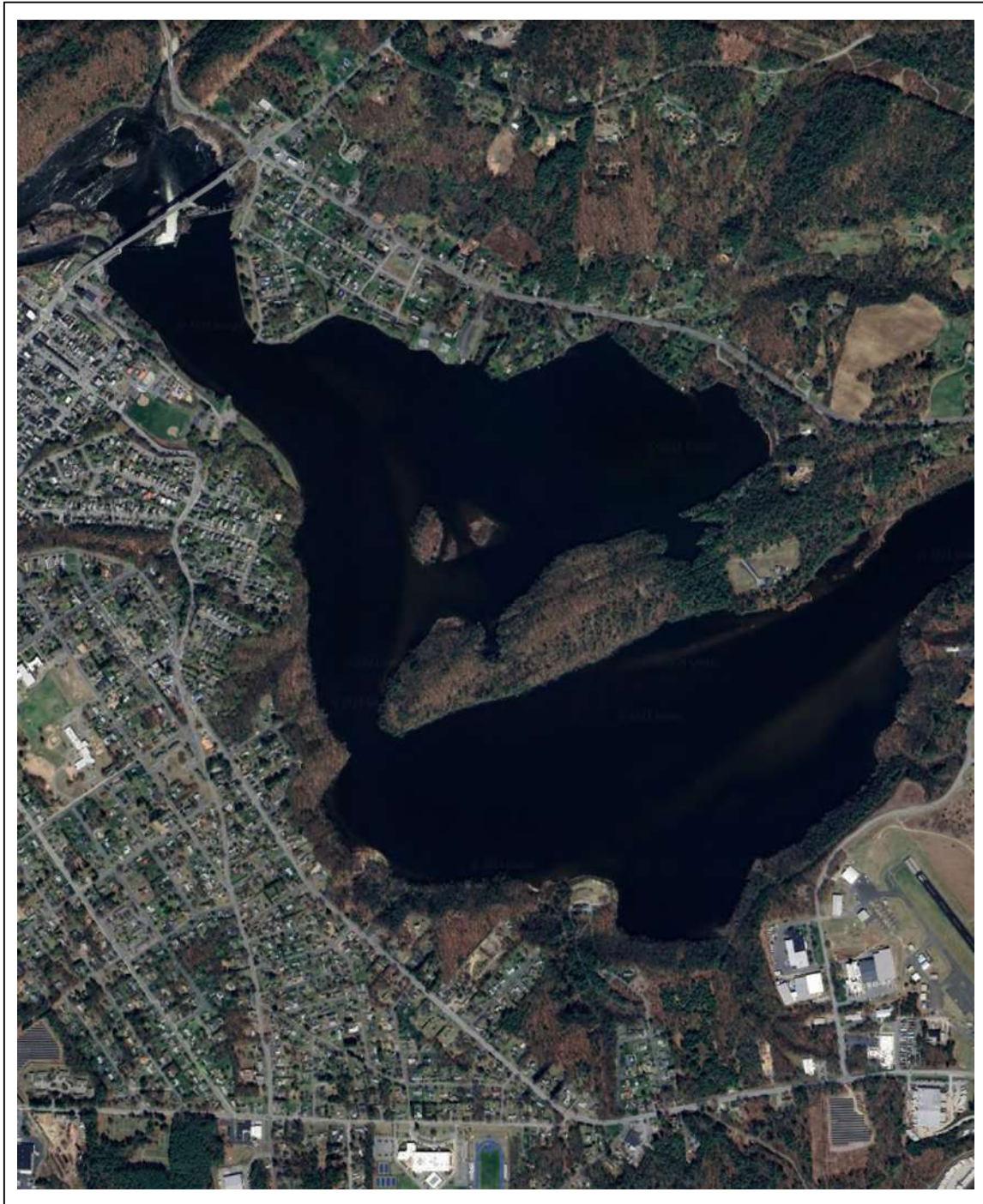


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Short Biography

Evan Dethier holds a Masters and PhD in Earth Science from Dartmouth College. He is an assistant professor of Geology at Colby College in Waterville, Maine. Evan is a fluvial geomorphologist who has studied erosion in New England rivers for the past decade. He uses field and remote-sensing methods to monitor and improve understanding of natural and anthropogenic disturbance to these rivers and those around the world, including by floods, landslides, mining, and dams.

Dr. Dethier's CV is attached at the end of this report for reference.

i. Executive Summary

Erosion in the Turners Falls Impoundment

There is substantial evidence of erosion in the Turners Falls Impoundment (TFI), much of it consistent with fluctuations in water level due to dam operations. Several reports and memos, including by the US Army Corps of Engineers, Field Geology Services, and Princeton Hydro, have already established that water level fluctuations in the TFI can, and likely do, enhance erosion in the reservoir.

Reports by FirstLight have repeatedly denied the connection between fluctuating water level and erosion. These denials defy direct observations, including those presented by FirstLight, showing the likely links between FirstLight operations and erosion in the TFI.

- Water fluctuations in the TFI result from a combination of natural flows, which are regulated to some extent by upstream dams, and approximately daily fluctuations that a) move water between the River as lower reservoir and Northfield Mountain's upper reservoir (pumping withdraws water from the river and generation returns water to the river) and b) regulate flow through the Turners Falls Dam and power canal for conventional hydropower. The combination of a) and b) are termed "Project operations" in this report.
- Erosion is clearly documented in both data and images produced by FirstLight.
- Erosion occurs with very few signs of deposition. In its pre-dam state much of the TFI may have been a net-depositional zone, given that the TFI is in a mostly alluvial reach of the Connecticut River, with limited bedrock, a well-developed floodplain, and decreasing stream power.
- River flows have rarely inundated floodplains since flood control dams were established in the mid-20th century, eliminating the possibility of replenishing overbank sediment.
- Observations and measurements included in the FirstLight Full River Reconnaissance and Erosion Causation Study point to numerous mechanisms that could enhance erosion in the TFI due to Project operations.
- FirstLight has not presented credible, reproducible evidence that their operations do not increase erosion in the TFI. Absent targeted mitigation, increase in the water-level range of typical Project operations may increase erosion in the impoundment.

Flaws in FirstLights Erosion Attribution Analyses

FirstLight's two relicensing studies, Study 3.1.1, the Full River Reconnaissance (FRR), and Study 3.1.2, Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report (commonly called the Erosion Causation Study) have numerous methodological flaws and gaps in reporting. These studies document widespread erosion in the TFI, but downplay this erosion in the text and summaries. Other studies and reviews prepared by scientists, including the 2007 and 2013 reports by Field Geology Services

and the Princeton Hydro peer review, point out flaws in FirstLight’s analyses and highlight the likelihood that FirstLight operations contribute to erosion.

- FirstLight documents substantial evidence of erosion, even attributing some of it to changing water levels due to dam operations. However, this finding is discounted in their text, conclusions, and executive summary.
- There is no mention of the inability of vegetation to colonize lower banks because of water level fluctuations, leaving them prone to erosion.
- There is no mention of freeze-thaw effects causing erosion on unvegetated, steep banks created and maintained (in their unvegetated state) by frequent inundation and erosion. Freeze-thaw erosion does not require ice floes, which FirstLight does address, but can occur from frost wedging and liquefaction on steep banks. In addition, FirstLight’s dismissal of erosion by ice jams is not evidence-based.
- The BSTEM model used by the consultants was developed by them. The report has a lack of transparency in model inputs that makes it impossible to judge its appropriateness.
- The version of the BSTEM model used in the Erosion Causation Study is not publicly available and thus the results cannot be understood or replicated.
- Despite high-resolution cross sections available to the model, only a simple parameterization is used (as far as can be understood from the summary). Average slopes for upper and lower banks are used, potentially diminishing estimates of erosion except during floods.
- Groundwater saturation is integral to the model, but almost no data was collected to inform its parameterization.
- Root cohesion data was only collected for large trees. There is no information on grasses and smaller vegetation that does much of the work of bank stability and velocity reduction. Cohesion does not vary through the model run, despite likely lower cohesion during late winter and spring, when soils are saturated and vegetation has not taken root for the season.

Erosion along the banks of the Turners Falls Impoundment has been documented since the construction of the reservoir. A series of independent, expert scientists have attributed at least part of this erosion to Project operations, which raise and lower the water level in the TFI or Connecticut River, exposing different parts of the bank to erosion.

The results of expert analysis—that erosion in the Turners Falls Impoundment is increased by Project operations—conform with the general scientific consensus about shoreline erosion in human-controlled impoundments, particularly in those with fluctuating water levels.

1. Background

1.1 Summary

Erosion is a natural process along any shoreline. Human activities can accelerate erosion processes, causing erosion to occur in excess of natural rates or at different seasons than is normal. Because natural processes generally continue, at least to some extent, after human intervention, and natural and human processes interact with each other, quantifying the precise contribution of natural and human processes to erosion is a difficult task. Over the past several decades, various analyses have attempted to do so. However, as Field Geology Services noted in 2007 (working as a consultant for FirstLight's predecessor), accurately separating human and natural contributions to the erosion in the Turners Falls Impoundment is not possible without more detailed and accurate monitoring than has yet been undertaken¹. This remains true.

Monitoring recommended by Field Geology Services in 2007 and 2012 (working as a consultant to a landowner group), such as annual lidar surveys^{2,3}, would address inconsistencies and gaps in historical monitoring efforts, but have not yet been undertaken. Stymied by this lack of certainty, the Field Geology Services Report from 2007 detailed the many potential sources of human and natural erosion and the challenge of separating them, given the interconnected natural and human processes in the TFI⁴. In this report, I summarize peer-reviewed literature about the TFI and similar reservoirs, as well as non-peer-reviewed reports and observations. I also discuss shortcomings in FirstLight's recent analyses of erosion in the reservoir: Study 3.1.1 (the Full River Reconnaissance), Study 3.1.2 (aka the Erosion Causation Study), and several other FirstLight publications. This review should provide insight into the likely contribution of FirstLight operations to erosion on the TFI shorelines, while making clear that FirstLight claims that they are not contributing to erosion are much more certain than is scientifically supported.

1.2 Erosion on reservoir shorelines

1.2.1 Overview

For decades, the technical and scientific community has measured anomalous erosion on the banks of impounded reservoirs. Several studies have shown that erosion occurs or is increased due to reservoir construction and operation. Numerous scientists have found that such erosion can persist well into the lifespan of the dam.

¹ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. p. 42 ("Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.")

² Kaczmarek, H., Tyszkowski, S., Bartczak, A., Kramkowski, M., & Wasak, K. (2019). The role of freeze-thaw action in dam reservoir cliff degradation assessed by terrestrial laser scanning: A case study of Jeziorsko Reservoir (central Poland). *Science of the total environment*, 690, 1140-1150.

³ Field (Field Geology Services), 2012, Rebuttal of FirstLight's Response to Landowner Filing: Unpublished report prepared for Landowners and Concerned Citizens for License Compliance Turners Falls Pool, 12 p. p. 10 ("Given that both Landowners and Simons (2012) agree that the FRR methodology cannot be used to make comparisons of erosion from year to year, FERC should insist that FirstLight and its agents make no further representations that the 2008 FRR demonstrates a decline in erosion levels between 2004 and 2008. Since FirstLight (2012) makes clear that the objective of the 2013 FRR is, in part, to "analyze any change in the condition of the riverbank since the last FRR" (FirstLight, 2012, Appendix 1, p. 2), FERC should further insist that future FRRs be designed in a manner that allows for detailed site-by-site comparisons from year to year.")

⁴ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. p. 42 ("Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.")

The Turners Falls Impoundment is relatively long and narrow, resembling both a river and a typical ponded reservoir. Nonetheless, it does not appear to be an exception to this general pattern of increased erosion, because it experiences many of the same processes that enhance erosion in wider reservoirs. Indeed, its non-cohesive sediment banks, location in a freeze/thaw climate, and fluctuations from pump-storage operations increase its likelihood of increased erosion due to Project operations.

1.2.2 Why is there erosion along reservoir shorelines?

The area along a reservoir shoreline that is exposed to changing water level has been termed the “reservoir disturbance zone” due to “the cyclic submergence and exposure caused by the reservoir operation”⁵. Prior to reservoir construction, these elevations usually remain well above the high-water line. They would generally be inundated only during floods, if at all. After the reservoir is completed, frequent water inundation occurs in the reservoir disturbance zone, between the base and peak of normal dam operations. This inundation in the reservoir disturbance zone disrupts soils, vegetation, and fauna. In many cases, these disruptions contribute to erosion⁶.

A US Army Corps of Engineers review of ten reservoirs found wind-wave erosion, groundwater-induced sliding, freeze-thaw effects, and landsliding to be the dominant processes after the period of initial reservoir filling⁷. Each of these processes occurs in the reservoir disturbance zone and is caused or accentuated by the inundation of shoreline sediments. Consistent or intense wave action from wind and waves⁸ subjects the previously high-and-dry banks to the erosive action of water, leading to sediment removal. Flooding can increase flow velocity and increase erosion. In some cases, previous erosion at the “toe” (base) of steep banks can undercut the bank slope or soil saturation can reduce soil strength during to high-water fluctuations. These events can lead to mass sediment failure farther up the bank and above the disturbance zone⁹, as has been found in the Wilder Dam reservoir farther upstream on the Connecticut River¹⁰.

⁵ Bao, Y., Gao, P., & He, X. (2015). The water-level fluctuation zone of Three Gorges Reservoir—A unique geomorphological unit. *Earth-Science Reviews*, 150, 14-24. p. 15.

⁶ Bao, Y., He, X., Wen, A., Gao, P., Tang, Q., Yan, D., & Long, Y. (2018). Dynamic changes of soil erosion in a typical disturbance zone of China's Three Gorges Reservoir. *Catena*, 169, 128-139. p. 136 (“Influenced by this new hydrological regime, the abundance of the original plant species within the [Disturbance Zone] has been drastically reduced”).

⁷ Gatto, L. W., & Doe III, W. W. (1987). Bank conditions and erosion along selected reservoirs. *Environmental Geology and Water Sciences*, 9(3), 143-154. p. 143 “However, freezing can disrupt soil structure and draw pore water to the freezing zone, which may make bank sediment more susceptible to erosion after thaw.”

⁸ Vilmundardóttir, O. K., Magnússon, B., Gísladóttir, G., & Thorsteinsson, T. (2010). Shoreline erosion and aeolian deposition along a recently formed hydro-electric reservoir, Blöndulón, Iceland. *Geomorphology*, 114(4), 542-555. p. 550 (“After the formation of the Blöndulón Reservoir the most rapid initial erosion rate occurred on bluffs on the northern and western shores, comprising about one third of the shoreline of the reservoir, where the available wave energy was high. This is evident from the high cumulative wave power at those sites due to the long fetch towards the south and east and frequent south to south-easterly storms occurring during high water levels.”)

⁹ Kaczmarek, H., Mazaeva, O. A., Kozyreva, E. A., Babicheva, V. A., Tyszkowski, S., Rybchenko, A. A., ... & Słowiński, M. (2016). Impact of large water level fluctuations on geomorphological processes and their interactions in the shore zone of a dam reservoir. *Journal of Great Lakes Research*, 42(5), 926-941. p. 933 (“Landslide activation took place in 2004, 2006, and 2009, in periods of high water level in the reservoir, reaching 400 m a. s. l. or more”).

¹⁰ https://www.lymenh.gov/sites/g/files/vyhlf4636/f/uploads/lyme_hmp_finalforadopt_apr3_17.pdf

Inundation also increases the susceptibility of the reservoir banks to erosion. Devegetation due to inundation and erosion¹¹ reduces bank sediment cohesion, especially in silty and sandy soils like those present in the TFI¹², leading to easier removal by reservoir waters. Freeze-thaw erosive processes can physically separate blocks of soil from the bank¹³. Increased water saturation due to reservoir inundation can enhance these processes. Each of these erosion-increasing processes occurs in the Turners Falls Impoundment.

1.2.3 Where does erosion occur in reservoirs?

Despite investigating 32 causes of erosion in reservoirs, the US Army Corps of Engineers study makes virtually no mention of river flooding as an important factor¹⁴, nor do most of the other peer reviewed studies of reservoir erosion. Instead they find the importance of water fluctuations, combined with processes that occur consistently at the reservoir shoreline, facilitated by inundation and wave action¹⁵. The riverine geometry and flow characteristics of the TFI, especially its upper reaches, makes it susceptible to erosion by flooding, which is most likely a cause and perpetuator of erosion along the shoreline¹⁶. However, as these studies show, many processes contribute to erosion in a reservoir, and rarely can erosion be distilled to a single cause.

Which of the above processes is dominant in a given reservoir depends on the make-up, orientation, and slope of the reservoir banks, slope and vegetation, dam operations, the prevailing hydrology and climatology, and reservoir activity¹⁷. The primary cause of erosion may vary within a reservoir due to variations in current, exposure, or bank material. However, in each case erosion mostly occurs in the reservoir disturbance zone, which is largely determined by the dam or project operations^{18,19}.

In a given moment, erosion primarily occurs within a few vertical meters of the waterline²⁰, usually when waves or currents transport sediment away from banks^{21,22}. Because reservoir levels change with seasons, natural floods, and dam operations, the erosion band moves up and

¹¹ Bao, Y. et al. (2018). p. 136 (“Influenced by this new hydrological regime, the abundance of the original plant species within the [Disturbance Zone] has been drastically reduced”); Fig. 7.

¹² Kaczmarek et al. (2016) p. 927 (“Depending on rock resistance, the mean width of eroded shore varies from 80 m in sandstones to 140–200 m in silty deposits”)

¹³ Gatto, L. W., & Doe III, W. W. (1987). Bank conditions and erosion along selected reservoirs. *Environmental Geology and Water Sciences*, 9(3), 143-154. p. 143 “However, freezing can disrupt soil structure and draw pore water to the freezing zone, which may make bank sediment more susceptible to erosion after thaw.”

¹⁴ *Id.* at p. 147 Table 2 (“Summary of historical recession”).

¹⁵ Vilmundardóttir et al. (2010) p. 554 (“Bluff erosion and aeolian reworking of sediments at the Blöndulón Reservoir are closely linked to water level fluctuations.”)

¹⁶ U.S. Army Corps of Engineers, 1979, Report on Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire and Vermont: Department of the Army New England Division Corps of Engineers: Waltham, MA, 185 p.

¹⁷ Gatto and Doe III (1987) p. 143 (“The importance of a process or a set of processes or factors will vary at different sites and different times”).

¹⁸ Bao, Y. et al.(2018). p. 135 (“the fluctuation pattern of soil erosion rates in the DZ was consistent with that of the specific water level residence time. The residence times around the minimum and maximum levels were significantly longer than those at the other levels.”)

¹⁹ Newbury, R. W., & McCullough, G. K. (1984). Shoreline erosion and restabilization in the Southern Indian Lake reservoir. *Canadian Journal of Fisheries and Aquatic Sciences*, 41(4), 558-566. p. 561 (“melting occurs below and slightly above the water surface.”)

Gatto and Doe III (1987) p. 143 (“The importance of a process or a set of processes or factors will vary at different sites and different times”). p. 152 (“much of the bank erosion along most of the” reservoirs is caused by water action at the bank toe”)

²¹ Bao, Y. et al.(2018). p. 128.

²² Vilmundardóttir et al. (2010) p. 552 Fig. 11.

down throughout the year. The wider the band of water-level variation, the more area that is subject to inundation, scour, devegetation, and thus erosion, and the wider the reservoir disturbance zone.

The physical properties of the reservoir bank sediments are another important control on their erodibility. Where banks are comprised of sandy or silty sediments, they are less likely to be stable than banks made of coarser material or bedrock. Several studies of reservoir erosion have found that, within a reservoir, bank sediment is the most important spatial control on erosion rate. Where sediments are sandy or silty, similar to those in the TFI^{23,24}, banks are most susceptible to erosion during reservoir water fluctuations since they “lack cohesion and grains of boulder and cobble size”²⁵.

High slopes at or near the waterline are correlated with higher erosion rates²⁶. Although some studies have found elevated erosion even at low slope²⁷, in general steep banks like those found in glacial and floodplain sediments along much of the TFI are thought to be most susceptible to water-fluctuation erosion (and erosion in general).

Project operations in the TFI frequently raise and lower the water level. Thus, the local area of possible erosion is a dynamically changing band that spans normal pump-storage operations and moves up and down with natural variations in river flow (Figure 1). As opposed to other reservoirs where fluctuations might occur on a seasonal basis and/or with occasional flood events, fluctuations in the TFI occur daily or even multiple times in a day. Rapid erosion throughout the reservoir has occurred in and above this erosion band. FirstLight itself has documented this erosion, including wave-cut banks and bars, bank undercutting and failure, bank retreat, and rotational landslides and slumps²⁸. Erosion has encroached on land surrounding the reservoir, removing soil and acreage and threatening roads and infrastructure.

²³ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. p. 50 (“Most of the riverbank sediments in the Turners Falls Pool are naturally susceptible to erosion given their noncohesiveness and fine-grained texture”)

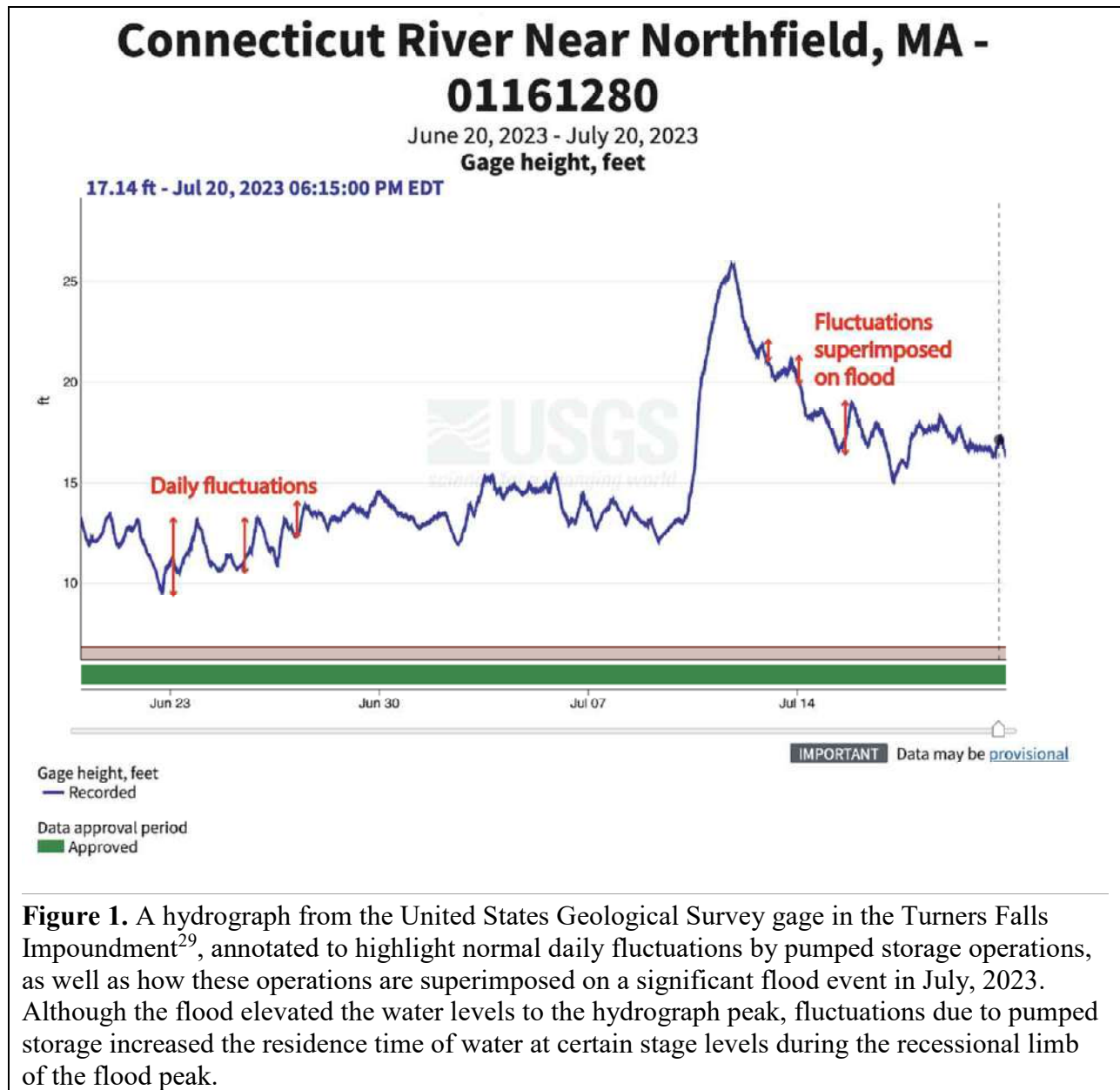
²⁴ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Table 4.2.6.3-4: Particle-size Data of the Bank Materials along the Turners Falls Impoundment

²⁵ Vilmundardóttir et al. (2010) p. 552 (“The current erosion rate is due to loose fluvioglacial substrate material; the texture of the fluvioglacial sediments did not create stable bluffs since it lacked cohesion and grains of boulder and cobble size. We suggest that the nature of the substrate material is the most important environmental factor affecting the development of bluffs towards equilibrium.”).

²⁶ Bao, Y. et al. (2018). p. 136 (“that the soil erosion rate was positively correlated with the slope gradient”); Fig. 6.

²⁷ Vilmundardóttir et al. (2010)

²⁸ FirstLight Relicensing Study 3.1.2 2017 Erosion Causation, Appendix M – 2013 Full River Reconnaissance Riverbank Segments With Causes Of Erosion



1.2.4 Are there close analogues for the Turners Falls Impoundment?

As discussed above, the Turners Falls Impoundment is a narrow, riverine reservoir, especially in its upper reaches. Thus, it is somewhat different from many of the reservoirs that have been studied for erosion, which tend to be broader. River currents are likely higher, especially in the upper sections of the reservoir, than is typical in large, ponded reservoirs.

Nonetheless, it is a reservoir with sub-daily water-level fluctuations, and with banks that are steep, sandy and silty. Reservoirs with these characteristics are highly prone to erosion from

²⁹ <https://waterdata.usgs.gov/monitoring-location/01161280/#parameterCode=00065&period=P7D&showMedian=false>

water fluctuations.³⁰ Its lower section near Bartons Cove, also much more resembles a ponded reservoir, with a maximum width of more than 4,000 feet. Flow velocities there must thus be much lower, even during floods. Despite the lower flow velocities, this section of the reservoir generally experiences comparable erosion rates to the upstream reaches³¹, suggesting that water fluctuations may play a larger role in erosion.

In Quebec, erosion rates of 10–30 meters over 20 years were found in similar sediments to those at TFI³². The erosion processes are very similar to those in the Turners Falls Impoundment, consistent with understand of geomorphology along sandy shorelines. They are described by Saint-Laurent et al., 2001:

“The mechanism of bank recession is ruled by shore dynamics and slope rheology (Whalen et al. 1995). The breaking waves dissipate energy and disperse weathering fine particles such as sand and silt towards deep water. The shore is thus depleted and further exposes the foot of the slope to the action of the waves. The sapping of the waves at the foot of the slope progressively removes material at the base until the breakpoint of the slope. The debris join the bottom part of the shore and form a sort of rampart against the effect of the waves. The erosion process thus continues and starts up again year after year (mobilization of shore material by the waves, sapping, and collapse, etc.).” (p. 491)

Photographs and descriptions from Saint-Laurent et al. document similar landforms and erosional features as are present in the TFI (Figure 2), suggesting similar and/or identical processes are at work in the TFI. Saint-Laurent et al., 2001 noted that fluctuations accentuated this erosion: “the equilibrium obtained at a relatively constant level is somehow lost with fluctuations in reservoir water levels.”

³⁰ *e.g.*, Saint-Laurent, D., Touileb, B. N., Saucet, J. P., Whalen, A., Gagnon, B., & Nzakimuena, T. (2001). Effects of simulated water level management on shore erosion rates. Case study: Baskatong Reservoir, Québec, Canada. *Canadian Journal of Civil Engineering*, 28(3), 482–495. p. 490 (“Proglacial sandy deposits, such as those observed around the Bras Nord and Du Diable Bay, are particularly prone to erosion, especially when exposed to wave action.”).

³¹ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. Table 5; Table 6.

³² *Id.* at p. 492 (“Windigo Bay (20–30 m over 20 years) and Du Diable Bay (10–15 m over 20 years)”)



Figure 2. Figure 6a. from Saint-Laurent et al., 2001 shows a shoreline bank failure that strongly resembles failures along the TFI shorelines.

In a study in Poland, silty glacial sediments similar to those at the TFI experienced 1.4–3 m of erosion per year³³. Another reservoir in Iceland with glacial sediments along its shoreline experienced erosion along its banks of 0–1.7 m per year³⁴. Erosion in the TFI is similar to these rates for some banks, with bank losses of >1 ft/yr at some cross sections³⁵.

The primary mechanism for erosion in each of these reservoirs is likely wave or frost action, as opposed to in the Turners Falls Impoundment, where it may be flood flows. Yet where the erosion occurs and, at least to some degree how much erosion occurs, is set by the reservoir water level. Erosion is highest in the reservoir disturbance zone, where the banks are subject to wave action, inundated or saturated, devegetated; because the reservoir exists, erosion likely occurs at higher rates than if it did not.

³³ Kaczmarek et al. (2016) p. 930 (“The rate of bluff recession was the highest in the initial period of reservoir use: on average 3 m/year in 1969–1980, compared to 1.4 m/year in 1980–2013.”)

³⁴ Vilmundardóttir et al. (2010) p. 547 (“The bluff retreat measured 1.3 m in 1997, while no erosion was measured in 1998 and 1999 (Table 3) when the water level was low and did not reach overflow level (Fig. 3). Erosion of 0.4 m was measured in 2000 but in 2001 again there was no erosion measured. The most rapid erosion period occurred in 2002 when the bluff receded 1.7 m. Since 2003 the erosion rate has greatly decreased to < 0.2 m yr⁻¹.”)

³⁵ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. Table 5; Table 6.

1.2.5 Will erosion naturally slow in the TFI, or has it already?

The Turners Falls Impoundment is an old reservoir, with operations at the present levels initiated in 1970 (the dam was raised first, before Project operations began in 1972). Reservoir shoreline erosion documented in some studies is rapid after initial inundation, then dramatically slows as erodible material is removed. Given the rapid initial erosion in the TFI after reservoir levels were raised in 1970 and the possible slowdown in the 1990s and early 2000s³⁶, it is reasonable to wonder whether this initial adjustment period has ended and erosion is no longer an issue. However, cessation of shoreline erosion principally occurs when shorelines are eroded to bedrock³⁷ or beaches can be established³⁸, protecting against wave action and inundation³⁹. Once easily eroded sediments are removed or protected, erosion rates plummet. However, these conditions are generally not present in the TFI. There is limited bedrock that might stabilize the channel, and beaches that might provide a buffer against bank erosion may be destroyed by high flows, limiting bank protection⁴⁰ (see below, Figures 6–8).

Reservoirs like the TFI, with shorelines primarily comprised of unconsolidated sediments, tend to maintain higher erosion rates for the reservoir lifespan⁴¹. Although some slowing usually occurs, as may be the case in the TFI, its sandy and silty banks and general lack of bedrock shoreline means that erosion can essentially continue unchecked⁴². This is particularly true if water level fluctuations remain the same or are increased.⁴³ In the TFI, if Project operations use a wider range than has been typical during the past 50 years, it is possible that a new wave of erosion will occur, as slopes on the upper bank are inundated for longer periods of the year⁴⁴, similar to the initial cycle of erosion that occurred when the reservoir levels were raised in the 1970s.

1.3 Past studies of erosion in the Turners Falls Impoundment

While the existing peer-reviewed literature on reservoir erosion clearly shows that water level fluctuations can cause or contribute to erosion, there is also a decades-long history of studies making a similar conclusion for the TFI specifically. In 1979 and 1991, the US Army Corps of

³⁶ Field (2007). p. 27 (“South of the Massachusetts state line, the data reveal an 18 percent increase in the amount of mapped erosion between 1978 and 1990, a 6 percent decline between 1990 and 2001, and a 3 percent decline between 2001 and 2004”); Figure 28a.

³⁷ Newbury, R. W., & McCullough, G. K. (1984). Shoreline erosion and restabilization in the Southern Indian Lake reservoir. *Canadian Journal of Fisheries and Aquatic Sciences*, 41(4), 558-566. p. 561 (“If bedrock is encountered at the eroding face, erosion at the water level ceases. In the wave-washed zone overlying the bedrock, erosion continues until a bedrock backshore zone is exposed up to the maximum wave upwash elevation.”).

³⁸ Field (2007)

³⁹ Vilmundardóttir et al. (2010)

⁴⁰ Field (2007). p. 43 (“The presence of higher beach deposits preserved at the base of the bank, particularly in protected areas, suggest prior beaches have been removed by scour”)

⁴¹ *Id.* at p. 551 (“Despite the low energy at the south-east shore (R13 and R15) the erosive substrate has prevented the shore from reaching even close to equilibrium.”).

⁴² Kaczmarek et al. (2016) p. 940 (“Although the reservoir has been operated for several dozen years, the activity of geomorphological processes in its shore zone, initiated or intensified by its creation, is still high.”); p. 940 (“Their activity has not decreased after several decades and the affected area is often gradually extended.”).

⁴³ *Id.* at p. 940 (“The course of geomorphological evolution is closely linked to large water level fluctuations. The intensity of their development is characterized by remarkable variation between years and within years, conditioned by high water level fluctuations... In periods of high water levels, which reach the base of the bluff, as a result of subaqueous coastal processes result and intensive bluff recession is observed.”).

⁴⁴ Bao, Y. et al. (2018). p. 135 (“the fluctuation pattern of soil erosion rates in the DZ was consistent with that of the specific water level residence time. The residence times around the minimum and maximum levels were significantly longer than those at the other levels.”)

Engineers identified flooding, seepage, project-caused water fluctuations, and boat wakes as possible causes of erosion^{45,46}. In 2007, Field Geology Services was hired by FirstLight to study erosion in the reservoir, and provided the most comprehensive summary of erosional processes in the TFI. They found that a combination of erosional processes, contingent on one another, most likely collectively cause erosion in the reservoir⁴⁷.

The 2007 Field Geology Services report, summarizing likely erosion processes occurring in the TFI, included natural erosion processes that may occur regardless of Project operations, including flood flows, undercutting and seepage, boat waves, freeze-thaw processes, and landsliding and slumping. However, it also discusses how pool fluctuations due to Project operations likely cause erosion themselves while also potentially initiating or perpetuating the “erosion sequence”. Field Geology Services added that “erosion is likely to persist as flood flows rework beach deposits and inundate the beach face, enabling boat waves, *pool fluctuations*, and natural river currents to remain active at the base of the banks” (emphasis added).

Since then, in FirstLight’s Full River Reconnaissance in 2008, Full River Reconnaissance in 2013, the Erosion Causation Study in 2017, and several other documents and rebuttals, FirstLight has scrupulously denied taking responsibility for almost any erosion in the reservoir, despite repeated reports and letters by independent scientists and community groups. Field Geology Services, who was considered a sufficiently reputable scientist to be hired by FirstLight in 2007, summarized this avoidance of responsibility and deflection in their 2012 critique of FirstLight’s approach⁴⁸:

“However, as detailed below, the supporting evidence for making such a strong charge is found wanting in accuracy, relevance, and evenhandedness in application. Simons (2012) uses six oft-repeated strategies to give the appearance of refuting Field’s (2011) claims without providing sufficiently compelling evidence to do so: 1) providing information that in fact contradicts the assertion being made, 2) presenting information that is inaccurate, misleading, or misrepresents the work of others, 3) presenting information that is factually correct but irrelevant in regards to changing erosion levels in the Pool, 4) presenting information that is not readily verifiable, 5) presenting new information that further calls into question findings of the 2008 [Full River Reconnaissance (FRR)], and 6) making assertions that if applied evenly would discredit Simons’ (2009) conclusion that erosion levels decreased between the 2004 FRR and 2008 FRR.” (p. 5)

These are strong rebukes from a respected scientist, and call into question the claims made by FirstLight. Nonetheless, in subsequent reports, FirstLight has persisted in this pattern of denial, rejecting even the possibility that Project operations are meaningfully contributing to erosion in the TFI.

The erosion sequence as proposed by Field (2007) (similar to the stages of erosion discussed in this report), describes processes and feedbacks potentially caused by Project operations that

⁴⁵ U.S. Army Corps of Engineers, 1979, Report on Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire and Vermont: Department of the Army New England Division Corps of Engineers: Waltham, MA, 185 p.

⁴⁶ Field (2007)

⁴⁷ *Id.* at p. 42 (“Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.”)

⁴⁸ Field (2012)

accentuate natural erosion processes and perpetuate a cycle of erosion in the reservoir⁴⁹. The original Field Geology Services report is still valid, and the processes it details refute the FirstLight claim that erosion cannot be attributed to Project operations. Field Geology Services provides numerous illustrations and photographs showing erosional landforms that could be caused or accentuated by Project operations (e.g., Figure 3, 4). In their reports, FirstLight provides many images showing the same erosional features, yet denies that Project operations could contribute to their formation.



Figure 8: a) Active beach face and b) remnants of a higher beach.

Figure 3. Figure 8 from Field Geology Services’ 2007 Fluvial Geomorphology Study of Connecticut River⁵⁰ shows erosion that is consistent with changing water levels forming and eroding beaches along a sandy bank of the TFI. Each “step” in the beach is consistent with water levels being at that height, possibly due to water level fluctuations, with wave-cut faces and ripples showing evidence of sediment transport away from each face.

⁴⁹ *Id.* at p. 42 (“boat waves and pool fluctuations play a role in the creation of undercuts that begin the erosion sequence”)

⁵⁰ Field (2007)



Figure 43: Seepage channels forming across a beach face.

Figure 4. Figure 43 from Field Geology Services’s 2007 Fluvial Geomorphology Study of Connecticut River⁵¹ shows erosion that is consistent with changing water levels forming and eroding beaches along a sandy bank of the TFI. In this case, Field Geology Service identified seepage channels, clearly transporting sediment away from the beach. FirstLight has denied the importance of this process and not included it in BSTEM modeling. However, its documentation has not been thorough in the reservoir.

Despite the well-reasoned and reasonable conclusions by these scientists, FirstLight has consistently contradicted independent, expert conclusions and does not acknowledge that dam operations most likely contribute to erosion in the reservoir. Instead, FirstLight has repeatedly attributed erosion to other factors and downplayed the amount of erosion occurring.

Most recently, the Erosion Causation Study is the latest report by FirstLight that selectively interprets or overinterprets results that downplay erosion in the TFI in general, and erosion attributable to Project operations specifically. FirstLight has used a proprietary software to claim that erosion is primarily due to natural flood flows through the reservoir. This computer software, BSTEM, attempts to model the erosion conditions in the reservoir. Although modeling of such dynamic systems is well known to be highly uncertain, particularly absent rigorous site-specific calibration and testing⁵², FirstLight claims a certainty from the model that is not

⁵¹ Field (2007)

⁵² Klavon, K., Fox, G., Guertault, L., Langendoen, E., Enlow, H., Miller, R., & Khanal, A. (2017). Evaluating a process-based model for use in streambank stabilization: insights on the Bank Stability and Toe Erosion Model (BSTEM). *Earth Surface*

credible. There are large uncertainties in its inputs and many “dial settings” that allow the model to be adjusted to achieve a range of results. The results do not sufficiently rule out the possibility of erosion due to water level fluctuations, which has been raised by many scientists, documented by landowners⁵³, and is supported by field observations from decades of monitoring in the reservoir.

More recently, Princeton Hydro⁵⁴ provided a systematic critique of the FirstLight Erosion Causation Study, particularly its reliance on BSTEM, which FirstLight has used to deny responsibility of erosion. The parameterization of BSTEM, and thus its results, has been similarly critiqued by an independent scientist for the US Department of Agriculture⁵⁵ and several peer-reviewed scientific papers, summarized by Klavon (2017)⁵⁶. Each of these independent experts find serious problems with the methods and results produced by BSTEM, which calls into question any interpretations by FirstLight.

1.4 Report objectives

In the remainder of this report, I summarize the ongoing erosion that is likely at least partly attributable to Project operations in the Turners Falls Impoundment (section 1). Much of this erosion analysis builds on past work by scientific experts and peer-reviewed literature about reservoir shoreline erosion. It also relies heavily on observations made by FirstLight and its consultants. For decades, scientists have presented such evidence, showing that FirstLight operations are most likely contributing to excess erosion in the TFI while acknowledging that the complexities in the reservoir prevent detailed, specific attribution to FirstLight, recreational, and natural process.

In contrast, FirstLight and its consultants have claimed to be *certain* that Project operations are not meaningfully contributing to erosion in the TFI. As a result, in Section 3 I also address the failings of the BSTEM model, which FirstLight claims shows they are not the “dominant, primary cause of erosion”⁵⁷ anywhere in the impoundment and only a “contributing cause of erosion” along 1.5 miles of shoreline (out of 44 miles)⁵⁸. Absent accurate, repeatable *documentation* of the erosional processes they favor, this modeling is not credible.

Processes and Landforms, 42(1), 191-213. p. 191 (“The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.”)

⁵³ Landowners and Concerned Citizens for License Compliance Connecticut River, Turners Falls Pool, Massachusetts. August 2nd, 2012.

⁵⁴ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

⁵⁵ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p.

⁵⁶ Klavon, K., Fox, G., Guertault, L., Langendoen, E., Enlow, H., Miller, R., & Khanal, A. (2017). Evaluating a process-based model for use in streambank stabilization: insights on the Bank Stability and Toe Erosion Model (BSTEM). *Earth Surface Processes and Landforms*, 42(1), 191-213. p. 191 (“The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.”)

⁵⁷ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume I – Executive Summary and Summary. p. vii.

⁵⁸ *Id.* p. viii

2. Evidence of erosion in the Turners Falls Impoundment

2.1 Summary

Evidence from the Turners Falls Impoundment (TFI) indicates that FirstLight operations likely contribute to erosion in the TFI. Project operations set the likely height of erosional impacts, contribute to processes that directly cause erosion on banks in the impoundment, and most likely prevent natural recovery and re-stabilization from occurring.

This evidence, summarized both here and in past studies^{59,60}, consistently points toward FirstLight operations contributing to anomalously high erosion rates throughout the impoundment. These erosional processes occur in five primary ways, which are all interrelated and very likely attributable to FirstLight operations, as supported by direct observations in the TFI, past reports from various stakeholders, and decades of peer-reviewed research on erosion.

One note: these erosion mechanisms resemble closely the proposed ‘sequence of erosion’ proposed by Field (2007)⁶¹. They align with clearly established geomorphic processes on shorelines, specifically of reservoirs with fluctuating water levels.

2.1.1 Overview of likely erosion mechanisms or “sequence of erosion” in the Turners Falls Impoundment

1. Operations of the TFI reservoir (pumped storage and conventional hydro) cause water level in the impoundment to be repeatedly raised and lowered. Water levels are also subject to natural variability and upstream projects, including Vernon Dam immediately upstream. The year-round undercutting of the bank from sub-daily river fluctuations may decrease upper slope stability. Trees are undermined throughout the reservoir, indicating further reduced stability in a feedback loop.
2. Vegetation likely cannot colonize because of repeated inundation by fluctuating water in the impoundment during the growing season.
3. Daily FirstLight fluctuations likely saturate banks and toe slopes, reducing internal strength and accelerating erosion.
4. Moderate and flood flows transport eroded sediment away from toeslopes and bars, destroying beaches that might stabilize bank erosion.
5. Overbank and bank deposition is limited, so net change *on both banks* is erosional. In a river in equilibrium, erosion occurs but is approximately balanced by deposition on the opposite bank. In the TFI, upstream flood control and sediment trapping (not by FirstLight), sediment settling in the reservoir, and loss of vegetation due to FirstLight operations likely limit such balancing deposition.

Each of these erosion mechanisms is likely directly caused or accentuated by FirstLight operations. There is no doubt that flood flows contribute to erosion in the Turners Falls Impoundment, as they do in all natural rivers. However, FirstLight operations likely also

⁵⁹ Field (2007)

⁶⁰ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

⁶¹ Field (2007) p. 11 (“FRR methodology cannot be used to make comparisons of erosion from year to year”)

contribute to erosion and allow flood flows to be more erosional than they would be in a natural river.

Rather than taking steps to mitigate ongoing erosion in the TFI, FirstLight claims that it will continue similar fluctuation of water levels and has left open the possibility of increasing fluctuations.

FirstLight justifies this potential change by claiming⁶²:

“FirstLight’s proposed changes in operations under the Agreement do not change the basic finding that FirstLight’s operations are an insignificant cause of bank erosion in the TFI. Because FirstLight’s operations under the Agreement will not be a significant cause of erosion, it is not within FirstLight’s control to prevent it; and neither should FirstLight be responsible for remediating it.” (p. 14)

The magnitude of erosion attributable FirstLight operations (“significant” vs. “insignificant”) cannot be credibly quantified due to the lack of rigor in FirstLight monitoring^{63,64,65} and unacknowledged uncertainties in the BSTEM model approach⁶⁶. However, FirstLight studies *do* document numerous field instances of bank erosion that is likely ongoing due to, and/or accentuated by, FirstLight operations. Much of the erosion documented in each study commissioned by FirstLight is consistent with regular, repeated cycles of inundation and exposure of river bars and banks that occurs at least partly as a result of Project operations. An increase in the frequent range of this inundation would likely increase erosion in the TFI. FirstLight’s arguments that it will not shows an unscientific and unsupported degree of certainty about uncertain processes, while also defying evidence in its own reports and decades of geomorphology and reservoir study.

Below, each point is explained and evidence for project operation contribution to these erosional processes is presented. In each case, the findings show that the BSTEM model is not modeling the full suite of erosional processes occurring in the Turners Falls Impoundment. The BSTEM model and FirstLight reports consistently discount or ignore erosional processes that can be attributed to FirstLight operations. BSTEM is not adequately capturing erosion processes in the TFI, nor is uncertainty reported in its presentation; accordingly, its results cannot be treated as definitive.

Several scientists have described these erosion processes and demonstrated critical failings in scientific methods and inference made by FirstLight consultants, including the most recent

⁶² Response of Firstlight MA Hydro LLC And Northfield Mountain LLC to Comments on Flows and Fish Passage Settlement Agreement. June 12, 2023. 49 p. p. 14.

⁶³ Field (2007) p. 7 (“Many areas of additional study are necessary including surveys of erosion using a systematic and explicit method for mapping the types of erosion present in order to eliminate artifacts in the mapping process.”)

⁶⁴ Field (2012) p. 11 (“FRR methodology cannot be used to make comparisons of erosion from year to year”)

⁶⁵ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. p. 5 (“Large Portions of the Turners Falls Impoundment Remain Unassessed”)

⁶⁶ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

BSTEM Model. These include two reviews since 2010^{67,68}, which are both rigorous and document failings in erosion attribution by FirstLight.

2.2 Repeated undercutting of the bank decreases upper slope stability. Trees are undermined, further reducing stability in a feedback loop

FirstLight claims several times that the upper slopes of river banks are not wetted by their operations, and only experience erosional flows during floods. However, it is clear from FirstLight's reports that Project operations regularly inundate steep banks along the TFI reservoir shoreline. Plots of water surface elevation show as much as 6 ft of daily water surface elevation changes during just one example period⁶⁹. In addition, pumping and release occurs during high-flow events. Fluctuations are thus superimposed on larger fluctuations in the hydrograph, potentially amplifying the erosional effects of those events (Figure 1, Figure 5).

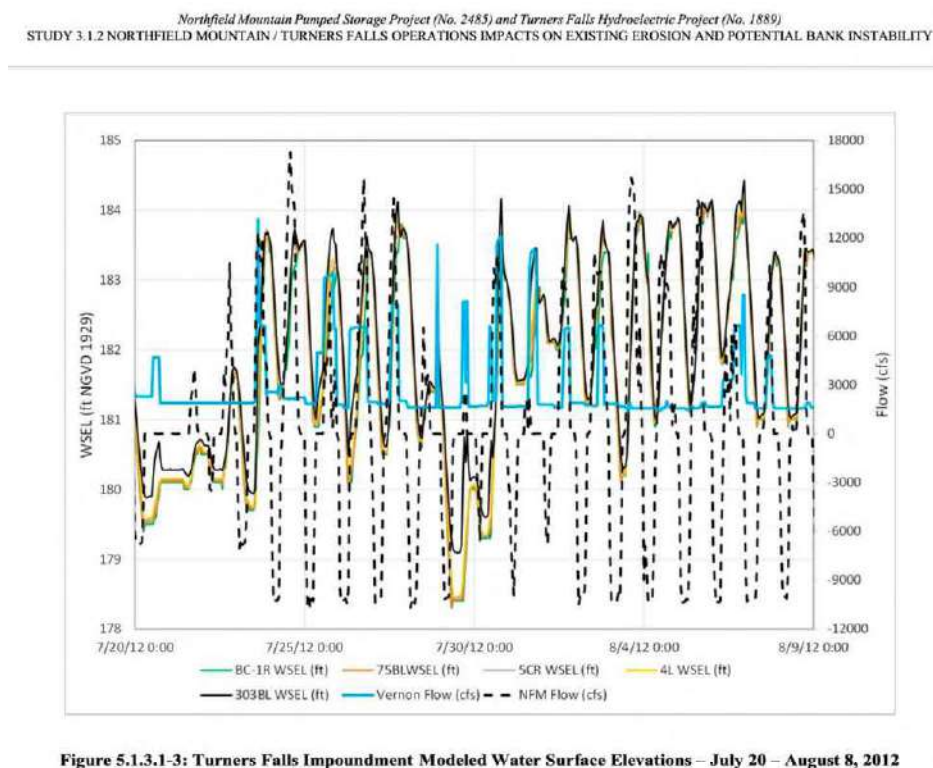


Figure 5. A plot of modeled water surface elevation from Study 3.1.2⁷⁰ shows up to 6 feet of elevation variation in an approximately weeklong stretch, with similar elevation differences at several cross-section locations in the reservoir.

⁶⁷ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

⁶⁸ Field (Field Geology Services), 2012, Rebuttal of FirstLight's Response to Landowner Filing: Unpublished report prepared for Landowners and Concerned Citizens for License Compliance Turners Falls Pool, 12 p.

⁶⁹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Figure 5.1.3.1-3: Turners Falls Impoundment Modeled Water Surface Elevations – July 20 – August 8, 2012

⁷⁰ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Figure 5.1.3.1-3: Turners Falls Impoundment Modeled Water Surface Elevations – July 20 – August 8, 2012

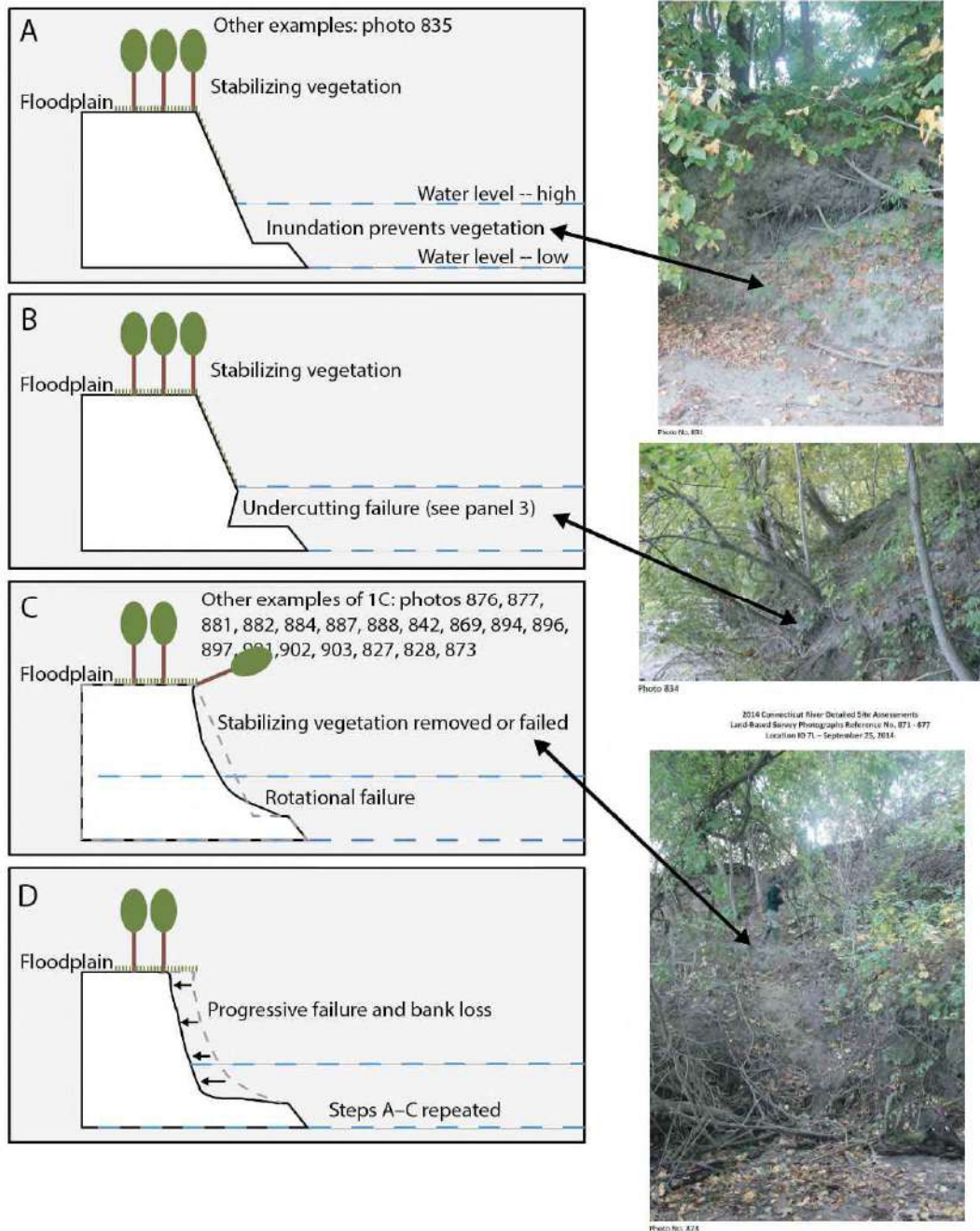


Figure 6. A diagram showing mechanisms for erosion in the Turners Falls Impoundment, specifically illustrating how water fluctuations could contribute or cause erosion of steep banks. Images from the FirstLight Erosion Causation Study on the right illustrate the erosional landforms in the diagram. Photographs are from the Study 3.1.2, Volume III, Connecticut River – Turners Falls Impoundment Riverbank Detailed Site Assessments.

Figure 6 illustrates a sequence of bank undercutting that is likely accentuated by Project operations continually fluctuating water levels up and down, saturating the bank sediments and exposing them to currents and wave action (Figure 6, A). Sediment is eroded when water levels are high, transported away from river banks, tree roots, and beaches. When the reservoir level drops, the undercut sediment may also fail as the water's confining pressure is removed. It is also more susceptible to wave and current erosion because it has been saturated. In each case, because sediment buttresses the banks, its removal destabilizes those banks (Figure 6, B). Community members have observed these processes occurring in the reservoir⁷¹:

“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.*” (p. 2) (emphasis added)

As the community members have observed, this process may occur almost daily in some places on the TFI shoreline during reservoir storage and release. Vegetation is sporadic in the lower banks, where undercutting is very common, limiting the cohesive strength of bank sediments (see Section 2, below). Undercutting of the banks can lead to failure during rain events and snowmelt periods, as has been observed by landowners⁷²:

“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.” (p. 2)

Erosion of this nature has been documented at other reservoirs, including in similar temperate climates where reservoir bank substrate is glacial sediment. Reid (1985)⁷³ found that:

“During high pool levels, waves pound that area, exposing this sand unit, resulting in rapid undercutting of the overlying till. Upon lowering of the pool level, the undercut till quickly fails”. (p. 783)

Field evidence presented in the Erosion Causation Study⁷⁴ shows similar processes are active in TFI. The combination of fluctuating reservoirs and wave and current erosion (driven by flow, wind, and/or boat wakes) leads to undercutting of steep, unvegetated banks. Upper slope destabilization consistent with consistent lower bank erosion and undercutting is documented in numerous photographs in the Full River Reconnaissance⁷⁵ (see photos 876, 877, 881, 882, 884, 887, 888, 842, 869, 894, 896, 897, 901, 902, 903, 827, 828, 873) (Figures 6–9). Three examples are provided here, showing undercutting and undermining of bank-stabilizing tree roots (Figure 7), and high bank failures above evidence of lower bank undercutting (Figure 8 and Figure 9).

⁷¹ Landowners and Concerned Citizens for License Compliance Connecticut River, Turners Falls Pool, Massachusetts. August 2nd, 2012. p. 2

⁷² *Id.*

⁷³ Reid Jr., J. R. (1985). Bank-erosion processes in a cool-temperate environment, Orwell Lake, Minnesota. Geological Society of America Bulletin, 96(6), 781-792.

⁷⁴ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

⁷⁵ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.



Photo No. 887

Figure 7. An image from the FirstLight Study 3.1.2, Volume III Appendix D (pdf page 200) shows undercutting of a lower bank has stripped vegetation, removed vegetation under tree roots, and undermined sediments on the upper bank.

2014 Photo: Montague



Observations: Erosion has been ongoing at this site for quite some time and has been recommended for preventative maintenance and/or bank stabilization work in the 2013 FRR report.

Figure 8. An image from the FirstLight Causation Study Volume II shows minimal protection by a beach of a slope failure in the reservoir disturbance zone.



Observations: This site has been eroded for some time and was recommended for preventative maintenance and/or bank stabilization work in the 2013 FRR report.

Figure 9. An image from the FirstLight Causation Study Volume II shows that undercutting erosion can occur on steep banks even when there is a well-developed beach protecting them.



FIG. 2. Erosion in frozen lacustrine clay at site 1.

Figure 10. An image from Southern Indian Lake in Manitoba, Canada shows erosion that strongly resembles erosion depicted in images of the shoreline of the Turners Falls Impoundment.⁷⁶ Researchers attributed Southern Indian Lake erosion partly to inundation and devegetation of the banks, which combined to reduce sediment cohesion.

Other researchers have reported on reservoir shoreline erosion attributable to lack of bank cohesion that strongly resembles erosion at TFI (Figure 10). At Southern Indian Lake, a dam-regulated reservoir in Manitoba, shoreline substrate, although frozen, is unconsolidated glacial sediment similar to that in the TFI, with grassy vegetation and trees providing some strength⁷⁷. Researchers found that wave energy and inundation were found to cause an erosional feedback loop, with an anticipated 35 meters of horizontal erosion forecast before bedrock would be encountered. The researchers observed the inundation of frozen sediments, after which “bank materials become oversaturated with water and form a slurry-like mixture. The partially thawed materials flow out” and are subsequently “completely removed during storms”⁷⁸. The processes and feedback loop described here are very similar to the “sequence of erosion” described by Field Geology Services (2007)⁷⁹ and here in the five-step erosion feedback loop.

⁷⁶ Newbury, R. W., & McCullough, G. K. (1984). Shoreline erosion and restabilization in the Southern Indian Lake reservoir. *Canadian Journal of Fisheries and Aquatic Sciences*, 41(4), 558-566. p. 561 Fig. 2.

⁷⁷ Newbury, R. W., & McCullough, G. K. (1984). p. 561 Fig. 2.

⁷⁸ Newbury, R. W., & McCullough, G. K. (1984). p. 561 (“melting occurs below and slightly above the water surface.”).

⁷⁹ Field (2007) p. 11 (“FRR methodology cannot be used to make comparisons of erosion from year to year”)

In addition, FirstLight downplays the magnitude of existing fluctuations in the TFI. For all of the days (other than May – November 2010) that were modeled, they report that 15% of the daily water surface elevation variations were less than 1.6 feet and about 95% were less than 4.0 feet. However, this means that 85% of days have > 1.6 feet of variation – constant rise and fall of water level consistent with erosion on beaches, bars, and steep banks that are not protected by beaches. The 5% of days with more than 4.0 feet of elevation change likely accentuated erosion further.

2.3 Vegetation cannot colonize because of repeated inundation during the growing season.

The second component of the erosion feedback loop is the removal of vegetation along beaches, benches, and steep banks of the reservoir shoreline by frequent inundation. In the Connecticut River watershed, erosion is generally low compared to other regions⁸⁰ despite abundant unconsolidated glacial sediments in the river valley. The general stability of riverbanks in the Connecticut River watershed, and New England generally, is mostly explained by the presence of abundant stabilizing vegetation in the region, which has approximately 80% forest cover and pervasive riparian vegetation.

Many plant species not suited to water are threatened by any inundation, and substantial loss of vegetation due to inundation in the reservoir disturbance zone has been documented along other reservoir shorelines⁸¹. FirstLight’s own HEC-RAS modeling shows that flows rest on the upper bank between 1–22% of the time for selected reaches—10–20% of the time is substantial and consistent with numerous images in the FirstLight Full River Reconnaissance, as well as the 2007 Field Report, showing bare tree root balls, devegetated banks and bars, and undercut slopes⁸² (Figure 11).

Figure 11 shows the cycle of devegetation that can occur from frequent inundation. As FirstLight stated in their Full River Reconnaissance in 2008⁸³:

“Vegetation plays a significant role in the stability of riverbanks. Vegetation colonizing and expanding onto a riverbank where vegetation did not exist or was sparse indicates that the riverbank is becoming more stable. As vegetation expands and matures, it offers greater protection against erosion.”

Vegetation is not able to colonize banks in the reservoir disturbance zone due to unsuitable conditions. Lack of vegetation prevents sediment trapping, leading to beach and bank instability and further erosion. The absence of root cohesion also limits shoreline resistance to erosion.

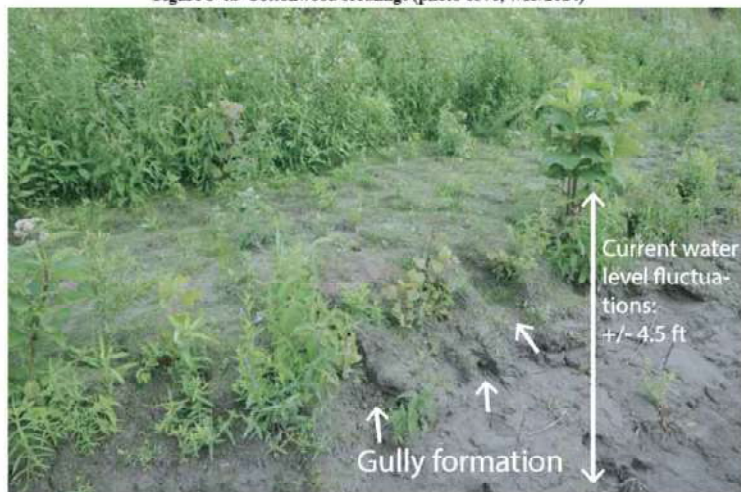
⁸⁰ Rainwater, F.H., Stream Composition of the Conterminous United States, USGS Atlas HA 61, Washington, D.C., 1962.

⁸¹ Bao, Y. et al.(2018). p. 136 (“Influenced by this new hydrological regime, the abundance of the original plant species within the [Disturbance Zone] has been drastically reduced”); Fig. 7.

⁸² FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

⁸³ FirstLight Full River Reconnaissance. 2008 TURNERS FALLS POOL, CONNECTICUT RIVER. p. 27.

Figure J-4.9 Cottonwood seedlings (photo 6576, 7/15/2014)



Inundation and erosion during hydropower water level fluctuations (see panel 3) and floods prevent stable conditions necessary for vegetation establishment. While these flows can contribute to seed dispersal, they also remove soil necessary for root establishment.

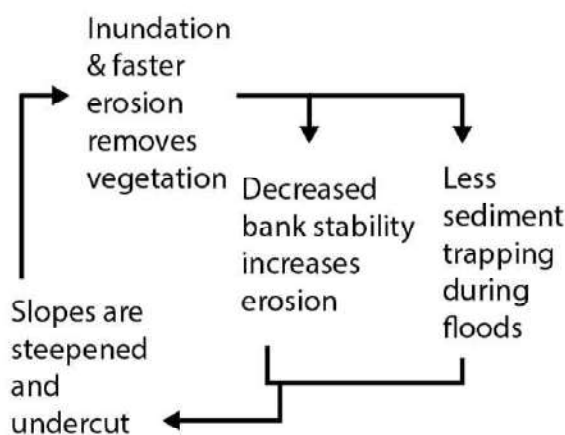


Photo 828

Progressive erosion has occurred during years of unreliable vegetation colonization. This erosion contributes to bank loss. Many images are similar to this one: overhanging trees with soils eroded from their roots. These trees were once part of stable riparian buffers, but have been steadily lost, likely reducing flood resilience.

Figure 11. A diagram showing the erosion feedback loop that occurs with devegetation. Inundation removes vegetation or prevents vegetation from successfully growing. Upper⁸⁴ and lower⁸⁵ images are from FirstLight surveys; annotations and text are from this report. Lack of vegetation lowers root-based cohesion of the banks and traps sediment less effectively, leading to further destabilization and heightened erosion. This diagram is illustrated by ongoing, linked erosional and devegetation processes in the Turners Falls Impoundment, each of which is consistent with erosion caused or aided by fluctuating water levels due to Project operations.

⁸⁴ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix J.

⁸⁵ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

Vegetation that does colonize steep reservoir banks during the summer may not persist through the late fall and winter, leaving slopes susceptible to erosion especially during those months. Even where trees have maintained root structure, frequent inundation likely limits understory growth, allow rapid erosion and progressive undermining of larger trees. Lack of understory was documented at least at two sites by FirstLight and reported in the Erosion Causation Study⁸⁶:

“It should be noted that although the tree cover is 95% and 70% at sites 75BL and BC-1R respectively, the understory data at these locations indicates a high percentage (80%) of the soil under the trees is bare. In these cases, although the trees are contributing to root-reinforcement within the banks themselves, there is less surface protection from hydraulic forces.” (p. 4-113)

However, in FirstLight’s response to the Princeton Hydro letter, they defend the BSTEM model inputs by directly contradicting their own field observations, saying “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*”⁸⁷ (emphasis added). The banks are only vegetated sporadically, and are mostly unvegetated in many of the critical erosion locations. The inputs to BSTEM are thus both flawed and incomplete, casting doubt on its results.

Revegetation is also a primary factor in the recovery of destabilized slopes. In the case of bank failure caused by flooding, undercutting, freeze-thaw processes, or other causes, revegetation can stop the sequence of erosion, preventing the erosion feedback loop from running unchecked. In its analysis of erosion sources, FirstLight does not account for how the lack of stabilizing vegetation prevents banks from recovering once they are perturbed. Similarly, BSTEM only uses a one-time vegetation parameter. Because it does not seem as though vegetation is allowed to vary or evolve during the model, BSTEM is not accounting for critical changes in bank cohesion and thus erodibility that may be attributable to FirstLight Project operations.

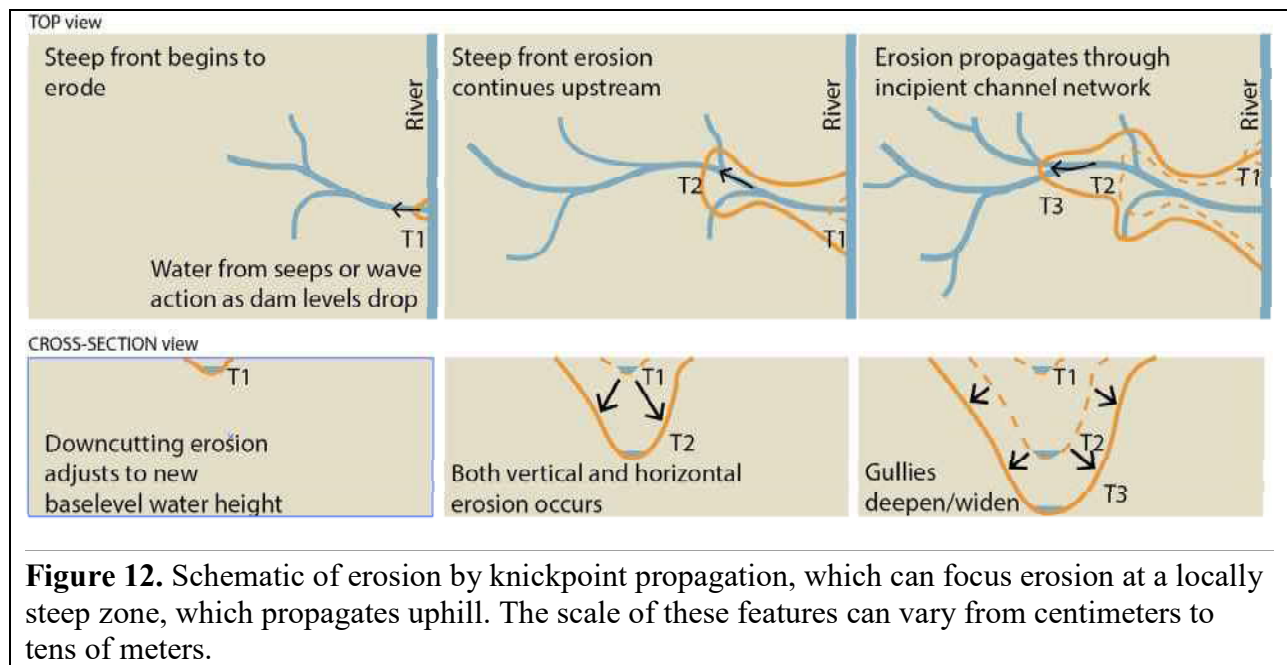
2.4 Daily FirstLight fluctuations likely saturate banks and toe slopes, reducing internal strength and accelerating erosion.

2.4.1 Fluctuations can cause sapping, rilling, and gulying in bank sediments

As water levels rise and fall over unconsolidated sediments, progressive erosion can occur on beaches, bars, and banks – even those that are not as steep as the undercut banks in (Section 1). Sapping occurs when confining pressure from surrounding water is removed from saturated sediments. Resulting flow through the sediments can “sap” the bank of its water and sediment, transporting eroded sediment toward the receding water. Rilling, gulying, and knickpoint propagation can also occur. These processes occur in natural circumstances by runoff over the ground during precipitation or melting events. The erosional power of this runoff is focused where the bank or beach slope is locally steep (Figure 12).

⁸⁶ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 4-113

⁸⁷ FirstLight Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary. January 17, 2017. p. 2

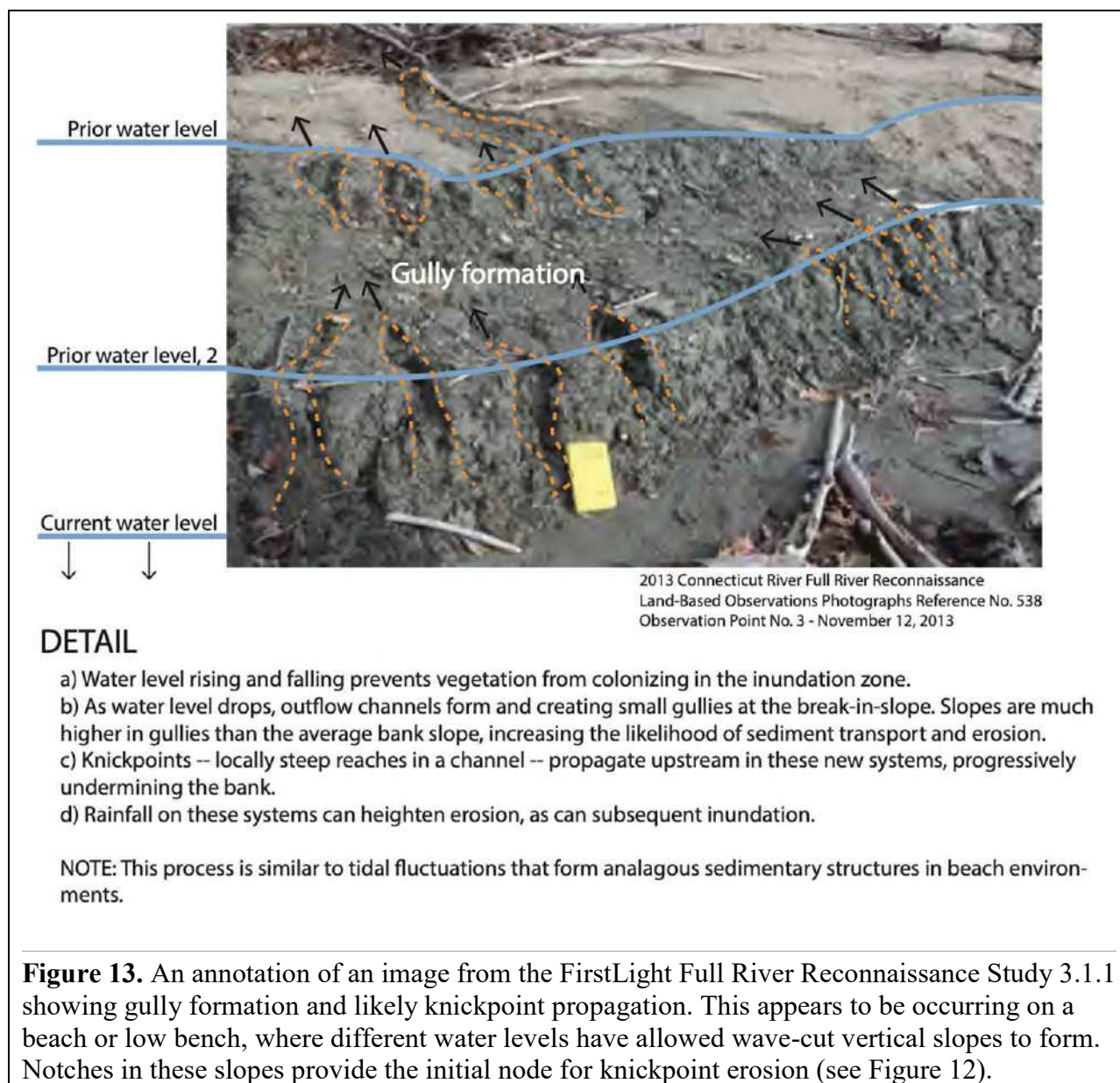


Sapping and local oversteepening of the bank can occur during rapid water level recession, which is often called “baselevel fall”. Kaczmarek et al., (2016) found evolution of gullies to be strongly related to reservoir water fluctuations⁸⁸:

“In periods of high water levels, due to coastal erosion of the bluff, the terminal, flattest parts of the gully were destroyed, which triggered their further development. In contrast, declining water level in the reservoir is a cause of intensified deep erosion in the gully bottom, which consequently initiates backward erosion at the bottom of these forms.” (p. 937)

Gullying, rilling, and knickpoint erosion are part of strong erosional feedback loops, as the locally oversteepened point progressively moves uphill, cutting farther into the bank. This process is illustrated in Figure 12 (diagram) and Figure 13 (annotated photograph), which show the process of gully development as it appears to occur along the shoreline of the TFI.

⁸⁸ Kaczmarek et al. (2016)



The “FL Response to Study Comments” states: “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.”

However, numerous photographs provided by FirstLight consultants in the Erosion Causation Study directly contradict this claim that there is minimal erosion in the flat, beach-like lower bank. This includes the photograph in Figure 13, as well as photos 583 (Figure 14), 638 (Figure 15), 698 (Figure 16), 709 (Figure 17), 833, 834, 882, 796⁸⁹, J-4.1 (Figure 18), and J-4.9⁹⁰ from

⁸⁹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

⁹⁰ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix J -- Ice Data And Supplemental Information.

the 2017 FirstLight Erosion Causation Study. These photographs show significant erosion, including rilling, bank failure, devegetation, and winnowing of sediment in the lower bank zone. They also include successive benches on beaches, each showing gullying that was likely initiated by dropping water levels. As was noted by the Princeton Hydro review⁹¹, ***the fact that the BSTEM model failed to capture sediment transport or significant erosion in these lower bank zones indicates its failure to capture critical erosion dynamics in the TFI.***

These landforms and features are not all necessarily caused by Project water level fluctuations. However, they are clearly consistent with erosion by water level fluctuations and occur at elevations set by Project-determined water levels. Gullying has been consistently identified as a result of shoreline erosion related to changing water levels⁹². In Poland, erosion in glacial sediments similar to those in the TFI caused gullying on a variety of scales, with development strongly resembling gullies documented by FirstLight in the TFI⁹³:

“...gullies disturbed the stability of the bluff by developing in the easily degraded sandy-silty deposits, their dense network deeply indents the bluff and disrupts its continuity. Their development is cyclic and ***strongly related to water level fluctuations in the reservoir.***” (p. 932) (emphasis added)

This passage highlights the challenges with gully erosion if it is left unchecked. The local steepening of slopes continues to propagate into the bank and perpetuate the cycle of erosion being outlined here. Especially absent stabilizing vegetation (See Section 2) or the presence of bedrock⁹⁴, this propagation can also contribute to undercutting of steeper banks or undermining of upper banks (See Section 1), leading to mass failure.

Significant erosion at or near the low-flow water line is shown in the following photos and many others. In Figures 13–16, low, steep banks on several beaches show evidence of notching, which can be an initiation point for knickpoint erosion. In several instances, these steep banks have multiple wave-cut elevations, consistent with water levels fluctuating and thus focusing erosion at a certain beach elevation.

2.4.2 High water levels can exacerbate bank erosion during spring snowmelt

Saturation of sediments along the reservoir shoreline, especially given the lack of vegetation and root cohesion, also increases bank susceptibility to erosion during the spring snowmelt period. Freeze-thaw processes can physically wedge apart the banks, in processes similar to the ones that cause frost heaves in roads. Water that percolates into sediment pore space freezes and expands, wedging apart sediment. This can either cause erosion directly or make extra space for more

⁹¹ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. p. 13 (“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.”)

⁹² Kaczmarek et al. (2016) p. 937 (“In periods of high water levels, due to coastal erosion of the bluff, the terminal, flat- test parts of the gully were destroyed, which triggered their further development. In contrast, declining water level in the reservoir is a cause of intensified deep erosion in the gully bottom, which consequently initiates backward erosion at the bottom of these forms.”).

⁹³ Kaczmarek et al. (2016). p. 932 (“Gully development is also partly due to linear erosion, which is particularly important during summer rainstorms. Such forms appear frequently on primary pathways of surface runoff from local microcatchments.”).

⁹⁴ Newbury, R. W., & McCullough, G. K. (1984). p. 561 Fig. 2.

water to intrude, leading to more “frost wedging” and/or increasing the potential saturation of the banks during the spring. If the bank remains intact through the frost-wedging period, the extra water it retains can cause it to liquefy when the ice melts because of the loss of internal sediment grain contact and cohesion. Each of these well-known erosion processes may be increased by frequent saturation because of Project operations fluctuating water levels in the reservoir.

The FirstLight Erosion Causation Study does not account for freeze-thaw erosion of steep banks. The Causation Study and BSTEM also do not specifically model winter and spring snowmelt conditions, which, due to the processes described above, are both complex and lead to far higher erosion susceptibility than summer in the Connecticut River.

The Erosion Causation Study makes two admissions about freeze-thaw erosion. The first is that these processes have mostly been ignored by FirstLight studies of the reservoir, despite the importance of the snowmelt period in erosion in the Connecticut River watershed⁹⁵:

“No actual data exist that allows quantification of the effect of freeze-thaw cycles on riverbank stability in the TFI. Freeze-thaw is a natural process that is primarily influenced by weather and climatic cycles and is not considered a primary factor in riverbank erosion processes in the TFI, nonetheless it is likely to contribute to riverbank instability to some lesser degree.” (p. 5-271)

As this passage states, although FirstLight acknowledges the likely contribution of freeze-thaw to erosion processes, they have not collected any data about it. As a result, all of the claims about erosion in the TFI are at least partly based on conjecture.

The second admission is the possible importance of ice processes in killing vegetation in the reservoir⁹⁶:

“Ice both destroys riparian vegetation and limits its establishment and growth as demonstrated by various analyses and observations (and has been quantitatively demonstrated by vegetation demography studies, analysis and computer modeling that ice plays a “*significant, if not dominant*” role in removing and limiting riparian vegetation on the Platte River). As shown in the erosion causation study, riparian vegetation plays a significant role in riverbank stability” (p. 5-303)

Indeed, the contribution of freeze-thaw processes may be substantial. As noted in a similar geologic setting in Poland by a high-resolution study by Kaczmarek et al (2019)⁹⁷:

⁹⁵ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report.

⁹⁶ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report.

⁹⁷ Kaczmarek, H., Tyszkowski, S., Bartczak, A., Kramkowski, M., & Wasak, K. (2019). The role of freeze-thaw action in dam reservoir cliff degradation assessed by terrestrial laser scanning: A case study of Jeziorsko Reservoir (central Poland). *Science of the total environment*, 690, 1140-1150.

“As a result of the creation and operation of this water body, the formation of bare, nearly vertical cliff faces (which were absent in this location before the impoundment) facilitated the frost processes, and their course is specific, having no equivalent in natural conditions. When the water level is high, the periodical wave erosion at the bluff toe does not allow stabilization of the transformed cliff and long-term accumulation of talus slopes protecting the bluff toe. In such conditions, the whole cliff face is subject to frost processes.” (p. 1149)

In this reservoir in Poland, on years when water levels are high and wave action can contribute to erosion, frost action contributes approximately 20% of annual erosion. When water levels are low, frost action contributes approximately 70% of annual erosion.

FirstLight thus acknowledges that freeze-thaw erosion processes may be important contributors to reservoir erosion, that no data have been collected about them, and that riparian vegetation may be destroyed by ice processes related to Project operations. However, these are relegated to a section mostly devoted to abrasion and gouging by ice floes.

In their rebuttal to the Princeton Hydro memo, FirstLight states that “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.”⁹⁸ Yet its reports do not sufficiently measure or model erosion during this critical period: snowmelt in the winter and spring. Despite the importance of this period in cold climates, processes associated with snowmelt and freeze-thaw are discounted and/or not measured by FirstLight⁹⁹:

“it was noted that ice typically does not cause erosion if the ice simply melts in place without significant break-up and if ice floes moving down river causing ice jams and impacting banks do not occur. This is consistent with the findings of the historic analysis conducted and with observations made during field monitoring which occurred during the 2014/2015 winter when much of the TFI was frozen over but the ice simply melted in place during the later winter, early spring of 2015. 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.” (p. 5-245)

This ice jam dismissal is cursory and not scientific, but also misses an important point: freeze-thaw processes can contribute to erosion even without ice flows. Landowners along the river have observed such erosion, potentially magnified by boat wakes, as they documented in a 2016 letter¹⁰⁰:

“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... 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

⁹⁸ FirstLight Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary. January 17, 2017. p. 2

⁹⁹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 5-245

¹⁰⁰ Bathory letter (2016) p. 2

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.” (p. 2)

In not measuring or considering freeze-thaw processes¹⁰¹ and ignoring these first-hand observations, FirstLight is potentially missing a major source of erosion, which Project-caused water fluctuations and devegetation could accentuate. Their contribution to erosion in the TFI must be rigorously quantified in order for the claims of erosion timing and attribution to be considered valid.

**2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 581 - 588
Observation Point No. 11 - November 13, 2013**



Photo No. 583

Figure 14. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 11 showing a wave-cut beach and incipient gullying.

¹⁰¹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume I – Executive Summary and Summary. p. vii (“a quantitative analysis of the impact of ice as a cause of erosion was not possible given weather conditions during the monitoring period and available historic data”)

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 638 - 641
Observation Point No. 17 - November 15, 2013



Photo No. 638

Figure 15. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 17 showing a wave-cut bench, fallen-down sediment blocks, and incipient gullying.

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 691 – 696, 698 - 699
Observation Point No. 24 - November 16, 2013



Photo No. 698

Figure 16. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 24 showing a wave-cut bench, fallen-down sediment blocks, and incipient gullying.

**2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 705 - 710
Observation Point No. 25 - November 16, 2013**



Photo No. 709

Figure 17. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 25 showing a wave-cut bench, fallen-down sediment blocks, and incipient gullying.

Figure J-4.1 Maple seeds (photo 0202, 9/28/2015)



Figure J-4.2 Location of photo #0202



Figure 18. Photograph from the FirstLight Relicensing Study 3.1.2 Appendix J, showing maple seed dispersal but also challenges with vegetation establishment, given frequent inundation and signs of incipient gullyng.

2.5 Moderate and flood flows transport eroded sediment away from toeslopes, beaches, and bars.

In the alluvial sections of the Connecticut River watershed, where the Turners Falls Dam is located, the substrate is mostly comprised of erosion-prone sediments and occasional bedrock¹⁰². Although Connecticut River streams and rivers generally erode slowly, sediment is mobilized during flooding that is endemic to the region. Moderate floods transport sediment that is not

¹⁰² Field (2007)

secured by vegetation¹⁰³. Larger floods can strip vegetation and undermine steep banks, leading to much more erosion. Even without high flows, riverbanks without perennial vegetation can erode as snowpack melts in the spring (typically March and April). However, during the summer low-water season, very little erosion occurs unless a flood occurs.

The role of flood flows in erosion in the TFI is summarized in Figure 19. The annotated images illustrate erosional processes consistent with flood transport. Erosion is a natural process that occurs along all rivers and does not, by itself, indicate compromised river health or processes. However, as is shown in the figure, natural erosion processes may be accentuated by Project operations, including steep or overhanging banks that are prone to erosion and lack of vegetation that can provide cohesion for sediments and slow flood flows, leading to deposition rather than erosion.

¹⁰³ Renshaw, C. E., Dethier, E. N., Landis, J. D., & Kaste, J. M. (2022). Seasonal and longitudinal variations in suspended load connectivity between river channels and their margins. *Water Resources Research*, 58(4), e2021WR031212.

Flows onto low banks and benches have removed soil. This can reduce the stabilizing effects of vegetation and undermine banks, causing trees to collapse. These effects and others are evident in numerous photographs from the Erosion Study.

2014 Connecticut River Detailed Site Assessments
Land-Based Survey Photographs Reference No. 836 - 843
Location ID 8C-1R – September 24, 2014



Photo No. 840



Photo No. 841

Ripples on this beach indicate transport away from the base of the bank. The image shows clearly several fallen trees that have collapsed as the bank was undermined. Also clearly shown are the tree roots with soil removed from them.

Other examples: photos 874, 876, 877, 881, 882, 884, 887, 840, 841, 798, 904, 809, 812, 814, 826, 827, 828, 904

2014 Connecticut River Detailed Site Assessments
Land-Based Survey Photographs Reference No. 871 - 877
Location ID 7L – September 25, 2014



Photo No. 875

2014 Connecticut River Detailed Site Assessments
Land-Based Survey Photographs Reference No. 885 - 891
Location ID 8BL – September 25, 2014



Photo No. 887

Figure 19. Annotated photographs from FirstLight Relicensing Study 3.1.2, Locations 8C-1R (left), 7L (upper right), and 8BL (lower right), showing evidence of bank undercutting, sediment transport, and vegetation removal that are consistent with Project-caused water-level fluctuations.

In the Turners Falls Impoundment floods likely transport sediment in processes that resemble unregulated river reaches in the region. FirstLight identifies these floods as the sole “significant” or “dominant” cause of erosion in the TFI. Floods may be the largest cause of erosion in the reservoir¹⁰⁴. However, the geomorphic effectiveness of these floods is likely accentuated by the bank destabilization due to devegetation and saturation described above and in prior reviews by independent scientists^{105,106}.

The challenge of attributing erosion to flood flows alone was highlighted by Field (2007), who analyzed annual erosion at monumented cross sections in the TFI, relative to flood magnitudes for those years. They found that peak annual discharge did not have a direct relationship with measured erosion¹⁰⁷:

“The year with the highest peak discharge since 1990 at the Montague gauge was 1998, a year in which the greatest one-year change in bank position did not occur at any of the cross sections. A careful analysis of rainfall in the area preceding these flood events would be needed to determine if variations in soil moisture can explain the variations in response to these larger flood events. The most significant period of bank recession for several cross sections occurred in the early 1990’s with average rates of recession ranging between 1.7 and 4.5 ft/yr during this short time period (Table 5). No high flood discharges were recorded during this period (Figure 4).” (p. 30)

In addition, a raised water level allows floods to erode higher on the bank. Flood water levels will be elevated by the number of feet the water level is raised. Although FirstLight claims that there is minimal effect of Northfield Mountain generation during high flows, they actually report that flood heights are raised by as much as 1.5 feet when generation is at 10,000 cfs and river flows are 30,000; 40,000; 50,000; and 60,000 cfs. This is equivalent to 20–30% additional discharge during some floods¹⁰⁸. The erosional impact of this additional discharge and flood elevation is not quantified by FirstLight, nor do they claim responsibility for any additional erosion that may occur.

Project operations may also limit recovery. After an erosional event, relatively rapid revegetation can restabilize sediments, preventing chronic erosion. However, the normal recovery processes that follow floods are also consistently disrupted by post-flood inundation/exposure cycles during Project operations, extending the erosional sequence. These are summarized above in sections 1–3.

¹⁰⁴ U.S. Army Corps of Engineers, 1979, Report on Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire and Vermont: Department of the Army New England Division Corps of Engineers: Waltham, MA, 185 p.

¹⁰⁵ Field (2007) p. 42. “Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.”

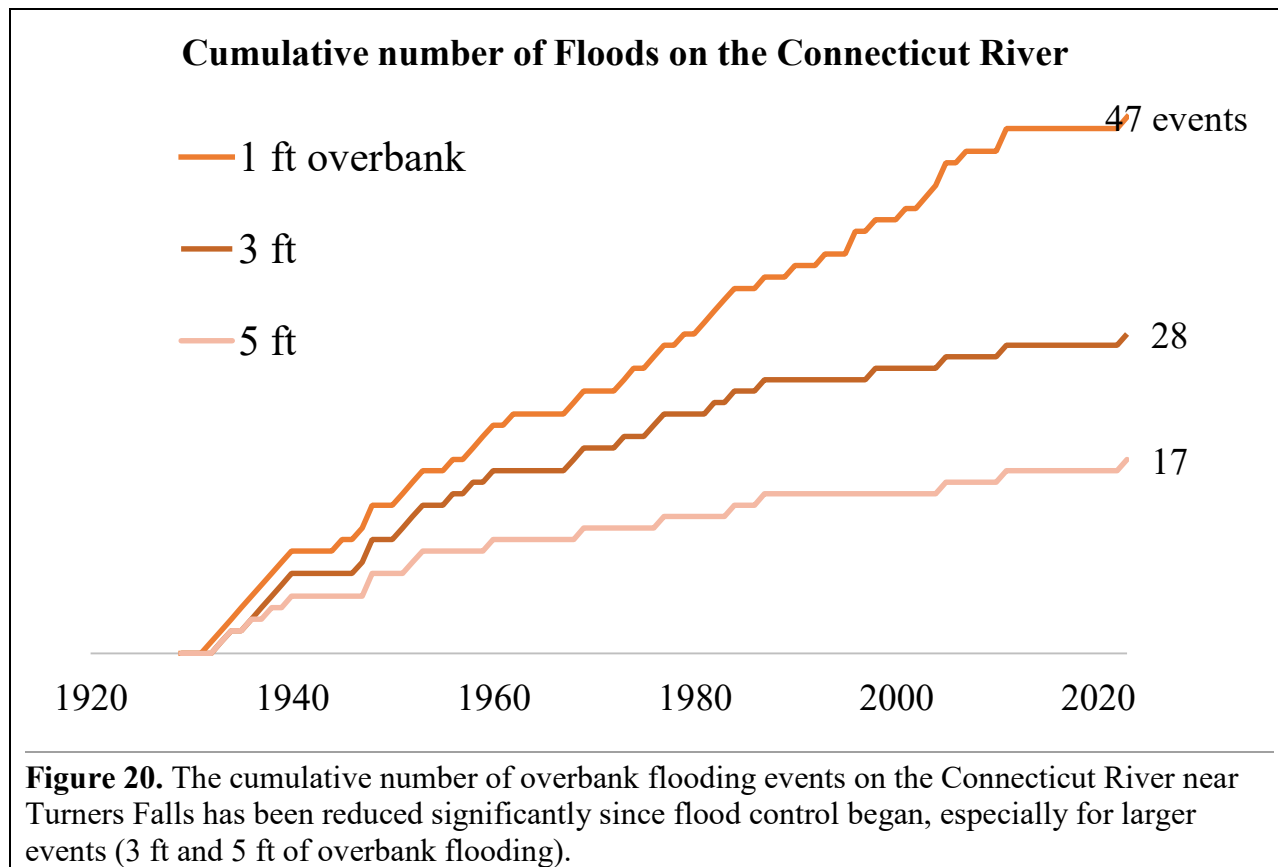
¹⁰⁶ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

¹⁰⁷ Field (2007) p. 30.

¹⁰⁸ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 5-30 and accompanying figures.

2.6 Flood control and loss of vegetation limits overbank and bank deposition, so net change is erosional.

Prior to flow regulation by dams, the Connecticut River would regularly overtop its banks, replenishing floodplain sediments. Since flood-control dams were constructed in the mid-20th century, this natural floodplain exchange has been reduced. From 1961–present, the Connecticut River has only had substantial flow (> 3 ft) onto its floodplains 12 times (Figure 20).



In a normal alluvial reach in equilibrium, erosion is typically balanced by deposition. However, significant bank erosion is present throughout the reach, with only transient deposition on beaches, which are often destroyed by floods in the reservoir¹⁰⁹.

The presence of erosion without evidence of deposition may indicate that Project operations are both contributing to erosion and preventing deposition. Rapid erosion on both banks is also shown in cross sections surveyed by FirstLight. In 2007, Field¹¹⁰ noted that erosion occurred on both sides of the TFI, as opposed to a typical alluvial river in equilibrium, where erosion on one

¹⁰⁹ Field (2007). p. 32 (“However, if river currents still periodically remove sediment at the base of the bank or remove the accumulating beach sediment entirely, then notching and undercutting at the base of the bank can be rejuvenated and the bank will once again be prone to further erosion.”); p. 43 (“The presence of higher beach deposits preserved at the base of the bank, particularly in protected areas, suggest prior beaches have been removed by scour”).

¹¹⁰ Field (2007). Table 5.

bank is approximately balanced by deposition on the opposite bank or bars. This does not appear to be the case in the TFI, where erosion predominates (Figure 21).

The prevalence of these erosional sites are ignored or summarily downplayed by Erosion Causation Study text, particularly the Executive Summary¹¹¹. Considerably more slopes are vertical/overhanging than indicated in the study. Extensive erosion is also shown in the 2016 Hydraulic Study addendum¹¹². Evidence of deposition is not presented. Downplaying or underreporting erosion in the TFI is consistent with past reports by FirstLight¹¹³.

¹¹¹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume I – Executive Summary and Summary Report

¹¹² Relicensing Study 3.2.2 Hydraulic Study Of Turners Falls Impoundment, Bypass Reach And Below Cabot Addendum. March 2016.

¹¹³ Field (Field Geology Services), 2012. p. 6 (“However, the dates on the photographs are in some cases inaccurate and the angles and distances from the bank vary between photographs giving rise to a misleading impression of bank stability when either no change has occurred or the purported change can’t be confirmed.”)

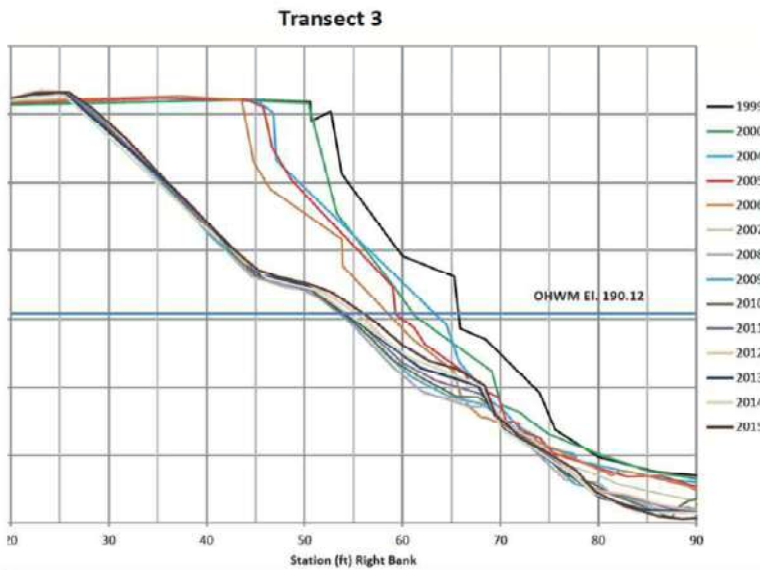
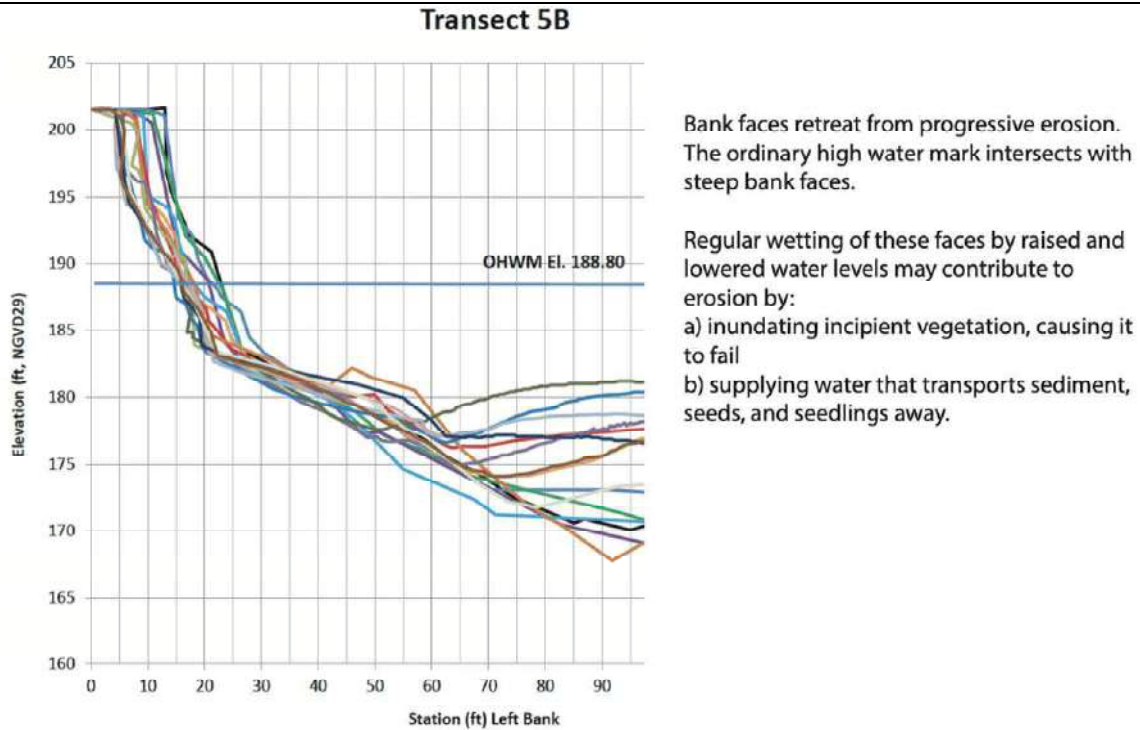


Figure 21. Cross-section profile analysis shows erosion of the shoreline in the Turners Falls Reservoir. These surveys have been conducted approximately annually by FirstLight as a requirement of its current FERC license. High rates of erosion have occurred coincident with large flood events; for instance, historic Tropical Storm Irene caused major flooding and erosion throughout the Connecticut River watershed in 2011. A single at-a-point erosion value per year at these sites does not provide sufficient detail to attribute erosion to certain mechanisms. However, these spatial erosion patterns are consistent both with erosion by flood flows and by water level fluctuations from Project operations, or, more likely, a combination of both.

3. Peer review of FirstLight reports and BSTEM methodology

3.1 Summary

Many of FirstLight's claims rest on a bank erosion model, BSTEM, which was developed by the consultants who prepared the Erosion Causation Study. BSTEM has been used for some peer-reviewed studies, which find it to be a sometimes useful, but inconsistent tool for estimating erosion¹¹⁴.

Because of the substantial back-and-forth about the Full River Reconnaissance, the Erosion Causation Study, and BSTEM, it seems more valuable to focus on the general failings of the FirstLight studies and BSTEM model (see above), as well as constructive steps to study and reduce erosion in the TFI. However, the following points emphasize specific continuing areas of concern that make the BSTEM model less certain than implied by FirstLight denials of responsibility. ***Any use of BSTEM by FirstLight should be strongly caveated until BSTEM suitability and statistical rigor can be shown.***

The BSTEM Model has substantial uncertainties and lack of transparency in its application to TFI. Although it has been used in several academic studies, a "state-of-the-science" review of BSTEM found it to have uneven success¹¹⁵:

"The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters." (p. 191)

There are several concerns documented below. These are in addition to, and have some overlap with, the many concerns raised by PrincetonHydro in their Peer Review, which were not satisfactorily rebutted by FirstLight in its rebuttal (*Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary*, date: 1/17/2017), as well as those by US Department of Agriculture scientist Eddy Langendoen¹¹⁶.

3.2 Rough field methods were used despite available of high-quality data

Due to the reduction in cohesive forces (vegetation root systems, sediment grain contacts) and increase in bank slope by undercutting, the slope stability of undercut banks is likely very low. A model evaluating the sources of erosion should incorporate these oversteepened banks, which are often vertical or overhanging. However, despite measuring detailed cross-sections in the TFI for decades as a requirement of its current FERC license, FirstLight does not incorporate the high-

¹¹⁴ Klavon, K., Fox, G., Guertault, L., Langendoen, E., Enlow, H., Miller, R., & Khanal, A. (2017). Evaluating a process-based model for use in streambank stabilization: insights on the Bank Stability and Toe Erosion Model (BSTEM). *Earth Surface Processes and Landforms*, 42(1), 191-213. p. 191 ("The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.")

¹¹⁵ Klavon et al. (2017).

¹¹⁶ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p.

resolution from these cross-sections in the BSTEM model¹¹⁷. Although it is not perfectly clear, given the confusing and sparse descriptions of their methods, it appears that FirstLight used an extremely simple bank geometry parameterization to run BSTEM, generated by “rough surveys of the tested banks”¹¹⁸:

Rough surveys of the tested banks were also carried out at each site with a tape and Brunton compass to provide bank heights, angles, and stratigraphic layering for the tested bank. The data collected in the field were used by Cardno to populate BSTEM-Dynamic 2.3. (p. 4-65)

“Rough surveys” are not sufficient for parameterizing this sensitive model, and no explanation is given for why detailed measurements were not used instead. Such rough surveys would underestimate the effect of locally high slopes. In particular, steep and overhanging slopes that are common in the reservoir are likely not captured in this approach, nor are locally high slopes that may be the nexus of knickpoint erosion (See Section 2.3).

The BSTEM model similarly does not appear to have a way of predicting progressive bank failure by undercutting or rotational failure that may occur when buttressing fails. This is a potentially serious oversight that would shift erosion attribution toward flood flows and away from failure of steep banks during periods of saturation.

Even when field data are incorporated into the model, measurements are often averaged and then applied generally, both at individual sites and by extrapolating to other sites in the TFI (see *Extrapolation*, below). This type of averaging is acceptable in some scientific approaches but must be accompanied by uncertainty and sensitivity analyses to demonstrate that the results do not change dramatically within the range of possible input data.

3.3 BSTEM toe transport is highly uncertain

Sediment transport at bank toes is a complex, highly uncertain process. This uncertainty, and its ramifications for the use of BSTEM, is described in the USACE manual for BSTEM use¹¹⁹:

“Also, it should be noted that most of these transport functions were derived for one-dimensional alluvial transport at the cross section scale. BSTEM applies these transport functions to bank scour at the node scale. This makes transport functions, already uncertain in their intended setting, loose process analogies in toe scour. ***The transport functions often over predict scour substantially*** and results should be interpreted carefully.” (Emphasis added)

Although written in technical language, the message from US Army Corps of Engineers is clear: BSTEM tends to overestimate erosion by flooding due to the uncertainty and bias in sediment transport functions in the model. This could directly lead to mis-attribution of erosion to flooding.

¹¹⁷ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 4-65. (“Rough surveys of the tested banks were also carried out at each site with a tape and Brunton compass to provide bank heights, angles, and stratigraphic layering for the tested bank. The data collected in the field were used by Cardno to populate BSTEM-Dynamic 2.3.”)

¹¹⁸ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report

¹¹⁹ <https://www.hec.usace.army.mil/confluence/rasdocs/rassed1d/1d-sediment-transport-user-s-manual/bstem-user-s-manual/transport-function-bstem>

Despite these cautions from independent reviewers of the BSTEM model, FirstLight in the Erosion Causation Study does not completely document or justify the shear stress and cohesion calculations used to estimate erosion. The erodibility coefficient (k), which is part of an equation with shear stress, t_c , was similarly calculated or established without justification, using just the equation published by Hanson and Simon (2001)¹²⁰:

$$k = 0.2 t_c^{-0.5}$$

They provide no satisfactory explanation for its suitability to the TFI, parameterization, or variability along the diverse reaches along the TFI, never mind vertically on the banks. The shear stress parameterization has been independently assessed as problematic. Klavon et al. (2017) states¹²¹:

“BSTEM users should be aware that the τ distribution methods used in BSTEM may be limited in being able to represent actual field conditions.” (p. 197)

The uncertainty in toeslope erosion leads to problematic results and discussion throughout the Erosion Causation Study. This uncertainty is essentially unacknowledged by the Erosion Causation Study. However, the approach is clearly highly uncertain. In particular, the jet tests for shear stress have more than an order-of-magnitude variation at individual sites. Yet the median value seems to be applied in each case with no acknowledgement or assessment of the range encapsulated in that median¹²².

The models of sediment transport at several sites also indicate the likely error in these analyses, especially during large modeled floods. For example, at Site 3L (and others) there is no shear stress that exceeds sediment transport, even at 100-yr flow event (see below). Yet this site has undergone the 5th most erosion of any site. ***This is not a plausible result in an alluvial reach, particularly one experiencing significant erosion, and suggests the underlying physics used to calculate erosion are incorrect.***

Numerous other sites require a 100-year flood event or greater to cause sediment transport. This is not a physically plausible condition and yet another key failure of the BSTEM model that is not acknowledged. At each site, the critical shear stress, t_c (required for sediment motion), is greater than the shear stress modeled by the Erosion Causation Study during a 100-year flood. The values of t_c and $t_{100\text{-year}}$ for these sites are below¹²³:

- Site 5CR (t_c : 1.03; $t_{100\text{-year}}$: 0.98)

¹²⁰ Hanson and Simon (2001)

¹²¹ Klavon et al. (2017).

¹²² FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Table 4.2.6.6-1: Jet Test Data for Bank Materials of the Turners Falls Impoundment

¹²³ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Table 5.5.1.1-1: Comparison of Critical Shear Stress and River2D Bed Shear Stress at Detailed Study Sites

- 6AL (tc: 0.64; $t_{100\text{-year}}$: 0.08)
- 7R (tc: 7.14; $t_{100\text{-year}}$: 0.22)
- 8BL (tc: 3.33; $t_{100\text{-year}}$: 0.88)
- 9R (tc: 10.3; $t_{100\text{-year}}$: 1.34)
- 10L (tc: 0.585; $t_{100\text{-year}}$: 0.17)
- 10R (tc: 3.47; $t_{100\text{-year}}$: 1.71)
- 11L (tc: 2.91; $t_{100\text{-year}}$: 0.03)
- 18L (tc: 3.27; $t_{100\text{-year}}$: 0.22)
- 29R (tc: 1.51; $t_{100\text{-year}}$: 1.09)
- 303BL (tc: 2.49; $t_{100\text{-year}}$: 0.45)

In each case, critical shear stress, tc, should be lower than the shear stress during an extremely large flood. The shear stress, as parameterized in the model, suggests that sediment is essentially immobile at these 11 sites. Given the clear evidence of sediment transport throughout the reservoir, this is clearly incorrect and undermines model results. Even if some of these sites have been stabilized and thus the critical shear stress is affected by an estimate for rip-rap mobility, evidence of erosion at rip-rap sites documented by Field (2007)¹²⁴ shows that modeling a no-erosion scenario there is not reasonable.

Discharge data, as modeled by the new “dynamic” version of BSTEM, is also not sufficiently rigorous to support the confidence with which FirstLight presents its results. A review by a US Department of Agriculture Scientist found¹²⁵:

“The hourly discharge and erosion records were then used to calculate erosion exceedance probabilities. 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.” (p. 3)

3.4 Cohesion and slope stability provided by vegetation is poorly quantified

Root cohesion, a critical parameter in the BSTEM model, was based on RipRoot outputs for 5 species that have not been tested independently except for in this study. In model parameterization by FirstLight consultants, the percent tree cover was established for the cross-section bank top and bank face, then the percent each tree species contributed was added. Some key deficiencies suggest widespread oversimplification and lack of rigor:

- Only a single, uniform value of cohesion was established for the bank top.

¹²⁴ Field (2007) Fig. 29; Fig. 35.

¹²⁵ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study, United States Department of Agriculture. November 28, 2016. 4 p.

- Only 9 cross sections had vegetation-derived cohesion for the bank face. As with the bank top, only a single cohesion value was established, not accounting for the variations in root structure through the face.
- No vegetation-derived cohesion was input for the bank toe, despite vegetation existing at the toe (see above: BSTEM Toe Transport Uncertainty).
- Root cohesion data was only collected for large trees. There is no consideration of grass and smaller vegetation that does much of the work of bank stability and velocity reduction.
- Waves from wind, current, and boat wakes, and flood erosion clearly exists in a feedback process with bank undermining and vegetation, but no consideration of these connected systems is provided, nor are secondary sources of erosion included in the cohesion model.

The additional vegetation-derived cohesion increased erosional resistance by 200% on average.

The large uncertainties in these vegetation methods thus dramatically increase the uncertainty of the BSTEM model. The insufficient field methods and averaging techniques are described below¹²⁶:

“BSTEM contains a root-reinforcement algorithm, RipRoot that currently contains a database of 25 species, for which root tensile strength and root architecture have previously been collected. The data collection has focused largely on Southeastern, and Western USA riparian species. As part of this study, five species commonly found along the study reach were investigated, to be added to the RipRoot database, and used in BSTEM model simulations of the TFI.

Collection and analysis of root architecture data is time consuming and laborious. To be efficient with this data collection, root architecture data was collected for a range of tree ages for each of the species, and the average distribution of root densities and diameters was calculated for the range of ages. Plant assemblage data (percent cover, species and age) was recorded at each of the BSTEM modeling sites, so that these average root-architecture parameters and species specific root tensile-strength relations could be applied to give a specific root-reinforcement value at each BSTEM modeling site.” (p. 4-97)

In addition, it seems as though no time variation of vegetation, or cohesion in general, was included in BSTEM modeling. Cohesion varies with changes in vegetation through the seasons and as vegetation is destroyed or regrows. This is potentially a consequential oversight that could rebalance the attribution of erosion in FirstLight’s analysis. No effort was made to address the uncertainty that stems from these omissions.

3.5 “Dynamic” groundwater estimates are based solely on literature values, rather than observations.

In the Princeton Hydro peer review, the scientists raise the issue of pore-water saturation and groundwater, which they identified as being insufficiently characterized in the model.

FirstLight’s response was that the model was informed by literature values¹²⁷:

¹²⁶ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report

¹²⁷ FirstLight Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary. January 17, 2017. p. 2

“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.” (p. 9)

Groundwater is strongly dependent on local precipitation, vegetation, and event sequencing, and this rebuttal thus does not answer the Princeton Hydro question. Because no event-by-event observations of erosion have been made to validate the BSTEM model, the FirstLight claim that “No further study modifications are required given that the modeling results already take this dynamic groundwater table into account” is not supported. An independent review by a US Department of Agriculture Scientist similarly found the groundwater modeling to be insufficient¹²⁸. This over-reliance on literature values and absence of calibration to local values is characteristic of the FirstLight approach in applying BSTEM. As has been stated throughout, model success *must* be independently validated using independent test sites in the reservoir.

3.6 Extrapolation

The extrapolation from individual sites to the full TFI is summarized in the Erosion Causation Study at 6.1.2.1 Extrapolation Methodology (p. 6-20). The extrapolation presented by FirstLight is a subjective analysis, with no statistical rationale given for choosing the extrapolation method¹²⁹. The geomorphological rationale is not detailed beyond the following:

- “b. Identify the riverbank features, characteristics, and erosion conditions at those sites based on the results of the 2013 FRR;
- c. Identify other segments in hydraulic reach 4 (Vernon) or 2 (Northfield Mountain) that have the same features and characteristics.” (p. 6-21)

There was no effort made to test the accuracy of the extrapolation independently (using sites not incorporated in model development), which would be a bare minimum criterium for the wide application carried out here. *Without rigorous documentation of the statistical robustness of extrapolation, any conclusions should be treated as speculative.*

3.7 Boat wake and wind wave erosion

The processes invoked in wave erosion—by boat wakes and wind/current waves—are accentuated and/or facilitated by water level fluctuations. Erosional benches created by breaking waves become erosional fronts. As water comes back up, then is drawn down again, erosion will be focused on these vertical slopes. Knickpoints thus propagate through the beaches. Beach buffering and buttressing of upper slopes is thus diminished, increasing the likelihood of erosion from those areas.

¹²⁸ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p. p. 2 (“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.”)

¹²⁹ Study 3.1.2 *Northfield Mountain / Turners Falls Operations Impacts On Existing Erosion And Potential Bank Instability*. p. 6-21.

The hydropeaking process in the TFI may lead to higher-than-natural stages, particularly during summer days. Because boats are more common during sunny, warm summer days (when energy demand is highest), peaking is likely the most pronounced, with maximum water stored. As a result, boat waves likely cause more inundation and erosion than would normally occur (Figure 22). This is equivalent to the challenges with sea level rise and storms: with higher starting levels, storm surges are more pronounced.



Figure 5.5.3-3: Notching Due to Boat Waves

Figure 22. Figure 5.5.3–3 from Study 3.1.2 shows notching that FirstLight attributes to boat waves. Erosion has clearly occurred at two different levels, which is consistent with raising and lower of the reservoir level.

3.8 Slope instability due to seepage is ignored/downplayed

According to FirstLight's Erosion Causation Study, seepage was "observed only at a few sites". FirstLight justifies its omission in the following passage and several others like it¹³⁰:

"Bank undercutting by seepage erosion is similarly not included in the version described herein. This is not considered a problem along the Turners Falls reach as evidence of seepage processes were observed at only a few sites by field crews. Finally, the hydrologic effects of riparian vegetation, including interception, evapotranspiration and the accelerated delivery of water along roots and macro pores cannot be simulated at this time." (p. 4-65)

However, seepage is often difficult to identify in the field, or distinguish from other erosional landforms, particularly after some time has passed. Seepage may lead to other failure modes that would also obscure it as a root cause. Absent more timely, detailed observations, it is difficult to rule out the role of seepage, which thus may be far more relevant than is being implied. For example Field Geology Services in 2007 found that "Springs and seeps were observed repeatedly along banks exposed below higher terraces"¹³¹.

3.9 Floods are identified as important but erosion from floods is not documented

Despite FirstLight's insistence on the importance of floods in causing erosion, no flood erosion is documented except for during Hurricane Irene.

3.10 BSTEM Conclusion

Practitioners using BSTEM have found its results to be uneven and uncertain¹³². They describe how BSTEM requires extensive calibration, often produces erroneous or spatially inconsistent results, and is generally best suited to the Central United States, where it was developed¹³³.

This is no surprise. River erosion processes are notoriously difficult to model, with model inputs often having uncertainties that span orders of magnitude¹³⁴. This has been noted in past independent reviews of BSTEM, which urge caution in interpreting its results. A model like BSTEM is useful for helping to untangle processes in complex river systems. However, its results must be treated with caution, given the uncertainty in both its inputs and the processes it models. The certainty with which FirstLight treats its results is not sound scientific practice, particularly since no uncertainty metrics are presented in FirstLight reports. Instead of relying solely on a flawed model, FirstLight should account for the direct observational evidence that its consultants have collected in the impoundment.

¹³⁰ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report

¹³¹ Field (2007) p. 39

¹³² Klavon et al. (2017).

¹³³ Klavon et al. (2017).

¹³⁴ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p. p. 2 ("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.")

4. Conclusions and recommendations

Erosion in the TFI potentially threatens riparian land, archaeological artifacts, and infrastructure, riverine and riparian ecology, and reservoir functioning production due to sedimentation and turbine damage by eroded sediments. The erosion likely results at least in part from Project operations. As independent scientists have pointed out in several reports, claims by FirstLight that Project operations contribute minimally to erosion are not robustly supported by BSTEM modeling or field observations.

FirstLight should acknowledge and seek to mitigate the likely causes of this erosion in the TFI, regardless of source. This is in the best interest of the community and is also in FirstLight's interest, given the potential threat to dam operations posed by changing reservoir area and volume, the challenges from increased precipitation and flooding by climate change, and the good will that can be built by addressing valid community concerns regarding erosion.

I propose several straightforward recommendations to better address erosion in the Turners Falls Impoundment and mitigate ongoing erosion as much as possible. These recommendations are reasonable and consistent with prior recommendations by Connecticut River Conservancy and Franklin Regional Council of Governments, as well as independent reviewers.

High-resolution, repeatable monitoring of the reservoir has been lacking and is needed. Much of the monitoring technology is much cheaper than in the past and thus improved study need not be prohibitively expensive. At minimum, repeat lidar monitoring of leaf-off banks of the reservoir should be carried out annually during a fall low-water period. For too long, FirstLight has been able to defer responsibility because erosion monitoring has been too poor to resolve the respective importance of natural processes and Project operations. As numerous scientists have detailed in past reports, modeling with BSTEM does not robustly capture the processes at work in the reservoir. The results of BSTEM should not be treated as scientific fact and should not be a substitute for better monitoring, which could much more reliably identify the causes of erosion.

- The current project operational range for reservoir levels likely exacerbates erosion relative to a narrower range by exposing a large swath of the reservoir banks to erosive properties and raising the “base-level” for natural flooding, adding to flood heights and thus erosive power.
- Lack of rigorous, objective study prevents a complete understanding of erosion mechanisms in the TFI. Rather than just once per year, erosion should be monitored multiple times per year at existing cross-section surveys, using lidar (light detecting and ranging), side-scanning sonar, and other detailed survey techniques. In addition, continuous monitoring of riverbank erosion, using a combination of erosion pins and cameras, should be established at representative sites in the reservoir to better understand timing and causes of erosion events. Study design for these monitoring campaigns should target: a) regular fluctuations in water level during normal project operation; b) natural floods; c) freeze-thaw and snowmelt periods.

- Insights from improved study should inform Project operations to limit erosion. If flow modification cannot mitigate erosion, further bank stabilization techniques should be employed in high-erosion areas in the TFI. Better monitoring (see above) is necessary to identify reaches in need of stabilization, as well as stabilization success.

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- August 2020 Ph.D. in Earth Science, Dartmouth College
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ACCEPTED PUBLICATIONS

Dethier, E. N., Fields, J. F., Renshaw, C. E., and Magilligan, F. J. (2024, *accepted at GSA Bulletin*), Hillslope destabilization delays fluvial recovery from catastrophic flooding.

Gunther, A. B.*, Camill, P., Jr, C. E. U., Stansfield, A., & **Dethier, E. N.** (2024, *accepted at JGR Bioscience*). Using relationships between vegetation and surface soil biogeochemical properties to assess regional soil carbon inventories for South Baffin Island, Nunavut, Canada

Dethier, E.N., Camalan, S., Silman, M.R., Alqahtani, S., Pauca, P., Díaz Levia, J., Fernandez, L., Renshaw, Tomhave, P*, C. E., and Magilligan, F. J., Lutz, D.A. (2023). A global rise in alluvial mining increases sediment load in tropical rivers. *Nature*, 620(7975), 787-793. doi:10.1038/s41586-023-06309-9

Dethier, E.N., Silman, M. R., Fernandez, L. E., Espejo, J. C., Alqahtani, S., Pauca, P., & Lutz, D. A. (2023). Operation mercury: Impacts of national-level armed forces intervention and anticorruption strategy on artisanal gold mining and water quality in the Peruvian Amazon. *Conservation Letters*, 00, e12978. <https://doi.org/10.1111/conl.12978>

Dethier, E. N., Renshaw, C. E., & Magilligan, F. J. (2022). Rapid changes to global river suspended sediment flux by humans. *Science*, 376(6600), 1447-1452.

Cui, K., Camalan, S., Li, R., Pauca, V.P., Alqahtani, S., Plemmons, R., Silman, M., **Dethier, E.N.**, Lutz, D. and Chan, R., 2022, September. Semi-supervised Change Detection of Small Water Bodies Using RGB and Multispectral Images in Peruvian Rainforests. In *2022 12th Workshop on Hyperspectral Imaging and Signal Processing: Evolution in Remote Sensing (WHISPERS)* (pp. 1-5). IEEE.

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Camalan, S., K. N. Cui, V. P. Pauca, S. Alqahtani, M. Silman, R. D. Chan, R. J. Plemmons, **E. N. Dethier**, L. E. Fernandez, and D. A. Lutz (2022), Change Detection of Amazonian Alluvial Gold Mining Using Deep Learning and Sentinel-2 Imagery, *Remote Sensing*, 14(7), doi:10.3390/rs14071746.

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Dethier, E. N., Sartain, S.L.*, Renshaw, C.E., and Magilligan, F. J. (2020), Spatially coherent regional changes in seasonal extreme streamflow events in the United States and Canada since 1950. *Science Advances*.

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Dethier, E. N., S. L. Sartain*, and D. A. Lutz (2019), Heightened levels and seasonal inversion of riverine suspended sediment in a tropical biodiversity hot spot due to artisanal gold mining. *Proceedings of the National Academy of Sciences of the United States of America*, 116(48), 23936-23941. doi:10.1073/pnas.1907842116

Renshaw, C. E., Magilligan F. J., Doyle, H. G., **E. N. Dethier**, and K. M. Kantack (2019), Rapid response of New England (USA) rivers to shifting boundary conditions: Processes, time frames, and pathways to post-flood channel equilibrium. *Geology*, 47(10), 997-1000. doi:10.1130/G46702.1.

Dethier, E.N., F. J. Magilligan, C. E. Renshaw, and K. H. Nislow (2016), The role of chronic and episodic disturbances on channel-hillslope coupling: the persistence and legacy of extreme floods. *Earth Surface Processes and Landforms*, 41(10), 1437-1447. doi:10.1002/esp.3958

PUBLICATIONS SUBMITTED AND IN PREPARATION

Lutz, D. A., Steele, B., **Dethier, E.N.**, Brentrup, J. A., Rubin, H. J. *, Herrick, C., Palace, M., Weathers, K. C., Ducey, M. J., Johnson, K. M., Cottingham, K. L. (2023, *submitted*), Estimating lake water clarity using Landsat imagery: a site-specific reflectance and machine learning approach.

Fields, J. F., Renshaw, C. E., **Dethier, E. N.**, Magilligan, F. J. (2024, *in review*). The longer arc of channel recovery post-dam removal.

Fields, J. F., Perotti, J. *, Kriesler, J. *, Renshaw, C. E., **Dethier, E. N.** (2024, *in review*). Temperature Controls Erosion along Arctic Rivers.

Valencius, I. *, Valencius, I., **Dethier, E. N.**, Sheehan, C., Snyder, N. (2024, *in prep*). Estimating River Suspended Sediment Concentration from Sentinel-2: Expansion of Satellite Methods and Applicability to Multi-Dammed Systems.

Erikson, C., Renshaw, C. E., **Dethier, E. N.**, Magilligan, F. J. (2024, *in review*). Watershed-Scale Runoff Efficiency Response to Climate Variability.

Boardman, E.N., Renshaw, C.E., Shriver, R.K., Walters, R., McGurk, B., Painter, T.H., Deems, J.S., Bormann, K.J., Lewis, G.M., Dethier, E.N., Harpold, A.A. (2024, *in review*). Sources of Seasonal Water Supply Forecast Uncertainty During Snow Drought in the Sierra Nevada.

* Denotes undergraduate student advisee

GRANTS AND AWARDS

- Aug., 2023 Principal investigator. *Satellite Monitoring of Rivers: A Distributed-Sampling Approach to Improve Satellite Estimates of River Water Quality on a Global Scale*. Funded by the National Aeronautics and Space Administration NSPIRES Program for 2023–2025 (\$579,451).
- June, 2020 Research Scientist. *Rapid Change from Alluvial Mining and Development in Madre de Dios, Peru: A Multi-Sensor Fusion Approach to Quantify Terrestrial and Aquatic Impacts and Test Policy Effectiveness*. Funded by the National Aeronautics and Space Administration NSPIRES Program for Jan. 2021– Jan. 2024 (\$748,224). (P.I. David Lutz)
- May, 2020 Guarini School of Graduate and Advanced Studies Award for Best Graduate Teaching. *Annually recognizes the individual in the Guarini Graduate School who best exemplifies the qualities of a college educator*.
<https://graduate.dartmouth.edu/news/2020/06/2020-guarini-teaching-award-recipient-evan-dethier>
- May, 2020 (also received 2017, 2018, 2019)
Outstanding Graduate Student Teacher, Dartmouth College. *Awarded to graduate students nominated by their undergraduate mentees in recognition of their outstanding teaching*.
- May, 2020 Dartmouth Earth Science Best Graduate Student Paper, 2020. *Recognizes the best peer-reviewed publication led by an Earth Science graduate student*.
- Jan, 2020 American Meteorological Soc. Annual Meeting Student Presentation Award in Hydrology, runner-up. *Awards presentations were judged on scientific content, presentation quality, and the overall effectiveness of the presentation*.
- April, 2017 AAG Gordon “Reds” Wolman Graduate Student Research Proposal Award. *Graduate student research grant awarded to the best written proposal, to help cover the costs of data acquisition, fieldwork, and laboratory analysis required to complete dissertation research*.
- April, 2017 AAG Graduate Student Paper Award. *Papers are evaluated on the research contribution to the field of geomorphology and on the effectiveness of the presentation*.
- June, 2017 Gary Malone ‘70 Memorial Award for most engaged graduate student. *Awarded to the graduate student in the Earth Science department who best exemplifies the qualities of Gary Malone ’70*.
- Mar., 2015 Presidential fellowship in graduate recruitment (Dartmouth College). *Awarded to the top PhD recruit for the Earth Sciences Department*.

Mar., 2014 Student Research Grant (Geological Society of America). *Award to provide partial support of Master's and Doctoral thesis research in the geological sciences for graduate students at universities in the United States, Canada, Mexico and Central America.*

INVITED PRESENTATIONS

February 5, 2024 University of Southern California, Dornsife Department of Earth Sciences.

December 14, 2023 AGU session, *Impacts of Mineral Extraction and Artisanal Mining on Societies and Natural Environments.*

October 18, 2023 AGU Earth and Planetary Surface Processes EPSP-Connects Webinar series

May 11, 2023. Bowdoin College, Department of Earth and Oceanographic Sciences.

April 21, 2023. University of Massachusetts, Department of Earth, Geographic, and Climate Sciences.

March 31, 2023. Colby College, Department of Geology.

October 26, 2022. Source to Sink Webinar Series.

February 9, 2022. Temple University, Department of Geology.

TEACHING EXPERIENCE

Primary instructor/mentor

Senior Thesis mentor (11 Honors Thesis students) ^{1,2}	2017–2022
Geomorphology ¹	2022
GIS and Spatial Analysis ^{1,3}	2022, 2024
Introduction to Geology, Lab instructor ³	2024
Introduction to Field Methods in Geology ³	2023
Advanced Hydrology, instructor ²	2020
Hydrology, co-instructor ²	2020
Geology, 11 th and 12 th grades ⁴	2012–2013
Earth Science, 8 th and 9 th grades ⁴	2011–2013
Writing and Journalism ⁴	2013
Anatomy, 7 th grade ⁴	2012

¹Bowdoin College (undergraduate)

²Dartmouth College (undergraduate, graduate)

³Occidental College (undergraduate)

⁴Green Mountain Valley School (Grades 7–12)

Teaching assistant at Dartmouth College

Advanced Methods – Environmental Data Analysis, TA and lecturer	2020
The Stretch, off-campus field program, TA	2014, 2015, 2017
River Processes and Watershed Sciences, TA	2015 & 2016
Environmental Applications of GIS, TA	2015
Remote Sensing, TA	2015
Hydrology and Watershed Resources, TA	2014
Hawaii Volcanology, off-campus field program, TA	2013
Intro to Earth Science: How the Earth Works, TA	2013

MENTORING AND VOLUNTEERING

Unlearning Racism in the Geosciences (URGE)
American Geophysical Union Earth and Planetary Surface Processes Executive Committee Graduate Student Representative to the Faculty, Dartmouth College
Faculty Hiring committee, Graduate Student Coordinator, Dartmouth College
Dartmouth Earth Science Like a Rock mentoring program
Ford Sayre Ski Club, Nordic Ski Coach for six seasons (2013–2018)

Reviewer for *Nature*, *Science*, *Nature Geoscience*, *JGR Earth Surface*, *Water Resources Research*, *Nature Communications*, *JGR Bioscience*, *Regional Environmental Change*, and *AGU Earth and Space Sciences*.

PROGRAMMING AND ANALYTICS

R Programming language used for statistical analysis and database management of large hydrologic datasets, particularly United States Geological Survey and Water Survey of Canada stream and lake monitoring records, Global Historical Climatology Network, and U.S. Historical Climatology Network precipitation and temperature records, and result of satellite remote sensing analysis in Google Earth Engine.

Python Used for retrieval and analysis of satellite imagery, geovisualization.

Google Earth Engine Used for massively scalable analysis of hydrological data, usually derived from satellite products.

Matlab Used for numerical modeling methods, but have mostly replaced Matlab with R.

JMP Used for rapid data visualization and some preliminary statistical analyses. Also sometimes used to teach statistics.

Cloud Compare Used for processing of high-resolution point cloud data derived from lidar or Structure-from-Motion analysis.

ArcGIS and QGIS Used for GIS analysis and teaching, though have transitioned to primarily using Google Earth Engine and R.

PRESS

Selected press for teaching and advising

Peter Tomhave '23 Contributes to Academic Article on Impact of River Mining. August 25, 2023. Tom Porter, Bowdoin College News. <https://www.bowdoin.edu/news/2023/08/peter-tomhave-23-contributes-to-academic-article-on-impact-of-river-mining.html>

EOS Professor Warns of Global Mining Crisis in Tropical Rivers. January 26, 2023. Jane Godiner, Bowdoin College News. <https://www.bowdoin.edu/news/2023/01/eos-professor-clears-up-murky-water-question-in-science-news-feature.html>

2020 Guarini Teaching Award Recipient: Evan Dethier. Jun. 25, 2020. Amy Skinner, Dartmouth Guarini School of Graduate and Advanced Studies, News. <https://graduate.dartmouth.edu/news/2020/06/2020-guarini-teaching-award-recipient-evan-dethier>

Women in Science Project Opens Door to Top Journal Publication. Nov. 26, 2019. Bill Platt, Dartmouth News. <https://news.dartmouth.edu/news/2019/11/women-science-project-opens-door-top-journal-publication>

In Dublin, an Undergraduate Dives Into Big Data. Sep. 27, 2018. Joseph Blumberg, Dartmouth News. <https://news.dartmouth.edu/news/2018/09/dublin-undergraduate-dives-big-data>

Two Juniors Named Goldwater Scholars. Apr. 29, 2020. Hannah Silverstein, Dartmouth News. <https://news.dartmouth.edu/news/2020/04/two-juniors-named-goldwater-scholars>

Selected press for mining in rivers

Ríos en riesgo: minería provoca cambios profundos en afluentes de todo el mundo. September 20, 2023. Antonio José Paz Cardona, Mongabay Latin America. <https://es.mongabay.com/2023/09/rios-en-riesgo-mineria-provoca-cambios-en-afluentes-de-todo-el-mundo-estudio/>

Satellite images show the widespread impact of mining on tropical rivers. August 23, 2023. Bryony Walmsley, Nature Vol 620, 729-730. <https://doi.org/10.1038/d41586-023-02349-3>

Illegal mining has muddied tropical rivers worldwide. January 11, 2023. Paul Voosen. Science, Vol 379, Issue 6628. <https://www.science.org/content/article/illegal-mining-has-muddied-tropical-rivers-worldwide>

Mercury-Based Gold Mining Haunts Peruvian Rain Forests. December 15, 2021. Alka Tripathy-Lang. EOS. <https://eos.org/articles/mercury-based-gold-mining-haunts-peruvian-rain-forests>

Illegal gold mining continues to harm Amazon ecosystem. December 15, 2021. Liza Lester. AGU News. <https://news.agu.org/press-release/illegal-gold-mining-continues-to-harm-amazon-ecosystem/>

Gold Mining Critically Impairs Water Quality in Rivers Across Peruvian Biodiversity Hotspot. Nov. 11, 2019. Dartmouth College Communications. https://www.dartmouth.edu/press/releases/gold_mining_critically_impairs_water_quality_in_rivers_across_peruvian_biodiversity_hotspot.html

Madre de Dios: imágenes satelitales muestran el impacto de 34 años de minería ilegal en ríos Translation: Madre de Dios: satellite images show the impact of 34 years of illegal river mining. Feb. 05, 2020. Mongabay Latam, El Comercio. <https://elcomercio.pe/tecnologia/ecologia/madre-de-dios-imagenes-satelitales-muestran-el-impacto-de-34-anos-de-mineria-ilegal-en-rios-fotos-noticia/>

Artisanal gold mining polluting Peruvian biodiversity hotspot—study. November 17, 2019. Valentina Ruiz Leotaud, mining.com. <https://www.mining.com/artisanal-gold-mining-polluting-peruvian-biodiversity-hotspot-study/>

Selected press for changing discharge and sediment flux

Satellites Show Magnitude of Human Influence on River Sediment Flux. July 12, 2022. Mohammed El-Said. EOS. <https://eos.org/articles/satellites-show-magnitude-of-human-influence-on-river-sediment-flux>

New analysis: Extreme flows in US streams are rising: mixed trends become clearer when similar streams are grouped together. December 05, 2020. Scott K. Johnson. Ars Technica. <https://arstechnica.com/science/2020/12/new-analysis-extreme-flows-in-us-streams-are-rising/>

Study Finds River Flooding on The Rise Across U.S. and Canada. January 31, 2021. The Weather Channel. <https://weather.com/news/weather/video/study-finds-river-flooding-on-the-rise-across-us-and-canada>

Selected press for rapid analysis of Hurricane Ida Flooding in Northeast US

Searches, sorrow in wake of Ida's destructive, deadly floods. September 3, 2021. Mike Catalini, Wayne Parry, and Michael R. Sisak. ABC News. <https://abcnews.go.com/US/wireStory/cleanup-mourning-continue-ida-soaks-northeast-us-79809550>

Ida's fatal power didn't shock scientists who study how climate change primed the pump. September 4, 2021. Frank Kummer. <https://www.inquirer.com/science/climate/ida-climate-change-philadelphia-flooding-tornado-20210904.html>

Ida's impact from the Gulf Coast to Northeast — by the numbers. September 3, 2021. Ian Livingston. <https://www.washingtonpost.com/weather/2021/09/03/hurricane-ida-numbers-surge-wind-pressure-damage/>

CONTRIBUTED PRESENTATIONS

- Dethier, E.N.**, Silman, M., Fernandez, L. E., Leiva, J. D., Alqahtani, S., Pauca, P., ... & Tomhave, P. (2023). A global 21 st century mining boom in tropical river systems: the driver of changes to forest health, riparian geomorphology, and suspended sediment transport. AGU23.
- Fields, J., Renshaw, C. E., Magilligan, F. J., & **Dethier, E.N.** (2023). Intrinsic and Extrinsic Controls of Channel Recovery Post-Disturbance and Lessons for River Restoration. AGU23.
- Dethier, E.N.**, Silman, M., Díaz Leiva, J., Alqahtani, S., Fernandez, L. E., Pauca, P., ... & Lutz, D. A. (2022, December). The recent rise of mining in rivers is a global crisis. In AGU Fall Meeting Abstracts (Vol. 2022, pp. H52C-03).
- Dethier, E.N.**, Renshaw, C.E. and Magilligan, F.J., 2021. Satellite analysis reveals global spatial and temporal variation in river suspended sediment transport. In *AGU Fall Meeting, 2021*.
- Dethier, E.N.**, Silman, M.R., Fernandez, L.E., Caballero Espejo, J., Alqahtani, S. Pauca, P. and Lutz, D.A., 2021. Changing Frequency of Flood and Drought on Rivers in the United States and Canada. In *AGU Fall Meeting, 2021*.
- Dethier, E.N.**, Sartain, S.L.*, Magilligan, F.J. and Renshaw, C.E., 2020, January. Shifts in the locus of artisanal gold mining and changes in water quality following national-level intervention in the Peruvian Amazon. In *100th American Meteorological Society Annual Meeting*.
- Dethier, E.N.**, Renshaw, C.E. and Magilligan, F.J., 2019. Temporal and spatial variations in watershed connectivity dictate suspended sediment source and fate. *AGUFM, 2019*, pp.EP51C-2103.
- Magilligan, F.J., Renshaw, C.E. and **Dethier, E.N.**, 2019. Bankfull Channel Adjustments to Episodic and Long-Term Changes in Sediment Supply. *AGU Fall Meeting, 2019*, pp.EP51F-2189.
- Dethier, E.N.**, Magilligan, F.J. and Renshaw, C.E., 2019, March. Timescales of response to a catastrophic flood: Quantifying “event” and “post-event” effects to assess stream recovery following Tropical Storm Irene. In *Northeastern Section-54th Annual Meeting 2019*. GSA.
- Dethier, E.N.**, Magilligan, F.J. and Renshaw, C.E., 2018, December. Elevated post-event sediment yield extends the impact of catastrophic flooding. In *AGU Fall Meeting Abstracts*.

- Dethier, E. N.**, Magilligan, F., and Renshaw, C., 2017b, The Legacy of an Extreme Flood: Landslides Extend Geomorphic Impacts to the Present, *in* Proceedings AAG Annual Meeting, Boston, MA.
- Dethier, E. N.**, Magilligan, F., and Renshaw, C., 2017a, Quantifying Suspended Sediment Concentration from Space: Global Variability and Trends, *in* Proceedings GSA Annual Meeting, Seattle, WA.
- Dethier, E. N.**, Magilligan, F., and Renshaw, C., 2016, Landslides Modulate Transient Adjustment to Catastrophic Flooding, *in* Proceedings GSA Annual Meeting, Denver, CO.
- Dethier, E. N.**, Magilligan, F., Renshaw, C., and Kantack, K., 2015, Response and recovery of streams to an intense regional flooding event, *in* Proceedings AGU Fall Meeting, San Francisco, CA.
- Dethier, E. N.**, Magilligan, F., Renshaw, C. E., and Sinclair, D. *, 2015, Irene-generated hillslope failures in New England: Widespread, persistent sources of sediment to streams, *in* Proceedings GSA Meeting, Northeast Section, Bretton Woods, NH.
- Doyle, H. G., Renshaw, C. E., Magilligan, F. J., and **Dethier, E. N.**, 2015, Stream Channel Adjustments to Dam Removal in Headwater Catchments, *in* Proceedings AGU, Fall Meeting, San Francisco, CA.
- Kantack, K., Renshaw, C., Magilligan, F., and **Dethier, E. N.**, 2015, Response and Recovery of Streams From an Extreme Flood, *in* Proceedings AGU Fall Meeting, San Francisco, CA.
- Dethier, E. N.**, Magilligan, F., Renshaw, C., and Sinclair, D., 2014, Persistence of Episodic Extreme Events: Sustained Colluvial Contributions of Fine Sediment to Vermont Rivers Post-Irene, *in* Proceedings AGU Fall Meeting, San Francisco, CA.
- Gartner, J., Renshaw, C., Magilligan, F., Buraas, E., **Dethier, E. N.**, and Dade, W., 2014, Spatial gradients in stream power and the implications for lateral and downstream transport of material during the 2013 Floods in Colorado and 2011 Irene Floods in Vermont, USA, *in* Proceedings AGU Fall Meeting, San Francisco, CA.
- Dethier, E. N.**, 2013, Knickpoint-Controlled Landscape Evolution In the Middle Boulder Creek Watershed, CO, *in* Proceedings GSA Meeting, Northeast Section, Bretton Woods, NH.

LRH: MATHUR ET AL.

RRH: ENTRAINMENT OF AMERICAN SHAD

Entrainment of Juvenile and Adult American Shad at a Pumped Storage Facility

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Abstract

The American Shad *Alosa sapidissima* has been targeted for restoration to the upper Susquehanna River, and entrainment losses at hydroelectric facilities on the river, including the Muddy Run Pumped Storage Facility, are of concern for the potential growth of the American Shad population. Based on the integration of pumping volume, time of entrainment, and literature-reported diel emigration of juvenile American Shad, the entrainment rate ($N = 145$; 53 exposed to pumping) was estimated at 3.5%. The entrainment rate for adults ($N = 507$) was estimated at 0.3–3.9%. Using multistate mark-recapture models, the estimated entrainment probabilities (Ψ) of radio-tagged juveniles were higher during periods of extended pumping (>1 h; $\Psi = 0.093$; confidence interval [CI] = 0.054–0.156) than at periods of no pumping or short-duration pumping (<1 h; $\Psi < 0.0001$; 95% CI = 0.0–0.001); the high extended pumping occurred between 2300 and 0600 hours. Entrainment probabilities for adults were low ($\Psi < 0.02$); the highest probability occurred for fish detected downstream of the intake during the peak portion of the run ($\Psi = 0.015$; CI = 0.004–0.047). Entrainment probability for most adult fish did not differ from zero. The low values of Ψ for both life stages were attributed to (1) the deep location of the intake (intake ceiling > 11.7 m below the water surface), (2) the surface orientation of American Shad (upper 3.1 m), (3) the low overlap between high-volume pumping and peak emigration/migration times, (4) the pumping volume relative to prevailing river flows, and (5) the prolonged, robust swimming speed of American Shad, particularly that of adults (>2.2 m/s), which exceeded the intake velocity (0.2–0.9 m/s). Entrainment of juveniles increased with co-occurrence of low incoming river flows, high pumping volume, and peak emigration times. Quantification of migratory species' entrainment at pumped storage facilities requires integration of diel migration/emigration times

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with the frequency, timing, and duration of pumping volume. <AQ: are confidence intervals 90% or 95%? Please specify for each case in Abstract, main text, and tables.>

[INTRODUCTION]

Populations of American Shad *Alosa sapidissima* have been declining over the past 170 years or are at historical low levels in most rivers along the Atlantic coast and therefore have been targeted for restoration or enhancement (ASMFC 2009). The declines have been attributed partly to overfishing, pollution, habitat loss due to dam construction, upland development, and other factors, but the contribution of each factor has not been quantified (ASMFC 2009). In the case of the Susquehanna River, the American Shad population reached a historical low level in 1980, which led to initiation of intensive restoration efforts (St. Pierre 2003). One of the key concerns of virtually all population restoration or enhancement plans has been the potential for entrainment losses of downstream-migrating American Shad through hydroelectric turbines during their seaward journey. Although turbine passage-related losses of alosines have been estimated at several hydroelectric projects on American Shad-bearing rivers across the northeast United States (Bell and Kynard 1985; Heisey et al. 1992, 2008; Mathur et al. 1994, 1996), little information is available on such estimates for pumped storage facilities.

Fish entrainment issues related to pumped storage station operations—including the Muddy Run Pumped Storage Facility (MRPSF), a pure pumped storage peaking station on the lower Susquehanna River (FIGURE 1)—were addressed to a large extent in the 1970s, but those studies were primarily focused on nonmigratory species (Robbins et al. 1970; Hauck and Edson 1976; Robbins and Mathur 1976; Clugston 1980; Heisey and Mathur 1980; Liston et al. 1980; Mathur and Heisey 1980). Concerns about entrainment at MRPSF have re-emerged, however, particularly in the context of renewed efforts to restore migratory species,

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such as the American Shad, to the upper Susquehanna River. When extensive ecological studies (Robbins et al. 1970; Robbins and Mathur 1976; Heisey and Mathur 1980) were conducted to assess the effects of MRPSF operations on fishes, aquatic biota, and water quality of Conowingo Pond (the lower reservoir of MRPSF; FIGURE 1), American Shad were absent in the vicinity of MRPSF, although feasibility studies of restoring the species to the upper Susquehanna River had been undertaken (Whitney 1961; Bell and Holmes 1962; Carlson 1968). Thus, the concern arose for potential entrainment of alosines (American Shad, Blueback Herring *A. aestivalis*, and Alewife *A. pseudoharengus*) at MRPSF and at the nearby Peach Bottom Atomic Station, which was under construction when MRPSF became operational (FIGURE 1). However, a combination of unsuitable tagging techniques and difficulty with the transport and handling of sensitive juvenile alosines in the field imposed significant constraints to obtaining reliable entrainment estimates at pumped storage or conventional hydroelectric stations with high-volume discharges at that time (Mathur and Heisey 1980). Additionally, the very small modern telemetry tags needed to study the movements of juvenile alosines did not exist at the time, making in-depth field studies on their entrainment all but impossible (Mathur and Heisey 1980). Historically, virtually all advances in radiotelemetry have occurred via studies on nonclupeids (Adams et al. 2012).

Knight et al. (1977) used small radio tags to monitor the movements of juvenile American Shad on an experimental basis near the Northfield Mountain Pumped Storage Station on the Connecticut River. To the best of our knowledge, the first and the only entrainment study of radio-tagged juvenile American Shad was conducted by Layzer (1978a) at the same facility; some handling/tagging-related mortality was noted. No published information on entrainment of adult American Shad at pumped storage facilities exists, although Layzer (1978b) reported on behavioral reactions of ultrasonic-tagged adults to the operations of the Northfield Mountain Pumped Storage Station. Techniques to minimize

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stress on juvenile alosines (i.e., due to transport, capture, holding, handling, and tagging) and availability of smaller radio transmitters have improved considerably for application to estimate entrainment and survival of juvenile and adult alosines at conventional and pumped storage facilities. These efforts have included minimal use of nets, water-to-water transfer, and use of sodium chloride (NaCl)-buffered river water to minimize stress during holding and tagging (Meinze 1978; Royer et al. 1988; RMC 1989; Heisey et al. 1992; Normandeau Associates 2001; Normandeau Associates and Gomez and Sullivan Engineers 2009). The telemetry technology along with the use of less-invasive tag attachment methods (for longer retention) for juvenile alosines has also improved since 2011. Recently, smaller and more powerful transmitters were successfully used to follow the emigration exit routes of juvenile American Shad ($N = 310$) at a hydroelectric station on the Connecticut River (Normandeau Associates 2017).

Coincident with refinements in handling, holding, and tagging techniques, particularly for juvenile alosines (Layzer 1978a, 1978b; Royer et al. 1988), efforts toward the restoration of American Shad to the upper Susquehanna River increased in the 1980s (Hendricks and St. Pierre 2002; St. Pierre 2003). These restoration efforts have included (1) installation of fishways at the four hydroelectric stations on the lower Susquehanna River (Conowingo Dam in 1991, Holtwood Dam in 1997, and two other upstream dams) to facilitate migration of American Shad to upstream spawning areas, (2) release of hatchery-reared American Shad larvae from eggs collected from different river systems, (3) intrabasin and interbasin translocation of prespawn adults, and (4) augmentation of fishery regulations. As a result of these restoration efforts, both juvenile and adult American Shad emigrate/migrate beyond MRPSF, albeit in low numbers (Long et al. 2012).

Unlike the situation with conventional hydroelectric stations on American Shad-bearing rivers, American Shad are not obligated to pass through pumped storage facilities to

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complete their life cycle between freshwater and marine environments. As a result, entrainment of alosines and other obligatory migrant species at pumped storage facilities is primarily a function of the degree of overlap between the timing of migration/emigration and the facilities' pumping times. In the present study, we used miniature telemetry tags and new analysis techniques for juvenile American Shad and we used conventional radio tags for adult American Shad to estimate the entrainment of juveniles and adults at MRPSF and identify some factors affecting entrainment at this facility.

Our investigation consisted of three separate study periods: one study period focused on American Shad juveniles, and the other two periods focused on adults. We conducted the juvenile entrainment study between October 20 and November 2, 2011, at water temperatures between 10°C and 16°C, a peak emigration period through Conowingo Pond (SRAFRS 1999–2010). Adult American Shad entrainment studies were conducted in late April through May in 2001 and 2008 at water temperatures between 13°C and 21°C, a peak period of adult upstream migration through Conowingo Pond (Long et al. 2012). The exact timing and duration of peak juvenile American Shad emigration and adult upstream/downstream migration may vary between river systems (Leggett 1976; O'Leary and Kynard 1986).

[A]METHODS

[B]Study Site

The MRPSF (river kilometer [rkm] 35.2) is an 828-MW, pure pumped storage peaking station (Hauck and Edson 1976) located on the eastern shore of Conowingo Pond, a mainstream impoundment on the lower Susquehanna River in Pennsylvania. The facility is situated approximately 3.6 km downstream of the Holtwood Hydroelectric Station (HHS; FIGURE 1). Conowingo Pond is 22.4 km long, averages 1.6 km in width, has an average

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depth of 6 m, and has a maximum depth of 27 m behind Conowingo Dam and in some channels within the upper reaches. Conowingo Pond is bounded upstream by HHS (rkm 38.4) and downstream by the Conowingo Hydroelectric Generating Station (rkm 16; FIGURE 1). Turbine discharges from the upstream HHS flow downstream parallel to the Conowingo Pond shoreline past MRPSF. Hydraulics of the upper reaches of Conowingo Pond are quite complex and are affected by the variable upstream river inflows and outflows and by pumping and generation flows from MRPSF. When river inflow exceeds HHS's generating capacity, spill is directed through a spillway, which is separated from the turbine discharge by Piney Island (FIGURE 1). This island and other channel features tend to direct spilled water away from the MRPSF intake area. However, distribution of entrained fish in spillage downstream of the dam is unknown.

The designed pumping capacity of MRPSF is about $793 \text{ m}^3/\text{s}$. Pumping from Conowingo Pond to the upper Muddy Run Pumped Storage Reservoir (hereafter, "Muddy Run Reservoir") for storage (FIGURE 1) generally occurs during non-peak power demand times (e.g., at night), and water is released back to Conowingo Pond during generation at peak power demand periods (Robbins et al. 1970; Robbins and Mathur 1976). The pumping volume and duration vary over a 24-h cycle, with pumping being rare between 1000 and 2100 hours and consistent between 2300 and 0600 hours (Normandeau Associates and Gomez and Sullivan Engineers 2012).

The MRPSF powerhouse contains eight Francis-type reversible pump/turbines, each with a runner speed of 180 rpm, 7 buckets, and 20 wicket gates. Each unit has a rated capacity of $103.5 \text{ m}^3/\text{s}$ under an operating head of 126 m. The ceiling of the MRPSF intake is approximately 12 m below the normal full elevation (33 m, National Geodetic Vertical Datum) of Conowingo Pond. The opening of each of the 16 intake bays is 5 m high $\times$ 5 m wide. The intake bays are protected by trash racks with a clear spacing of 14 cm. The intake structure is aligned perpendicular to the river flow. The intakes, which admit water from Muddy Run Reservoir for power generation, consist of four cylindrical gates and are protected by trash racks with a clear spacing of 14 cm. Each intake supplies two turbine units and includes a cylindrical tower, which leads to a 132.3-m-deep vertical shaft. The vertical shafts and horizontal power tunnels are concrete lined, with a diameter of 7.5 m. The concrete-lined power tunnels bifurcate approximately 153.9 m upstream of the powerhouse. Beginning approximately 123.1 m upstream of the powerhouse, the tunnels transition to 4.3-m-diameter steel penstocks that continue downstream to connect to one of the eight pump turbine units in the powerhouse. There are no inlet valves at the downstream end of the penstocks. At least two units are used in tandem during pumping or power generation.

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Velocity profiles that were taken approximately 2 m in front of the intake structure (Conowingo Pond side) in 2010 showed that velocities ranged from about 0.15 to 0.90 m/s with all eight units in a pumping mode; the higher velocities occurred infrequently and generally at depths greater than 6 m and decreased with distance from the intake structure (Long et al. 2012).

[B] *Juvenile American Shad Tagging and Release*

Because sufficient in-river-basin juvenile American Shad were not available, we used hatchery-reared fish supplied by the Maryland Department of Natural Resources' Manning Fish Hatchery between October 15 and October 25, 2011. The size range of hatchery fish (TL range = 108–145 mm; mean = 126 mm) was typical of emigrating juvenile American Shad in the Susquehanna River. For a minimum of 4 d prior to tagging and release, fish were held in circular holding tanks (3,596 and 6,397 L) that were continuously supplied with river water near the MRPSF intake deck, allowing fish acclimation to ambient river conditions. Prior to each tagging event, we added NaCl to holding tanks, providing a salinity of about 0.5% to reduce osmotic and ionic imbalance due to handling stress (Meinze 1978).

We used coded VHF cylindrical radio transmitters (Lotek Model NTC-M-2; Lotek Engineering, Inc., Newmarket, Ontario, Canada), which transmitted signals on two unique frequencies (150.460 and 151.560 MHz) via a flexible, 170-mm-long whip antenna to allow for individual fish identification. The transmitters propagated a signal every 2 s (burst rate) and had a minimum battery life of approximately 16 d. Each transmitter measured $14 \times 3 \times 5$ mm (length $\times$ height $\times$ width) and weighed 0.43 g (FIGURE 2). Specimens selected for radio-tagging were concentrated in a fine-mesh net and then water brailled into a tagging tub. Fish that showed signs of erratic behavior, infection, or fungus were not used. To the extent possible, American Shad were not removed from the water during capture and handling (Backman and Ross 1990; Heisey et al. 1992). The radio transmitter was externally attached

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by a single stainless-steel pin (15 mm long; weight = 0.3 g) that was passed through the dorsal musculature near the origin of the dorsal fin (FIGURE 2).

The stainless-steel pin was inserted with a modified ear-piercing gun (Heisey et al. 1992) and was secured by a small plastic disc (6-mm diameter; 0.75-mm thickness) on the opposite side of the fish's body (FIGURE 2). This external tag attachment methodology has proven successful for short-term use on juvenile alosines with soft tissue and minimizes tag detachment in turbulent waters (Heisey et al. 1992; Mathur et al. 1994, 1996). Additionally, we deemed the method suitable for the present study for the following reasons. First, Susquehanna River out-migrating juveniles are generally larger (mean length of ~125 mm) than those in other northeastern rivers (e.g., mean length in the Connecticut River is ~90 mm), and most are released as hatchery-reared fry. Second, our experiment was of short duration (<4 h) and of short distance (fish were released $\leq$ 1.0 km upstream of MRPSF in flowing water). Third, recent controlled on-site experiments with Connecticut River juvenile American Shad (Normandeau Associates 2014) at the Vernon Hydroelectric Station indicated no significant short-term (within 24 h) effects of this tag attachment method. Fourth, juvenile American Shad are naturally "motivated" to move downstream at that time of the season. Fifth, any tagged fish that were not swimming normally prior to release were culled. Finally, if tag burden had any effect, it would most likely have been negative, resulting in a greater probability of entrainment.

After radio-tagging, juvenile American Shad were transferred into a half-full 19-L bucket. Usually, two tagged juveniles were placed in each bucket along with four or five additional untagged juveniles. The additional fish were placed in the bucket to allow the fish to form a small school, likely decreasing stress (Ross and Backman 1992). The transport buckets were lowered by rope from the MRPSF intake deck to the tracking boats for transport

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to an area near Deepwater Island, 1 km upstream of MRPSF (FIGURE 3). Fish were released into the flowing water by lowering the bucket into the river and then tipping it.

Initially, tagged juvenile American Shad were to be released at a pre-specified schedule during reported peak juvenile emigration times (Layzer 1978a; O’Leary and Kynard 1986; Harza and RMC 1993). However, it became apparent with the pre-specified schedule that there was a low likelihood of released fish being exposed to pumping. Consequently, to ensure that fish releases included exposure to pumping, we withheld a portion of the tagged fish sample and did not release them until pumping began. Initially, eight radio-tagged juveniles were released in each of two release groups for a total of 16 fish per night. This was modified to four release groups of four fish per night (TABLE 1).

Signals from the tagged juvenile American Shad were detected by Lotek SRX400 receivers equipped with four types of antenna: Laird P1504 four-element Yagi; Laird PLC1426 six-element Yagi; Laird PLC1429 nine-element Yagi; and custom-made underwater dropper antennas (FIGURE 3). These antennas were used at the MRPSF powerhouse on the Conowingo Pond side to detect the presence of juveniles in the vicinity of the turbine intakes, assign entrainment of juveniles through a specific turbine unit, obtain near-field movement of fish (fish are not entrained during generation on the Conowingo Pond side of MRPSF), and encompass a large detection zone.

Antennas were constructed by stripping the shielded end of 50- Ω RG58A/U coaxial cable; the length of the stripped portion of cable was a multiple of half the wavelength of 150 MHz. Each dropper antenna was secured by threading through a weighted garden hose (i.e., shielded within the hose) inserted through the grating of a stop-log slot and lowered 11 m below the stop-log gallery deck into the unit’s pump intake bay/penstock. Each end of the garden hose was weighted to ensure that the antenna was oriented vertically within the stop-log slot. Each slot represented each pump at MRPSF. These vertically deployed dropper

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antennas within the water column in each stop-log slot at two different depths detected signals from radio transmitters at depths (>9–10 m) greater than those achieved from above-surface antennas. All antennas were calibrated to ensure a proper detection range within the desired area.

Monitoring stations were deployed in four general areas for comprehensive coverage (FIGURE 3): (1) upstream of MRPSF, (2) at the facility, (3) downstream of the facility, and (4) in the facility's upper power canal. Mobile tracking by boat (on the Conowingo Pond side) was conducted for each release and covered an area between the release site (Deepwater Island) and just below Forsythe Island, approximately 2.4 km downstream of MRPSF. Collectively, the four downstream monitoring stations confirmed the passage of juvenile American Shad through the study area (FIGURE 3).

Three continuous monitoring receivers were deployed in the upper power canal of MRPSF at three different locations to confirm entrainment of juvenile American Shad from Conowingo Pond into Muddy Run Reservoir (FIGURE 3). The upper power canal's depth changes by up to 15 m depending upon the operating status of MRPSF.

[B] *Muddy Run Pumped Storage Facility Operations*

Typical hourly pumping of units, based on historical October and November data, occurs most frequently between 0000 and 0500 hours (TABLE 2). A high pumping rate (5–8 units) usually occurs between 2300 and 0800 hours. Additional finer-level pumping data beyond that recorded during the release and tracking of the fish were not available.

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[B] *Adult American Shad Tagging and Release*

Adult American Shad migrating upstream were collected from the Conowingo Dam East Fish Lift (FIGURE 1) on seven occasions in 2001 and on nine occasions in 2008 to represent early, middle, and late segments of the run; in both years, fish were tagged in late April to late May. Since the Susquehanna River American Shad stock is of mixed river origin (e.g., Susquehanna, Potomac, Delaware, and Hudson rivers), it was not possible at the time of tagging and release in the field to determine the river origin of tagged fish. Prior to tagging, the attraction flow of the fish lift was minimized, and the water in the fish lift exit flume was lowered to allow biologists to safely enter the trough and crowd the fish into the downstream end of the trough.

Adult American Shad selected for tagging were carefully captured with a hand-held net and then were transferred into a tagging cooler equipped with a fine-mesh net to immobilize the specimen. A radio tag was orally inserted through the esophagus and into the fish's stomach by means of a cannula, guiding it gently through the esophagus. The radio tag's antenna trailed from the corner of the fish's mouth. The tagged individual was then placed on the upstream side of the crowder for release. Any adult that displayed erratic swimming behavior or that remained in the exit flume overnight was replaced. We released 204 radio-tagged American Shad into the Conowingo East Fish Lift exit trough during 2001; 303 radio-tagged adults were released into the exit trough during 2008. Ten additional adults were radio-tagged in 2008 and were held for 3 d to observe posttagging behavior and tag regurgitation; none of those fish died or regurgitated their transmitters during the holding period.

We utilized coded radio transmitters (Lotek Series MCFT-3EM) that propagated signals on one of five frequencies between 149.260 and 149.800 MHz. Each transmitter was cylindrical, measured 48 mm in length and 11 mm in diameter, weighed 4.5 g, and had a 455-mm-long whip antenna. Each transmitter propagated a unique code on its given frequency every 2 s (burst rate) and was powered by a 3-V battery with an expected operational life of 172 d.

We utilized Lotek SRX telemetry receivers (11 in 2001; 17 in 2008), coupled to one or two four-element Yagi antennas (Cushcraft P150-4), to monitor the migration of tagged adult American Shad from their release site (FIGURE 1) to upstream of MRPSF. These receivers were located to (1) quantify fallback through Conowingo Dam or failure to migrate upstream after tagging and release, (2) detect entrainment through a specific turbine at Muddy Run Reservoir, and (3) confirm entrainment by detection of fish in the power canal within upper Muddy Run Reservoir.

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[B]Data Analysis

[C]Dispersion of released juvenile American Shad.—Differences in downstream dispersion frequencies of juveniles released during the three operating modes (generating, pumping, and idle) were tested by use of chi-square analysis. The travel time of each tagged fish was calculated as the difference between release time and the time of first detection in the vicinity of MRPSF. The subsequent residency time near MRPSF was calculated as the difference between the time of the first detection and the time of the last detection.

[C]Estimation of entrainment rate for naturally emigrating juveniles.—Due to the cyclical nature of MRPSF operations, the availability of diel emigration patterns of juvenile American Shad reported only in studies conducted on the Connecticut River (Layzer 1978a; O’Leary and Kynard 1986; Harza and RMC 1993), and the absence of site-specific data on diel emigration, we integrated the emigration diel pattern data from the Connecticut River studies (TABLE 3) with the percentage of times the units were pumping when entrainment of radio-tagged juveniles occurred at MRPSF. Although the diel emigration studies in the Connecticut River were conducted several years apart, they showed a similar pattern (TABLE 3); we are not aware of other similar data. Most juvenile American Shad emigrate between 1600 and 2200 hours, which has only a small amount of overlap with peak high-volume pumping. Approximately 7% of the time, at least six units pumped between 1600 and 2200 hours, and 89–98% of the time at least six units pumped between 0000 and 0400 hours, when most (91.7%; 11 of 12 entrained fish) entrainment of radio-tagged juveniles occurred; one fish was entrained when four units were pumping. Our calculations took these data into account.

The calculation for estimation of pumping entrainment of radio-tagged juvenile American Shad was performed as follows:

$$E_{ps} = N_{r1} / N_{r2},$$

where E_{ps} = estimated pumping entrainment; N_{r1} = number of radio-tagged juveniles that were entrained ($N = 12$); and N_{r2} = number of radio-tagged juveniles that were exposed to pumping ($N = 53$). This yielded an estimated pumping entrainment rate of 22.6% ($= 100 \times [12/53]$). The 90% confidence limits on the estimated pumping entrainment rate (22.6%) were calculated using the binomial distribution.

We integrated the observed pumping entrainment rate with the reported diel emigration data in TABLE 3 and the MRPSF pumping volume at which entrainment occurred:

$$E_{nj} = \sum (H_p \times P_{units}) \times C,$$

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where E_{nj} = the estimated proportion of naturally emigrating juveniles that were entrained; H_p = the hourly proportion of emigrants exposed to pumping; P_{units} = the proportion of time a given number of units pumped each hour; and C = a constant representing the observed pumping entrainment rate (0.226, or 22.6%). Since there were three separate diel emigration data sets (TABLE 3), we performed this calculation for each of them to provide an idea of variability.

[C]*Assumptions for estimating entrainment probabilities of juveniles.*—We assumed that juvenile American Shad could only be entrained during periods when pumping was occurring. Because pumping almost exclusively occurred during off-peak emigration hours and fish could not be entrained unless pumping occurred, we did not estimate differences in entrainment probabilities between peak and off-peak migration hours.

We also assumed that hatchery-reared juveniles exhibited emigration patterns similar to those of river-run juveniles, as in the Connecticut River. This assumption was made because the release site was only 1 km upstream of MRPSF, fish were released into flowing water, and tagged fish moved out rapidly after release (generally < 30 min), indicating that they were motivated to emigrate. Additionally, an entrainment study (RMC 1989) of 14 radio-tagged, river-run American Shad juveniles (~125 mm long) at MRPSF showed behavioral patterns and entrainment rates similar to those we observed.

[C]*Assumptions for estimating entrainment of adult American Shad.*—We assumed that adult American Shad could only be entrained during periods when pumping was occurring. Because pumping almost exclusively occurred during off-peak emigration hours and because the fish could not be entrained unless pumping occurred, we did not estimate differences in entrainment probabilities between peak and off-peak migration hours.

American Shad adults that were entrained when water temperatures exceeded 21.1°C and/or in late May to mid-June were assumed to be postspawn or partially spent individuals; peak migration was assumed to occur during daylight hours, as others have observed (cited in ASMFC 2009; Long et al. 2012). The first assumption is consistent with the observed physical appearance of American Shad utilizing fishways on the lower Susquehanna River during late May and at water temperatures exceeding 21.1°C. Furthermore, Kynard and O'Leary (1993) reported that 86% of postspawn American Shad emigrated downstream during daylight hours at the Hadley Falls Station bypass system on the Connecticut River. No assumption on entrainment of upstream-migrating, prespawn American Shad was necessary because these fish were entrained at the temperatures and times of normal upstream migration.

[C]*Mark-recapture modeling.*—Program MARK (White and Burnham 1999) was used to construct two types of multistate mark-recapture models (Hestbeck et al. 1991; Brownie et al. 1993) for estimating entrainment probabilities of juvenile and adult American Shad via the methods described by Amaral et al. (2015). We estimated entrainment probability for juveniles by using two-state models that estimated the probability of moving from a non-entrained state to an entrained state. Because estimates of entrainment probabilities by day (the recapture period) were not of interest, all variables in the models were constant with respect to time (time, in this case, was equal to 1 d). We grouped juvenile release groups by the observed pumping time (0–1 h of pumping or >1 h of pumping) during their time at large. Almost all

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juvenile relocations fell within the area nearest to the pump intake (FIGURE 3), so we did not estimate entrainment probabilities for those fish with respect to location.

For adults, we used a four-state model to estimate the probability of moving from a non-entrained state to an entrained state. The four states were as follows: upstream of the pump intake (state A); near the pump intake (state B); entrained into Muddy Run Reservoir (state C); and downstream of the pump intake (state D). Release dates corresponding to early/prespawn (May 1–9, 2001; April 22–May 3, 2008), peak run (May 10–30, 2001; May 4–25, 2008), and late/postspawn (June 1–15, 2001; May 26–June 17, 2008) periods were used as groups in our models. No tagged adults that became entrained into Muddy Run Reservoir were able to subsequently exit the reservoir; thus, the probability of going from an entrained state to a non-entrained state was set to zero in all models to constrain parameter estimation. We determined whether entrainment probabilities were significantly different based on overlapping confidence intervals (CIs).

[A]RESULTS

[B]*Hydrological Conditions during the Juvenile American Shad Study*

River flows were generally higher during power generation than during the other operational modes at MRPSF (TABLE 4). Controlled turbine discharges of up to 622.9 m³/s and spillage of up to 2,152 m³/s occurred from HHS. Compared to the historical record, the prevailing river flows in October and November were higher and water temperatures were lower during the 2011 study (TABLE 4).

[B]*Dispersion of Juveniles*

Known numbers of juveniles that were exposed to each operating mode after release were as follows: 32 (78.0% of 41) were exposed to generation; 53 (89.8% of 59) were exposed to pumping; and 43 (95.6% of 45) were exposed to idle mode. The status of the remaining 17 fish could not be determined; these 17 individuals did not emigrate downstream, were not detected, or were detected only briefly. Immediate mortality of test specimens did not appear to be a factor; no mortality was observed either during tagging or during transport of tagged fish to the release site. Most (128 of 145, or 88.3%) of the released fish were accounted for within the study area. The chi-square test detected differences (Fisher's exact $\chi^2 = 6.585$, df = 2, $P = 0.05032$) in the juveniles' frequencies of dispersion among the three operational modes. Most (4.15, or 63%) of the total χ^2 value (6.585) was contributed by a higher frequency of nondispersion or nondetection of juveniles released during generation mode.

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[B] *Juvenile Emigration and Residency Times*

Exact emigration times of 112 juveniles from the point of release to initial detection at MRPSF were known. Sixteen additional fish traveled outside the detection zones of the monitors but were later detected via boat tracking downstream of MRPSF; thus, their exact emigration times could not be calculated. The travel times from the release point at Deepwater Island to initial detection at MRPSF were short, with a median value of 22 min for all juveniles (FIGURE 5). The median travel time was similar during generation (17 min) and idle (18 min) conditions but was slightly longer during pumping (26 min); the latter may have been affected by HHS discharge. When discharge from HHS was between 570 and 1,140 m³/s, the median travel time was nearly 35 min; at higher discharges (1,132–2,235.7 m³/s), median travel time decreased and was close to 15 min. This trend was not apparent when MRPSF was generating or idle, as median travel times were between 7 and 10 min at HHS discharge levels between 1,140 and 2,821 m³/s.

Residency of juveniles at MRPSF prior to passing was short regardless of passage or entrainment (FIGURE 6). The median residency time was 2 min during both generating and idle operations and 3 min during pumping.

[B] *Juvenile Travel Path*

Juvenile American Shad approaching MRPSF generally utilized one of three travel routes (FIGURE 7): (1) they passed directly in front of MRPSF and continued downstream along the east shore, (2) they entered the MRPSF discharge flow field and traveled toward the west shore, or (3) they were entrained.

[B] *Juvenile Entrainment Rate*

A combination of pumping volume, exposure time, and prevailing river flows appeared to affect the number of juveniles that were entrained (TABLE 5). Among the 53 juveniles that were exposed to pumping mode, 22 fish (41.5%) were exposed for a median time of 1 min or less when fewer than six units (339.9–453.3 m³/s) were pumping, with 1 individual (4.5%) becoming entrained; 31 fish (58.5%) were exposed for a median time of 2 min when six or more units (566.5–679.9 m³/s) were pumping, with 11 individuals (35.5%) becoming entrained. Overall, 12 of the 53 juveniles (mean ± 90% CI = 22.6 ± 9.4%) were entrained (TABLE 5).

When the observed entrainment rate (22.6%) of radio-tagged juveniles was adjusted for the pumping volume at which entrainment occurred and the reported diel emigration pattern from each of the three studies (TABLE 3) conducted in the Connecticut River, we estimated that the entrainment rate of naturally emigrating juveniles would range from 1.4% to 5.8%, with a mean of 3.5%.

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[B] *Juvenile Entrainment Probabilities*

The two-state model that used the same survival and re-encounter probabilities for groups released during no pumping/short pumping regimes and the same re-encounter and survival probabilities for all groups released during the long pumping regime was the top-ranked model based on Akaike's information criterion ($AIC_c = 533.17$; TABLE 6) compared to the model with separate survival and re-encounter probabilities for each group ($AIC_c = 535.25$; AIC_c difference [ΔAIC_c] = 2.09). Parameter estimates reported hereafter for juveniles are based only on those from the top-ranked model. Although re-encounter and survival probabilities did not differ by pumping regime exposure, entrainment probabilities for juvenile American Shad released during long-duration pumping were significantly higher (0.093; CI = 0.054–0.156; TABLE 7) than probabilities for those released during no pumping/short-duration pumping; entrainment probabilities for the latter group did not differ from zero.

[B] *Hydrological Conditions during the Adult American Shad Migration*

River flows from the time of radio-tagging to the termination of monitoring for adult American Shad ranged from 348.3 to 926.0 m³/s in 2001 and from 388 to 1,880.2 m³/s in 2008 (TABLE 8). Flows were substantially lower during May 2001 (504.0 m³/s), June 2001 (624.0 m³/s), and June 2008 (421.9 m³/s) relative to the historical averages for these months. Water temperatures ranged from 15.5°C to 22.0°C in 2001 and from 14.1°C to 26.9°C in 2008 and were generally higher—particularly in 2001—than the historical averages for the months of interest (TABLE 8).

[B] *Adult Upstream Migration and Entrainment Rate*

Between 27.9% (147 of 204; in 2001) and 32.3% (205 of 303; in 2008) of radio-tagged adults failed to migrate upstream from the release site at Conowingo East Fish Lift and past MRPSF. The drop off was likely due to stress induced by capture, handling, tagging, and fallback, and perhaps rising water temperature later in the season. Although rates are variable between sites, failure of American Shad to continue upstream migration after being radio-tagged has been commonly observed in virtually all American Shad migration studies (Smith et al. 2009). However, it is unknown whether the untagged portion of the migrating adult population would show a similar failure rate after being lifted upstream at Conowingo East Fish Lift.

The median travel times of prespawn adults from the release point at Conowingo East Fish Lift to upstream of MRPSF were 1.3 d in 2001 and 2.5 d in 2008. Entrainment rates of prespawn adults were low in both years: only 2 (1%) prespawn fish were entrained in 2001, and only 1 (0.3%) prespawn fish was entrained in 2008. Entrainment of postspawn individuals in both years was low as well and appeared to be related to pumping volume and prevailing river flows. In 2001, 5 (3.4%) postspawn adults were entrained; in 2008, 8 (3.9%) postspawn individuals were entrained. Entrainment occurred when pumping volume exceeded the prevailing river flows. With one exception in 2008 (prevailing river

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flow = 792 m³/s), fish were entrained only when the pumping volume (680–793 m³/s) exceeded river flows by approximately 30% or a ratio of 1.3:1 (range = 1.02–2.56:1). Higher ratios of pumping volume to river flow were also observed in 2001, when the prevailing river flows at the time of adult entrainment were mostly less than 538 m³/s; May (peak migration time) flow in 2001 was one of the lowest on record.

American Shad that successfully migrated upstream of MRPSF remained upstream for several days in the tailrace of HHS during both years. Once upstream, the general tendency was for adults in the HHS tailrace to leave this area during the late afternoon, move downstream in the eddy near Deepwater Island (thought to be a staging area), reside there until daybreak, and then return upstream to the HHS tailrace. These forays were sometimes repeated for several days. There was little evidence of adult movement downstream from this area to the vicinity of MRPSF during a 24-h period.

[B]Adult Entrainment Probabilities

Adult American Shad that were released and tracked had survival probabilities generally greater than 0.95 and had re-encounter probabilities generally higher than 0.90 (TABLE 9). Entrainment probability estimates for adults in both 2001 and 2008 were quite low (<0.02). The highest entrainment estimate was 0.015 (CI = 0.004–0.047), and no upper confidence bound exceeded 0.07 (TABLE 9). Importantly, 50% of the time period (early/prespawn, peak, or late/postspawn) × model state combinations had entrainment probabilities that were statistically indistinct from zero. Fish also had a higher entrainment probability when they occupied habitats near the intake. Among the time period × state combinations for which entrainment probability was greater than zero, there were no differences in entrainment probability between portions of the run at any location or among locations relative to the pump intake (TABLE 10).

[A]DISCUSSION

Detection of a relatively high percentage (>88%) of emigrating juvenile American Shad provided confidence in entrainment estimates for the studied operational schedule at MRPSF. The use of hatchery-reared juveniles did not appear to affect results. A small pilot entrainment study (RMC 1989) at this site using river-run juveniles (~125 mm) showed a similar entrainment rate. In that study, an estimated 14% of juveniles (versus the 22.6% observed in the present study) were entrained when all units were pumping at night. Because of the small sample size in that study, adjustments were not made for diel emigration pattern and cyclical operation of MRPSF. However, the pattern of entrainment was similar to that observed in the present study, when virtually all (11 of 12, or 91.7%) of the radio-tagged juveniles were entrained at high pumping volume at night.

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To maintain the safety of personnel, fish that were entrained into Muddy Run Reservoir were not tracked to confirm their status (alive or dead). Consequently, there was no way to evaluate turbine-caused tag damage. We did not observe any fish being entrained from MRPSF into the turbines and back into Conowingo Pond. If this occurred, we would expect significant injury and mortality given that MRPSF uses Francis turbines, which generally inflict higher fish injury and mortality than other types of turbine (Pracheil et al. 2016).

The magnitude of juveniles' susceptibility to entrainment at pumped storage facilities would depend to a large extent on the co-occurrence of the emigration period with a pumping volume that is high enough to draw fish into the intakes at prevailing river flows. A lack of significant overlap in the timing of these events should minimize the entrainment probability; the greater the overlap, the greater is the probability of entrainment. In our study, a low level of overlap occurred between the peak emigration of juveniles, which mostly occurs during the daytime, and high pumping volume, which occurs primarily at night. The near absence of co-occurrence for these two events resulted in a low estimated entrainment rate and a low probability of entrainment. We estimated that, on average, 3.5% of naturally emigrating juvenile American Shad may be entrained at MRPSF.

The only reported entrainment study was conducted by Layzer (1978a) at the previously mentioned Northfield Mountain Pumped Storage Station on the Connecticut River. Layzer (1978a) observed that the lack of entrainment of juvenile American Shad at the facility was most likely due to prevailing river flows being higher than the pumping volume; however, the pumping volume was not reported in that study. Results of our study are consistent with these observations. Most entrainment of juveniles at MRPSF occurred when pumping volume exceeded the prevailing river flows. Other factors also may have contributed to low entrainment of juvenile American Shad at MRPSF: the pumping volume may not have been high enough to draw surface-swimming fish (upper 3 m of the water column) into the intakes; the intakes were deep (intake ceiling was 12 m below the water surface); and exposure times near the powerhouse during pumping were short (median = 2 min).

Certain factors that could affect American Shad juveniles' probability of entrainment at MRPSF but that could not be accounted for in the present study include (1) the potential effects of increased turbine hydraulic capacity from 906 to 1,756 m³/s in 2013 at HHS (3.2 km upstream of MRPSF) and associated operational changes; and (2) the co-occurrence of juvenile emigration through multiple dams prior to exposure to the high pumping volume at MRPSF.

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Prevailing river flows may affect entrainment of juvenile American Shad. Entrainment of juveniles occurred at prevailing river flows that were higher than historical flows. Thus, the estimated entrainment rate for naturally emigrating juveniles is likely an underestimate, although we cannot quantify the magnitude of the underestimation. Historically, river flows of 906 m³/s or greater in October and November are exceeded 10% and 17% of the time, respectively, compared to 87% (November) and 100% (October) of the time during the present study. The effect of pumping is likely reduced at higher river flows and *vice versa*. Thus, the magnitude of variation in entrainment would depend upon the degree of fluctuation in river flows relative to pumping volume during the peak emigration period. Our study identifies the importance of considering pumping volume based on river flow conditions.

Some factors identified in contributing to a low probability of entrainment for juvenile American Shad may have also played an important role in minimizing the entrainment of adults. These included a minimal overlap between (1) the migration time of prespawn and postspawn adults and (2) the occurrence of a high pumping volume. Prespawn adult American Shad reportedly migrate upstream primarily during the day (Leggett 1976; Normandeau Associates 2001; Olney et al. 2006; ASMFC 2009; Normandeau Associates and Gomez and Sullivan Engineers 2009) when MRPSF is in generation mode, thus limiting the risk of entrainment to only the small fraction of the population that may be exposed to pumping at night. Although we observed diel movements of prespawn adults as noted by others (Barry and Kynard 1986; Haro and Kynard 1997), <AQ: Barry and Kynard 1986 is not found in the references.>the movements were mostly limited to an area between Deepwater Island and the HHS tailrace. There was little evidence of daily movements between MRPSF and upstream areas. Most of the prespawn adults were apparently motivated to continue their upstream migration or may have found a suitable spawning habitat in the HHS tailrace. Carlson (1968) characterized this area as suitable for spawning by American Shad.

Similarly, most of the postspawn American Shad emigrated downstream during the daytime, thereby lowering their exposure to nighttime pumping, when most of the entrainment occurred. Kynard and O'Leary (1993) observed that 86% of emigrating postspawn American Shad utilized the bypass system at Hadley Falls Station on the Connecticut River prior to 2300 hours. In the absence of site-specific data, we assumed a similar emigration pattern in the present study, and if this assumption holds true for the current situation, only up to 5% of the 14% (i.e., 0.7%) of downstream-migrating postspawn adults could be entrained. Even this low value may be an overestimate because most prespawn adults had spent several days upstream of MRPSF prior to being entrained; a large proportion of these fish had migrated past MRPSF during their upstream migration. They had ample opportunity to utilize the fish lift at HHS, which would have allowed them to continue upstream migration for spawning and to totally avoid exposure to MRPSF until they were ready to emigrate back to the ocean, presumably as spent fish. The efficiency of the HHS fish lift in passing upstream-migrating American Shad since its installation in 1997 has rarely exceeded 50%, so a large proportion of the population remains in the tailrace (Long et al. 2012).

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A combination of the robust swimming speed (>2.2 m/s; Weaver 1965; Haro et al. 2004) and swimming depth (upper 3 m of the water column) of adult American Shad during their upstream migration through Conowingo Pond compared to the depth (>11.7 m) and velocity (<0.3 m/s) of the intake appears to reduce their entrainment risk at MRPSF. Tracking of upstream-migrating adults through Conowingo Pond indicated that most detections of upstream migrants occurred within the top 3 m of the water column (Long et al. 2012). Literature on American Shad depth preferences (reviewed by ASMFC 2009) supported this finding and indicated a preference for depths less than 6 m. Thus, a large proportion of adults can avoid or may not be involuntarily drawn into the MRPSF intakes located at deeper depths with near-field water velocities of 1.0 m/s or less, and these velocities subside substantially within a short distance from the intakes (Long et al. 2012). Although the interactive effects of depth and velocity on migrating adult American Shad are not clear, empirical evidence (Normandeau Associates 2001; Normandeau Associates and Gomez and Sullivan Engineers 2009; Long et al. 2012) suggests that (1) neither prespawn nor postspawn radio-tagged adults were delayed near the MRPSF powerhouse and (2) large numbers were not drawn toward the intakes. However, when the pumping volume exceeds the upstream discharge volume, a small proportion of postspawn adults in a physically or physiologically weakened state may be drawn into the intakes at night, when the pumping volume is most likely to be maximal.

Entrainment of adult postspawn American Shad, though low in both years, was likely overestimated. The pumping volume averaged 50–100% higher than the prevailing river flow during the study. Historically, river flows of $793\text{ m}^3/\text{s}$ or less occurred 2% of the time in May and 42% of the time in June, whereas these flow conditions were present 90–97% of the time in May and 80–100% of the time in June during the current study.

In summary, MRPSF—with its close proximity to HHS in combination with the complex hydraulics of upper Conowingo Pond, which may fluctuate on a daily basis—presents a unique challenge for estimating the entrainment of juvenile and adult American Shad. Despite these hydraulic complexities, our findings should apply to other pumped storage facilities where juvenile alosines are present and where high pumping volume occurs outside of the peak emigration times. Although miniature radio transmitters provided reliable entrainment estimates for juvenile American Shad (>110 mm) during short-term investigations, more powerful radio transmitters that can be attached to juveniles (≥ 100 mm) by less-invasive methods are now available for longer-term investigations. Due to recent interest in developing a large number of pumped storage facilities in concert with renewable

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energy resources, based on our findings, we recommend siting the intakes in deep, flowing water.

[A]ACKNOWLEDGMENTS

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TABLE 1.—Releases of radio-tagged juvenile American Shad for the entrainment study at the Muddy Run Pumped Storage Facility (MRPSF) and prevailing hydrological conditions in the Susquehanna River, October 19–November 2, 2011 (MRPSF operations = number of units that were in generating or pumping mode; Holtwood = Holtwood Hydroelectric Station). <AQ: some of the abbreviations in Table 1 column headings were not defined. Please check to ensure accuracy of the revisions. Also, in the Release Time column, several values were only three digits (for example, 200 and 145). I assumed that these values should be in four-digit format (0200, 0145, etc.). Please confirm.>

Date	Release time (hours)	Water temperature (°C)	MRPSF operations at release		Number of juveniles released	Holtwood discharge (m ³ /s)	Spillage (m ³ /s)
			Generating	Pumping			
Oct 19, 2011	1818	14.8	2	0	4	622.9	2,067.1
	1847	14.8	2	0	4	622.9	2,067.1
Oct 20, 2011	1833	14.9	6	0	4	622.9	1,814.8
	1845	14.9	6	0	4	622.9	1,814.8
	2158	14.9	0	0	4	622.9	2,038.8
	2208	14.9	0	0	4	622.9	1,897.2
	1800	14.3	0	0	4	622.9	2,152
Oct 22, 2011	1955	14.3	2	0	4	622.9	2,152
	2200	14.1	0	0	4	622.9	2,152
	2355	14.9	0	0	4	622.9	2,010.4
	1757	13.3	0	0	4	594.6	1,557.4
Oct 23, 2011	1955	13.3	6	0	2	622.9	1,359.2
	1957	13.3	6	0	2	622.9	1,359.2
	2156	13.3	0	0	4	28.3	1,359.2
	2347	13.3	0	0	2	28.3	1,359.2
	2350	13.3	0	0	2	622.9	1,557.4
	1857	15.1	8	0	4	622.9	1,783.9
	2055	15.1	4	0	2	622.9	1,359.2
Oct 25, 2011	2058	15.1	4	0	2	622.9	1,359.2
	2300	15.1	0	2	4	622.9	283.1
Oct 26, 2011	0106	15.1	0	6	4	622.9	339.8
	2012	14.2	8	0	4	622.9	1,557.4

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Date	Release time (hours)	Water temperature (°C)	MRPSF operations at release		Number of juveniles released	Holtwood discharge (m ³ /s)	Spillage (m ³ /s)
			Generating	Pumping			
Oct 27, 2011	2201	14.2	0	0	2	622.9	962.7
	2203	14.2	0	0	2	622.9	962.7
	2357	14.2	0	4	2	622.9	962.7
	2359	14.2	0	4	2	622.9	962.7
	0200	14.2	0	8	4	–	–
Oct 28, 2011	2019	12	0	0	2	622.9	1,557.4
	2028	12	0	0	2	622.9	1,557.4
	2206	12	0	0	2	622.9	1,642.3
	2206	12	0	0	2	622.9	1,642.3
	2355	12	0	5	6	622.9	1,642.3
Oct 29, 2011	0145	12	0	8	6	622.9	28.3
Oct 31, 2011	1959	10	6	0	4	622.9	1,925.5
	2204	10	2	0	2	622.9	1,699
	2315	10	2	0	2	622.9	1,699
	2338	10	0	4	6	622.9	1,387.5
	0108	10	0	8	6	622.9	1,500.7
Nov 1, 2011	1927	9.9	8	0	2	622.9	1,415.8
	2219	9.9	8	0	2	622.9	1,415.8
	2239	9.9	0	2	2	622.9	707.9
	2353	9.9	0	4	6	594.6	707.9
	0141	9.9	0	8	5	594.6	481.3

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TABLE 2.—Historical percentage (%) of time that a given number of units were pumping at the Muddy Run Pumped Storage Facility (MRPSF) during a given hour of the diel cycle, 2006–2011.

Time (hours)	Number of MRPSF units pumping			
	1–2	3–4	5–6	7–8
0100	0	2	6	92
0200	0	1	5	94
0300	0	1	5	94
0400	0	1	5	94
0500	1	5	9	85
0600	3	9	12	75
0700	3	15	10	72
0800	6	25	18	51
0900	13	27	23	37
1000	20	57	6	17
1100	40	60	0	0
1200	67	33	0	0
1300	58	42	0	0
1400	43	57	0	0
1400	33	67	0	0
1500	47	53	0	0
1600	80	20	0	0
1700	100	0	0	0
1800	100	0	0	0
1900	100	0	0	0
2000	100	0	0	0
2100	100	0	0	0
2200	37	39	22	2
2300	9	29	35	28
0000	1	6	18	76

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TABLE 3.—Reported proportions of juvenile American Shad emigrating over a 24-h period from three studies on the Connecticut River and the corresponding proportion of time 6–8 units were pumping at the Muddy Run Pumped Storage Facility (MRPSF) during those times in October–November 2011.

Emigration time (hours)	Proportion of juveniles emigrating	Proportion of time 6–8 units were pumping at MRPSF
Layzer (1978a)		
1700–2200	0.87	0.067
2300–0500	0.13	0.888–0.981
O’Leary and Kynard (1986)^a		
1600–2200	0.79	0.067
2300–0500	0.21	0.888–0.987
Harza and RMC (1993)		
1700–2200	0.93	0.067
2300–0500	0.07	0.888–0.981

^aValues represent the average of numbers obtained by visual inspection of Figure 4 from O’Leary and Kynard (1986).

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TABLE 4.—Summary of radio-tagged juvenile American Shad exposed to each operational mode (*N*), along with the prevailing river flows (m^3/s) and water temperatures ($^{\circ}\text{C}$) for estimation of entrainment at the Muddy Run Pumped Storage Facility (MRPSF) in October–November 2011. Monthly natural river flow and water temperature averages for October and November 2011 are given in parentheses along with respective long-term historical averages.

Operational mode or month	<i>N</i>	River flow (m^3/s)	Water temperature ($^{\circ}\text{C}$)	Number of units operating at MRPSF
2011 conditions during MRPSF operational modes				
Pumping	53	651.3–2,038.8	9.9–15.1	2–8
Generation	32	1,982.2–2,775.1	9.9–15.1	2–8
Idle	43	1,585.7–2,77.1	12.0–14.9	0
Historical averages (1956–2011) and 2011 averages (in parentheses)				
Oct		594.7 (2,166.2)	16.8 (14.3)	
Nov		897.6 (1,625.4)	9.2 (8.7)	

TABLE 5.—Number of radio-tagged juvenile American Shad that were exposed to the Muddy Run Pumped Storage Facility pumping, the number of juveniles that were entrained, the pumping flow, and the prevailing river flow during October–November 2011.

Pumping flow (m^3/s)	River flow (m^3/s)	Number of juveniles exposed	Number of juveniles entrained
113–226.6	906.5–2,634.6	6	0
339.9–453.3	906.5–2,181.3	16	1
566.5–679.9	906.5–1,076.5	3	1
793.2–906.5	906.5–2,039.7	28	10
Total		53	12

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TABLE 6.—Comparison of two-state mark–recapture models tested for juvenile American Shad, where S is survival probability, ρ is re-encounter probability, and Ψ is the probability of a fish becoming entrained into the Muddy Run Pumped Storage Reservoir during October–November 2011 (k = number of parameters; AIC_c = Akaike’s information criterion corrected for small sample sizes; ΔAIC_c = difference in AIC_c value between the given model and the best-performing model; *pump* indicates that the term was grouped by pumping regime [<1 h or ≥ 1 h of pumping]; *g* indicates that the term was grouped by release group [there were nine release groups: four groups with <1 h of pumping, and five groups with >1 h of pumping]).

Model	k	AIC_c	ΔAIC_c
$S(pump), \rho(pump), \Psi(pump)$	6	533.165	0.000
$S(pump), \rho(g), \Psi(pump)$	7	535.250	2.085
$S(g), \rho(g), \Psi(g)$	20	545.564	12.399

TABLE 7.—Parameter estimates (with confidence intervals in parentheses) from the best-performing two-state model for juvenile American Shad (six-parameter model: $S[pump]$, $\rho[pump]$, $\Psi[pump]$; defined in Table 6) by pumping regime at the Muddy Run Pumped Storage Facility in October–November 2011. “Short/no pump” represents less than 1 h of pumping, and “long pump” represents over 1 h of pumping (asterisks indicate values < 0.0001). <AQ: in Table 7, you have asterisks next to both ρ values (1.000), even though you defined asterisks as indicating < 0.0001 . Please check.>

Pumping regime	ρ	S	Ψ
Short/no pump	1.000*	0.548 (0.460–0.634)	0.000*
Long pump	1.000*	0.629 (0.561–0.693)	0.093 (0.054–0.156)

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TABLE 8.—Prevailing water temperature (°C) and natural river flow (m³/s) during release of radio-tagged adult American Shad (*N*) at the Conowingo East Fish Lift and subsequent monitoring in Conowingo Pond during 2001 and 2008. Monthly averages within each study year along with the respective long-term historical (1956–2008) averages are also given.

Year	<i>N</i>	Monitoring duration	Water temperature (°C)	River flow (m ³ /s)
2001 release period and monthly averages				
2001 release period	204	May 1–Jun 15	15.5–22.0	348.3–926.0
Monthly averages		Apr	10.3	2,449.4
		May	20.1	504.0
		Jun	24.4	624.0
2008 release period and monthly averages				
2008 release period	303	Apr 22–Jun 13	14.1–26.9	388.0–1,880.2
Monthly averages		Apr	13.2	1,625.4
		May	16.6	1,379.0
		Jun	26.3	421.9
Historical averages (1956–2008)				
Monthly averages		Apr	10.0	2,194.6
		May	16.7	1,350.7
		Jun	22.8	846.7

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TABLE 9.—Survival probability (S) and re-encounter probability (ρ) estimates (with confidence intervals [CIs] in parentheses) for the four-state model of adult American Shad in 2001 and 2008. Model selection results are not presented because this model was the only one that gave plausible results (e.g., did not have CIs containing 0 and 1). State A represents estimates associated with habitats upstream of the pump intake at Muddy Run Pumped Storage Facility, state B represents estimates associated with habitats near the intake, state C represents estimates associated with entrainment into the Muddy Run Pumped Storage Reservoir (S and ρ were held constant for time periods in both years), and state D represents estimates associated with fish downstream of the intake.

Parameter	A	B	C	D
2001 early/prespawn period				
S	0.951 (0.913–0.973)	0.969 (0.903–0.963)	0.895 (0.745–0.961)	0.927 (0.913–0.973)
ρ	0.997 (0.358–0.999)	0.940 (0.880–0.971)	0.088 (0.040–0.182)	0.383 (0.352–0.414)
2001 peak period				
S	0.940 (0.903–0.963)	1.000 (0.999–1.000)		0.934 (0.917–0.948)
ρ	0.985 (0.917–0.997)	0.849 (0.783–0.898)		0.429 (0.400–0.457)
2008 early/prespawn period				
S	0.994 (0.973–0.999)	1.000 (0.999–1.000)	0.678 (0.473–0.832)	0.968 (0.953–0.978)
ρ	0.092 (0.075–0.114)	0.092 (0.075–0.114)	0.116 (0.035–0.321)	0.912 (0.864–0.943)
2008 peak period				
S	0.994 (0.975–0.998)	0.999 (0.007–1.000)		0.962 (0.935–0.978)
ρ	0.104 (0.090–0.119)	0.104 (0.090–0.119)		0.904 (0.848–0.941)
2008 late/postspawn period				
S	0.965 (0.930–0.983)	0.991 (0.937–0.999)		0.931 (0.858–0.936)
ρ	0.141 (0.113–0.175)	0.141 (0.113–0.175)		0.956 (0.744–0.994)

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TABLE 10.—Multistate mark–recapture entrainment probabilities (Ψ ; with confidence intervals in parentheses; asterisks indicate values < 0.0001) for adult American Shad during early, peak, and late portions of the run from 2001 and 2008 field efforts by previous location (state A = upstream of the pump intake at the Muddy Run Pumped Storage Facility; state B = near the pump intake; state C = entrained into the Muddy Run Pumped Storage Reservoir; state D = downstream of the pump intake). Locations are shown in FIGURE 1.

Period	Ψ_{A-C}	Ψ_{B-C}	Ψ_{D-C}
2001 early/prespawn	0.000*	0.003 (0.005–0.024)	0.000*
2001 peak	0.004 (0.001–0.027)	0.011 (0.005–0.024)	0.000*
2008 early/prespawn	0.000*	0.007 (0.002–0.027)	0.000*
2008 peak	0.000*	0.007 (0.000*–0.061)	0.015 (0.004–0.047)
2008 late/postspawn	0.000*	0.000*	0.008 (0.000*–0.065)

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FIGURE 1.—Map of the Susquehanna River and the Muddy Run Pumped Storage Facility (MRPSF), depicting locations of telemetry monitoring stations. Location of MRPSF within the contiguous United States is denoted by the star (lower left inset). Symbols represent the four states (used in mark–recapture models) to which each adult American Shad detection was assigned: state A = upstream of the MRPSF pump intake (open circles); state B = near the pump intake (gray circles); state C = entrained into the Muddy Run Pumped Storage Reservoir; and state D = downstream of the pump intake (black circles). Adult American Shad were released on the upstream side of Conowingo Dam (arrows indicate the direction of flow).

FIGURE 2.—Juvenile American Shad with a radio transmitter, tag attachment disc, and stainless-steel pin. The photograph was taken prior to the fish's release for estimation of entrainment at the Muddy Run Pumped Storage Facility in 2011. The radio transmitter was 14 mm long, 5 mm wide, and 3 mm high and weighed 0.43 g. The tag attachment disc was 6 mm in diameter and 0.75 mm thick. The stainless-steel pin was 15 mm long and weighed 0.3 g. <AQ: on Figure 2, please edit the leftmost text box to remove the extra word, “pin.” Also, there should be a space in each of the following (within text boxes): “15 mm” and “0.43 g.”>

FIGURE 3.—Map of upper Conowingo Pond, depicting islands and the locations of 13 continuous monitoring receivers used to estimate entrainment of radio-tagged juvenile American Shad at the Muddy Run Pumped Storage Facility (MRPSF). Fish were released at Deepwater Island during October–November 2011.

FIGURE 4.—Map of the Muddy Run Pumped Storage Facility (MRPSF) and detection locations of juvenile American Shad. Radio-tagged juveniles were released at Deepwater Island upstream of the MRPSF. Detections were used in the two-state models wherein fish could move from a non-entrained state to an entrained state. Solid black circles represent monitoring locations; gray circles denote juvenile detection locations.

FIGURE 5.—Frequency distribution (%) of emigration times (min) exhibited by radio-tagged juvenile American Shad from the release site at Deepwater Island to the Muddy Run Pumped Storage Facility during three operation modes, October–November 2011.

Figure 6.—Frequency distribution (%) of residency times (min) exhibited by radio-tagged juvenile American Shad in the vicinity of the Muddy Run Pumped Storage Facility during three operation modes, October–November 2011.

FIGURE 7.—Examples of downstream travel paths of radio-tagged juvenile American Shad from the release site at Deepwater Island to the monitored area near the Muddy Run Pumped Storage Facility (MRPSF) during pumping, generation, and idle modes, October–November 2011. Times are in hours; flow rates are in cubic meters per second (CMS).

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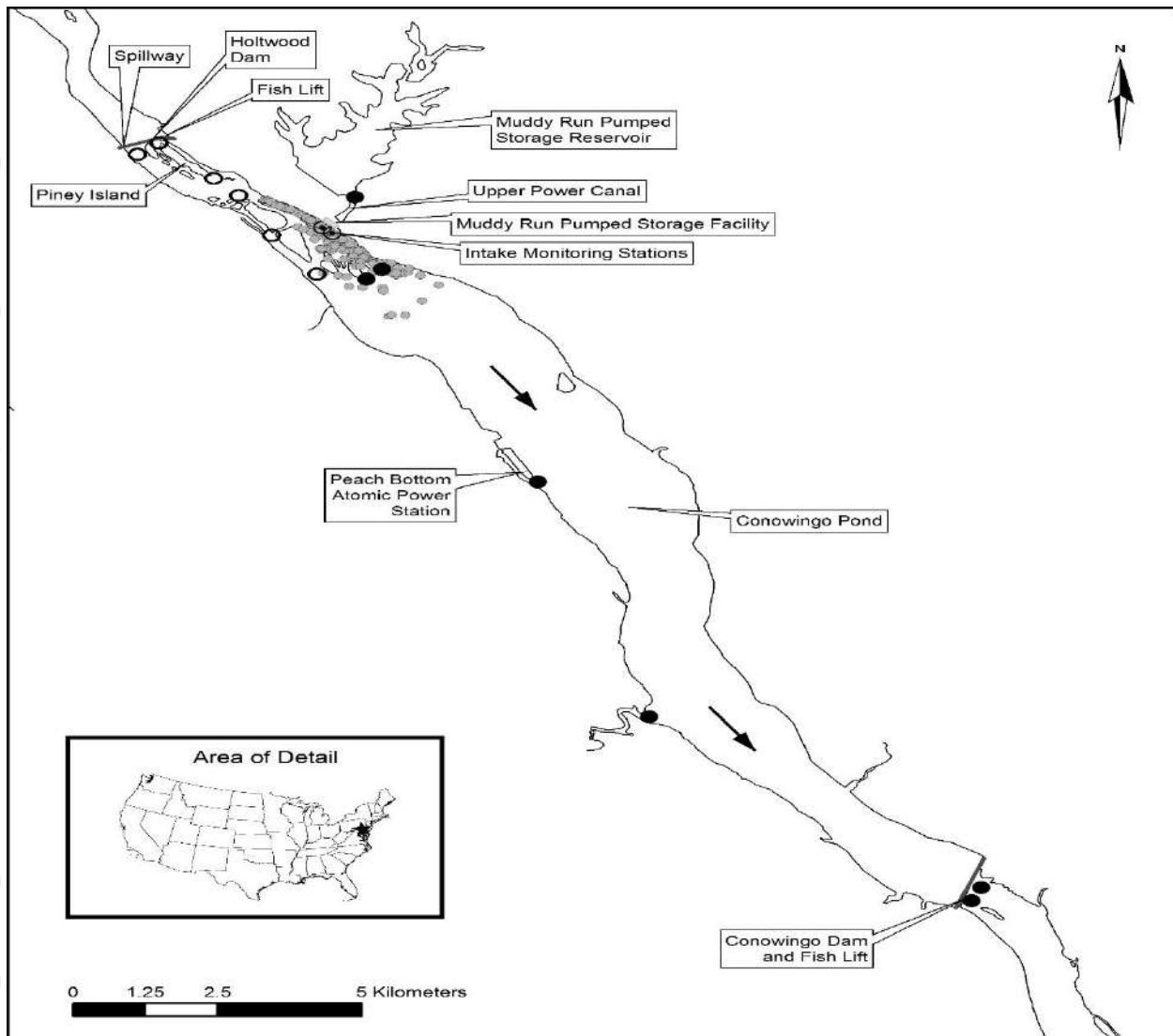


Figure 1. Map of Susquehanna River and Muddy Run Pumped Storage Facility (MRPSF) depicting locations of telemetry monitoring stations. Location of Muddy Run Pumped Storage Facility within the contiguous United States is shown by star (lower left). Differences in symbols denote to which of the four states used in mark-recapture models detections by each adult American Shad monitoring station were assigned: state A-upstream of MRPSF intake (hollow circles); state B-near MRPSF (gray circles); state C- entrained into Muddy Run Pumped Storage Reservoir; state D- downstream of MRPSF (black circles). Adult American Shad were released on the upstream side of Conowingo Dam (arrows indicate direction of flow).

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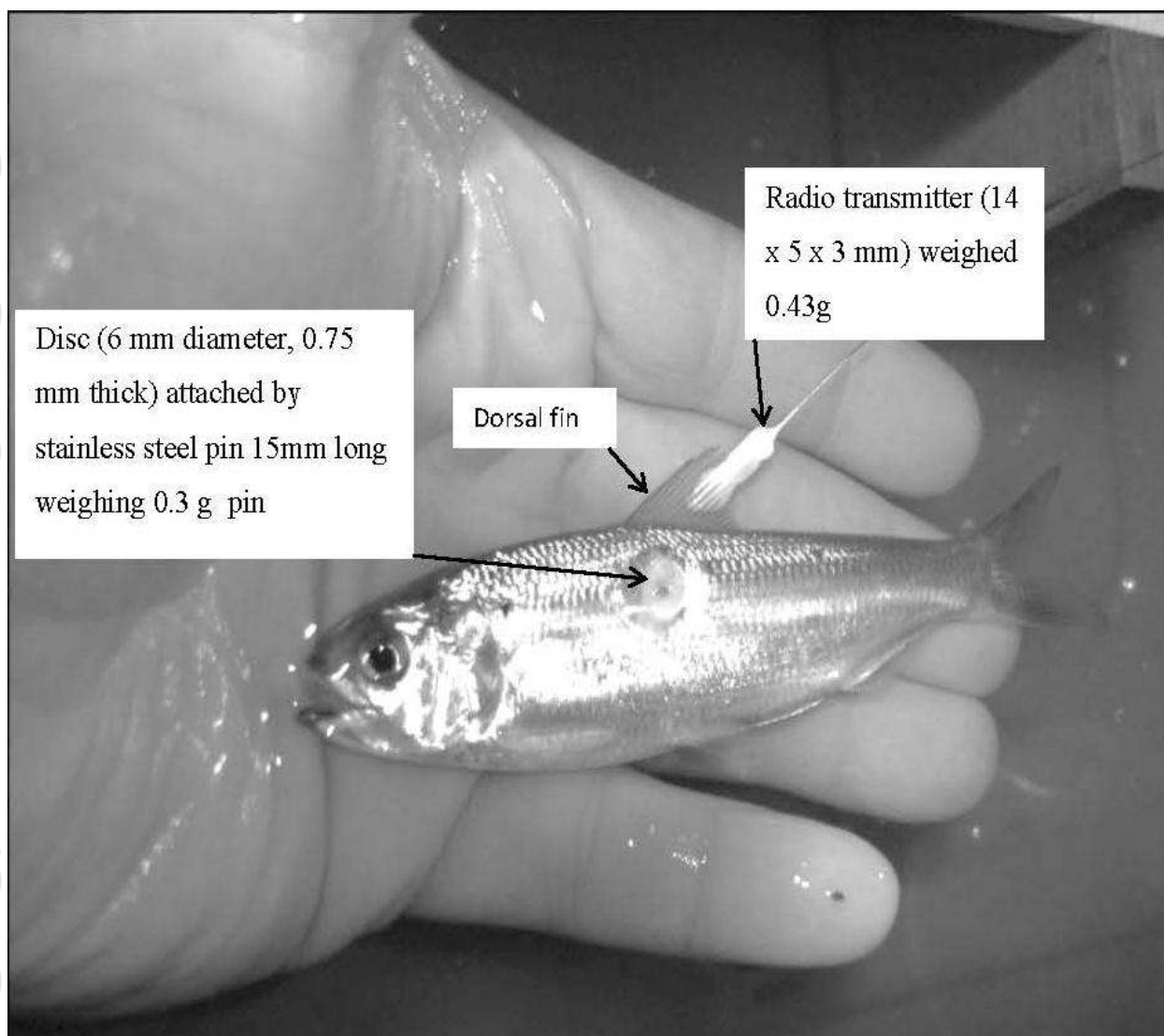


Figure 2. Juvenile American Shad with radio transmitter and tag attachment disc and stainless steel pin prior to release for estimation of entrainment at the MRPSF, 2011. Radio transmitter was 14 mm long, 5 mm wide, 3 mm high, and weighed 0.43 g. Stainless steel pin was 15 mm long and weighed 0.3 g.

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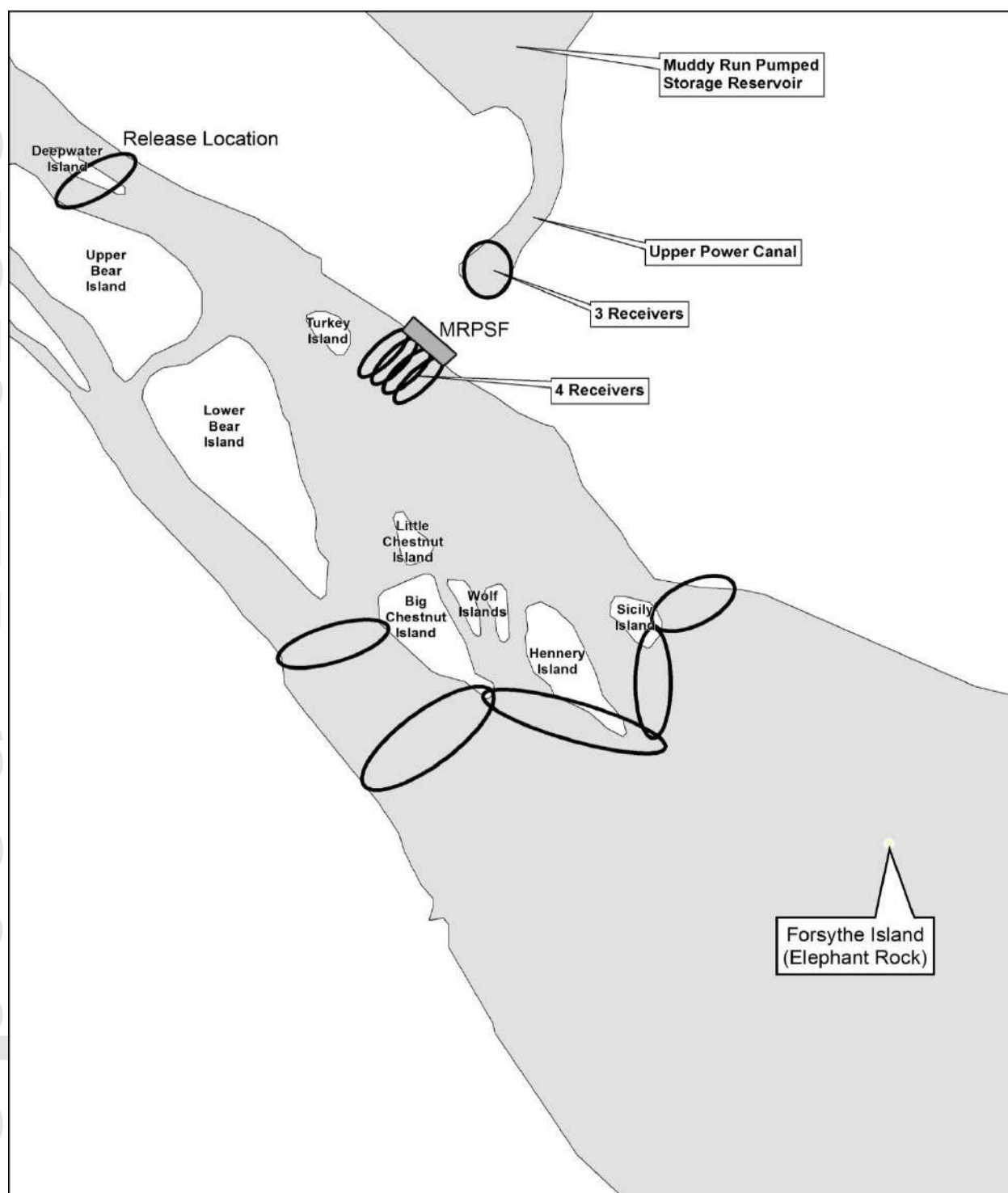


Figure 3. Map of upper Conowingo Pond with islands and locations of 13 continuous monitoring receivers for estimating entrainment of radio tagged juvenile American Shad at the Muddy Run Pumped Storage Facility; fish released at Deep Water Island, October-November, 2011.

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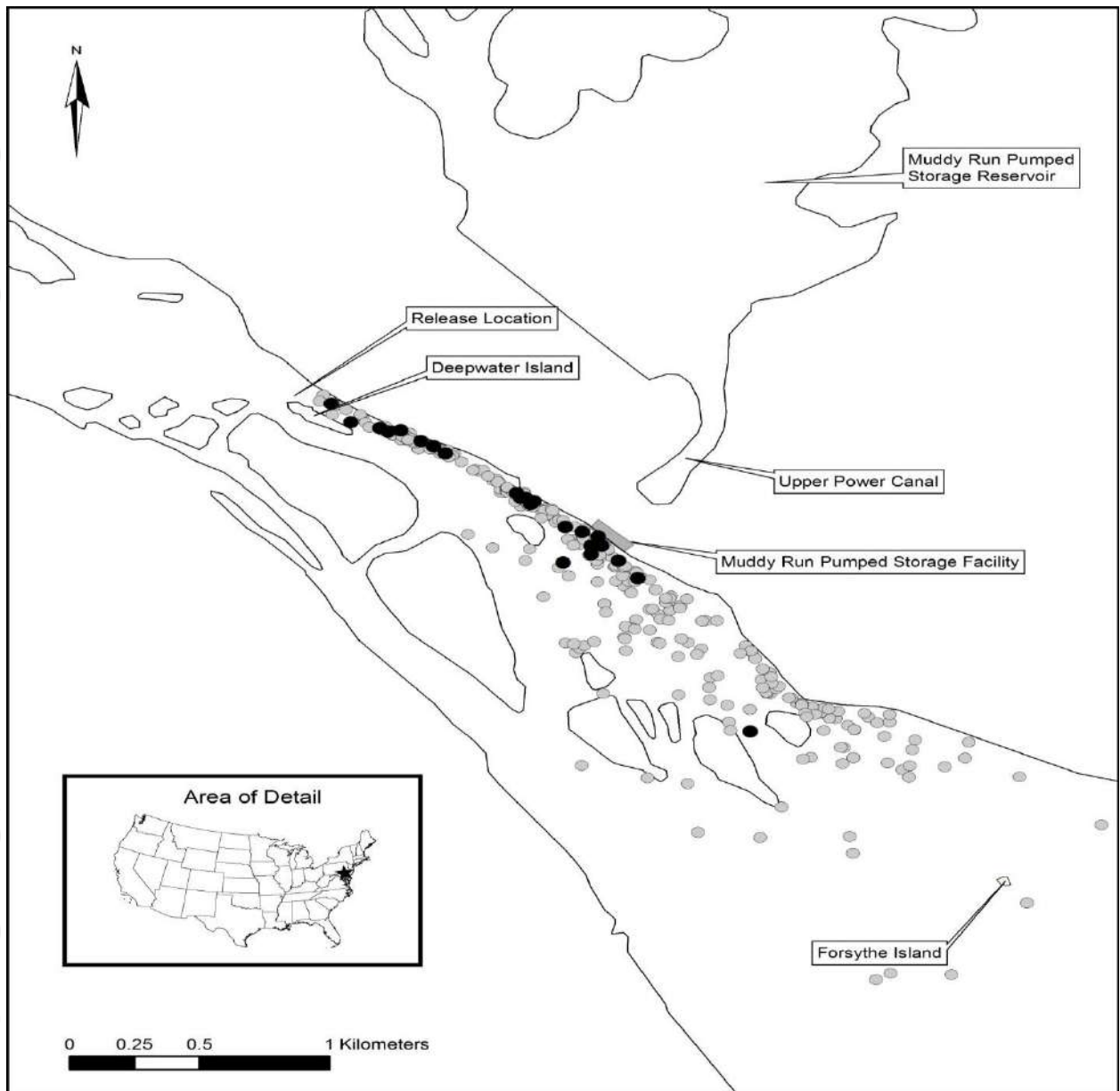


Figure 4. Map of the Muddy Run Pumped Storage Facility (MRPSF) and locations of juvenile American Shad detection locations. Juvenile shad were released upstream of the MRPSF at Deep Water Island. Detections were used in the two- state models: moving from non-entrained state to entrained state. Symbols denote: Black solid circles represent monitoring locations and gray circles are juvenile shad detection locations.

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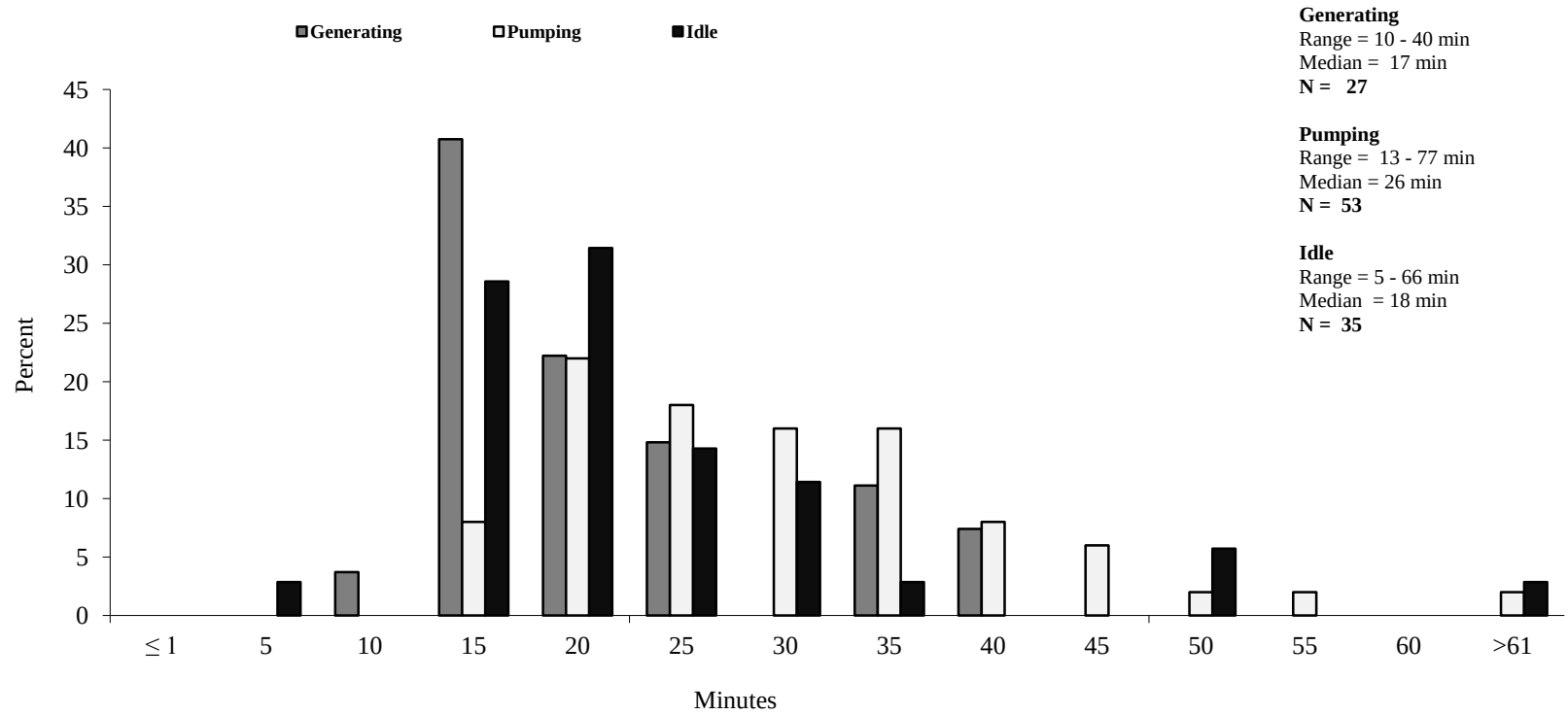


Figure 5. Frequency distribution of emigration times (percent) of radio tagged juvenile American Shad from Deep Water Island (release site) to the Muddy Run Pumped Storage Facility, October - November, 2011.

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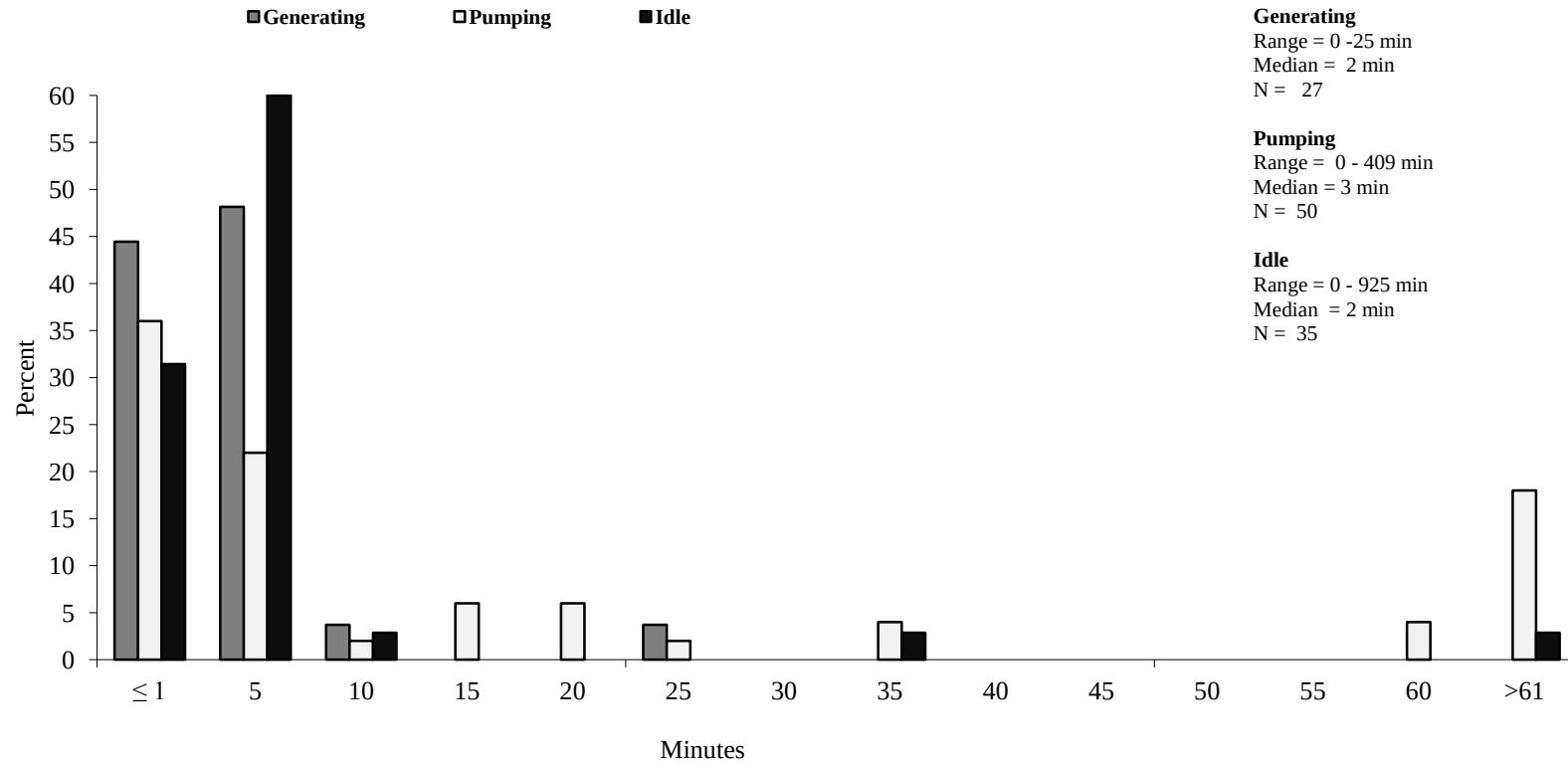


Figure 6. Frequency distribution (percent) of residency times of juvenile radio tagged American Shad in the vicinity of the Muddy Run Pumped Storage Facility, October-November, 2011.

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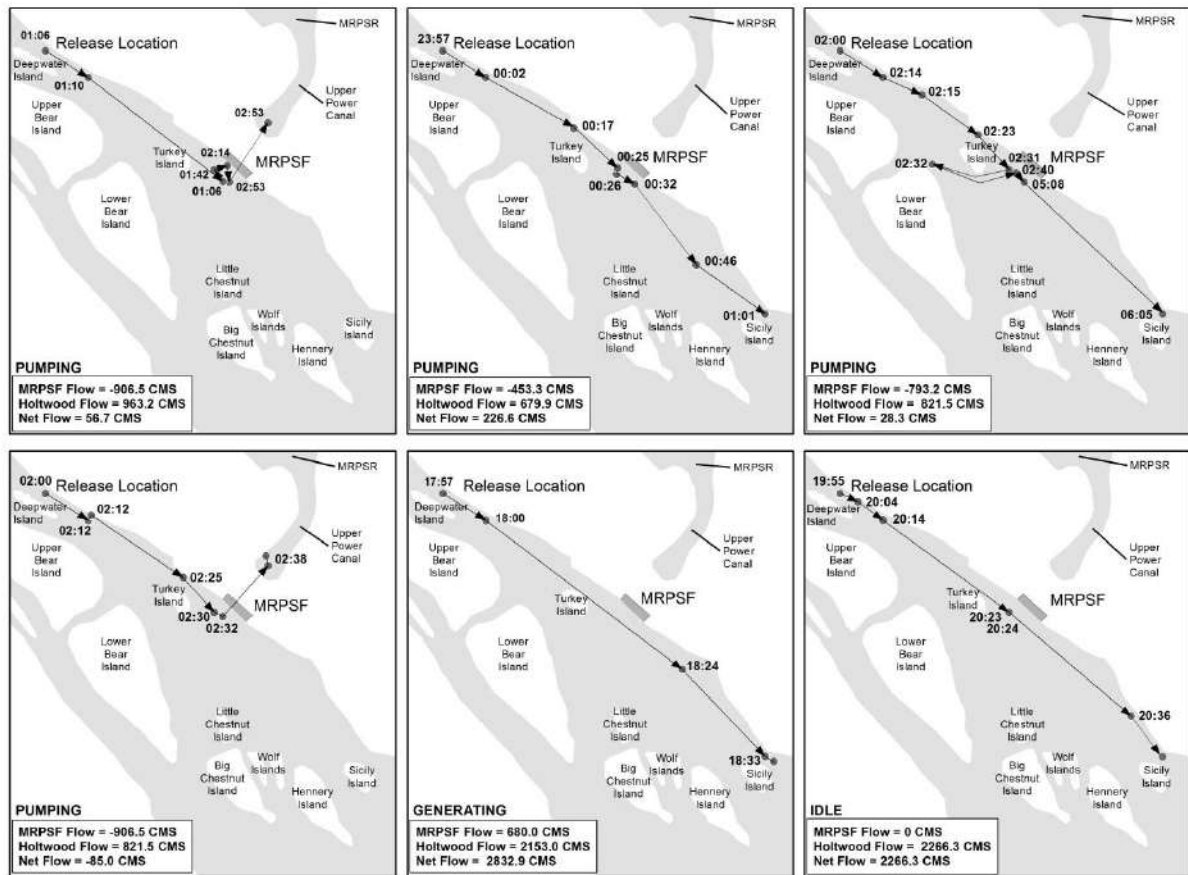


Figure 7. Examples of downstream travel paths of radio tagged juvenile American Shad from the release site at Deep Water Island upstream of the Muddy Run Pumped Storage Facility during pumping, generation, and idle modes, October-November, 2011.

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CONNECTICUT RIVER AMERICAN SHAD MANAGEMENT PLAN



**Connecticut River Atlantic Salmon Commission
103 East Plumtree Road
Sunderland, Massachusetts 01375**

*Management Plan Approved June 9, 2017
Addendum on Fish Passage Performance Approved February 28, 2020*

INTRODUCTION

The Connecticut River population of American Shad has been cooperatively managed by the basin state and federal fishery agencies since 1967. In that year the “Policy Committee for Fishery Management of the Connecticut River Basin” was formed in response to the passage of the 1965 Anadromous Fish Conservation Act (Public Law 89-304) by the U.S. Congress. This committee was replaced by the more formal “Connecticut River Atlantic Salmon Commission” (CRASC), which was created by act of Congress (P.L. 98-138) in 1983 (Gephard and McMenemy 2004) and coordinates restoration and management activities with American Shad (<http://www.fws.gov/r5csrc/>). The CRASC American Shad Management Plan had a stated objective of 1.5 to 2.0 million fish entering the river mouth annually (CRASC 1992). Diverse legislative authorities for the basin state and federal fish and wildlife agencies, including formal agreements to restore and manage American Shad, have been approved over time and are listed in Appendix A. The following Plan updates the existing CRASC Management Plan for American Shad in the Connecticut River Basin (1992), in order to reflect current restoration and management priorities and new information. An overview of American Shad life history and biology is provided in Appendix B.

Annual estimates of adult returns to the river mouth for the period 1966-2015 have ranged from 226,000 to 1,628,000, with an annual mean of 638,504 fish (Appendix C). Access to historical habitat has increased since 1955 when the first modern-era fishlift was constructed at Holyoke Dam, with significant passage improvements made when the fishlift was rebuilt in 1976 and again in 2004. Since 1980, access to additional habitat has increased through the deterioration of the Enfield Dam and fishway construction at three main stem and four tributary dams. Bellows Falls, Vermont (river kilometer-rkm 280) has been identified as the historic extent of the species’ range on the main stem river, but a fishway completed in 1984 to pass Atlantic Salmon upstream at that barrier now allows shad to migrate beyond that dam (Figure 1; Appendix D and E).

The size of the annual shad run increased from 1967 to 1992 concurrent with the installation of fishways at main stem dams but the population experienced a dramatic and unexpected decline beginning after 1992 (Crecco and Savoy 2004). Some recovery has occurred from 2012-2016 as the number of shad lifted at Holyoke has exceeded the mean annual count for the period 1976-2011, in each of these recent years (Appendix E). At this time, the Connecticut River American Shad population is considered stable, but at reduced levels of abundance, according to the Atlantic States Marine Fisheries Commission’s (ASMFC) American Shad Benchmark Stock Assessment (ASMFC 2007).

In the Connecticut River, fishway passage counts (Appendix E) are an important metric to help determine adult abundance and trends over time, although many factors can influence fish passage rates and counts within and among years. Additional long-term population monitoring information includes stock structure data (e.g., age, spawning history) for Holyoke Fish Lift and downstream areas, as well as a juvenile shad seine survey, conducted by the Connecticut Department of Energy and Environment (CTDEEP) (Appendix F and G). Other long-term monitoring data compiled by the CTDEEP include landings and effort data for the lower river commercial gill net fishery (Appendix G).

Beginning in 2013, commercial (in-river only) and/or recreational harvest of American Shad by a state required a Sustainable Fishery Management Plan approved by the Atlantic States Marine Fisheries Commission (Amendment 3 to the ASMFC Interstate Fishery Management Plan for Shad and River Herring, 2010). Subsequently, the State of Connecticut developed an ASMFC approved Sustainable Fishery Management Plan (2012) that maintained both its commercial and recreational fisheries, with harvest. Massachusetts also received approval to maintain a recreational fishery with allowed harvest (MADMF 2012). The State of New Hampshire chose not to develop a sustainability plan and therefore its fisheries are limited to catch-and-release. Vermont is not a member of ASMFC and is free to maintain a recreational fishery without a sustainability plan but has followed New Hampshire’s regulations. In

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addition, ASMFC required development of a Habitat Plan for American Shad, which was completed by both the State of Connecticut for its portion of the basin and CRASC for the entire basin. Both were approved in 2014 (ASMFC 2014).

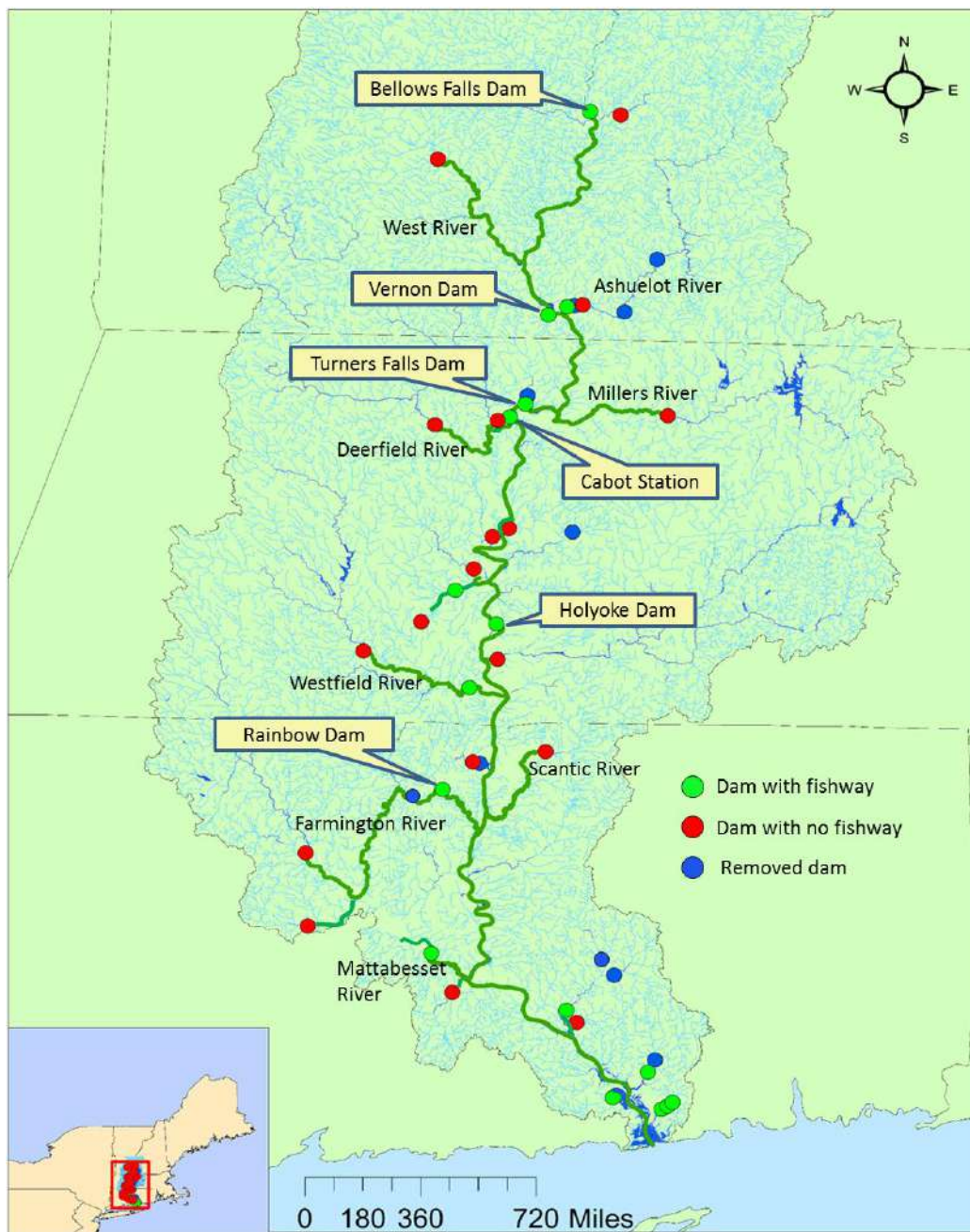


Figure 1. Restored habitat access within the historical range of American Shad in the Connecticut River.

American Shad have also been designated as a “Species of Greatest Conservation Need,” as stated in the comprehensive State Wildlife Action Plan(s), in each of the four basin states (TWW 2015). This designation recognizes the need to develop and implement conservation strategies and actions to improve American Shad’s status in the Connecticut River basin.

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This Plan reflects knowledge gained since the development of the 1992 American Shad Plan, which includes advances on shad population status and dynamics, physiology and energetics, reproduction, movement/behavior, fishway use/passage, fishway design/modification, and both fishway and facility operation and flow management.

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GOALS

To restore and maintain a naturally reproducing American Shad population to its historic range in the Connecticut River basin at targeted management levels of both abundance and stock structure, to provide and maintain recreational fisheries in the four basin states and the traditional in-river commercial fisheries for the species in Connecticut, and provide for the diverse ecological benefits derived from all life stages of shad in freshwater, estuarine and marine habitats.

OBJECTIVES

1. POPULATION

- 1.1 Achieve and sustain a minimum population of **1.7** million adult American Shad entering the mouth of the Connecticut River annually based on **8,800 hectares** (ha) of spawning and nursery habitat in the main stem and identified tributaries (Appendix I); and
- 1.2 Achieve and sustain a management target adult return rate of a minimum of **203 adults per hectare in the main stem** (Appendix I); and
 - 1.2.1 Achieve a run of > 1,027,000 shad downstream of Holyoke;
 - 1.2.2 Pass > 687,000 shad at Holyoke Dam; and
 - 1.2.3 Pass >397,000 shad at Turners Falls Dam; and
 - 1.2.4 Pass >227,000 shad at Vernon Dam; and
- 1.3 Achieve and sustain a management target adult return rate of a minimum of **111 adults per hectare in targeted tributaries** (Appendix I); and
- 1.4 Achieve an adult stock structure that over a five-year running average has a repeat spawner component minimum of **15%** for each sex; maintains a sex ratio close to 1:1, and is composed of a diverse age structure, including fish age-6 and older; and
- 1.5 Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post spawn adults, and juveniles [Refer to Addendum]; and
- 1.6 Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency and delay at these three stages, as suitable information is available, to support other objectives of this Plan [Refer to Addendum]; and
- 1.7 Establish downstream performance measures, for adult and juvenile life stages that maximizes survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan [Refer to Addendum].

2. FISHERIES

- 2.1 Maintain and/or establish a sustainable spring shad recreational fishery with harvest opportunities throughout its historical range on the main stem and on targeted tributaries guided by population size and fish passage objectives from this Plan; and
- 2.2 Enhance and promote recreational fishing opportunities throughout the species' historical range; and
- 2.3 Maintain a sustainable spring in-river commercial fishery in the lower main stem river in Connecticut; and

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- 2.4 Participate in other fisheries management organizations to support science-based management of Connecticut River American Shad fisheries.

3. ECOLOGICAL

- 3.1 Maintain an American Shad population to provide the diverse ecological contributions of American Shad, at all life stages, in the freshwater, estuarine, and marine environments, based upon population targets listed under 1.2 and 1.3.

4. MONITORING AND RESEARCH

- 4.1 Conduct fishery independent and dependent monitoring programs to assess population status and trends; and
- 4.2 Periodically determine long and short-term research needs to achieve or evaluate the Plan Goal and Objectives; and
- 4.3 Identify anthropogenic impacts that limit achieving the other Objectives of this Plan and develop corrective measures.

5. PUBLIC OUTREACH AND EDUCATION

- 5.1 Provide communications and education for the public on the CRASC Plan, and the benefits and ecological values of American Shad in the Connecticut River, Long Island Sound, and the East Coast in the Atlantic Ocean.

STRATEGIES

1. POPULATION

- 1.1 Increase American Shad access to spawning and nursery habitat in both the main stem and the targeted tributaries when possible; and
- 1.2 Determine if fish passage measures are safe, timely, and effective for upstream migrating adult and downstream migrating adults and juveniles, at individual dams, hydropower projects, for cumulative project effects, and assess whether Plan Goals and Objectives are being achieved. Develop corrective action plans as needed; and
- 1.3 Monitor hydropower operations and facilities for any detrimental effects that may impact Plan Goals and Objectives. Develop corrective action plans as needed; and
- 1.4 Conduct annual pre-season, in-season, and post season inspections of fishways, by qualified fish passage specialists (biologist and engineers), to ensure they are functioning within design criteria; and
- 1.5 Evaluate annually information for stock status, trends of metrics and special study results to determine if adaptive management approaches should be developed.

Supporting Narrative

The adult American Shad production target(s), which are based on accessible and potentially accessible spawning and nursery habitat area and future mixed age class spawning stock returns (within year), have been utilized in other recent American Shad plans and studies including the Roanoke River, Virginia (Harris and Hightower 2015); Susquehanna River, Maryland, Pennsylvania, New York (SRAFR 2010); Merrimack River, Massachusetts, New Hampshire (USFWS 2010); and Penobscot River, Maine (MDMR 2008). The CRASC Management Plan for River Herring in the Connecticut River Basin (2004) provides river surface areas in hectares (ha) for the main stem to determine habitat estimates for this Plan. CRASC biologists reduced the estimated available habitat from the River Herring Plan by 15% (or 852 ha) to account for the brackish water habitat in the lower Connecticut River, which is unsuitable spawning and nursery habitat for American Shad.

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This Plan has a minimum target annual adult return/production rate of 203 adults/ha for the main stem, derived from Connecticut River specific estimates for adult returns and composed of multiple age classes of both sexes to the river mouth in relation to available habitat. The highest estimated adult shad return to the river mouth (1992), when divided by the number of hectares of all available main stem habitat to Bellows Falls, Vermont yields a return/production of 203 adults/ha (Appendices E and I). This estimate likely underestimates the full return/production potential due to problems of reduced passage issues (up and downstream) that were known to exist at each dam. CRASC may increase the minimum adult production target values as improvements to habitat quantity and quality and fish passage occur in the future with pending hydropower relicensing opportunities and other advances in technologies and regulatory or partnering opportunities.

The adult return/production rate in identified tributaries was adjusted to 55% (111 adults/ha) of the main stem production and is consistent with tributary adult shad targets identified by each State agency. Research in the Delaware River supports the hypothesis that American Shad home to tributary spawning grounds (Hendricks et al. 2002) so we expect that the abundance of adults entering the Westfield and other rivers are largely independent of abundance trends in the main stem population. Adult production potential from tributaries can be inferred from shad passage counts at the West Springfield Fishway on the Westfield River, Massachusetts operating since 1996, that had a record high passage of 10,300 (2012) into an estimated 92 ha of habitat, yielding an estimate of 111 adults/ha.

Resilience based approaches to population management through actions that protect and promote diverse age structure, life histories, and habitat use will support Population, Fishery, and Ecological objectives identified in this Plan. A population maintained among many river segments and tributaries may have greater reproductive potential to buffer against negative impacts from environmental perturbations over space and time (Hillborn et al. 2003, Schindler et al. 2010). Likewise, diverse age structure and behavioral patterns within a population of migratory fish can help mitigate against stochastic or anthropomorphic effects and capitalize on ideal conditions for population recruitment (Kerr et al. 2010, Secor 2007).

The Connecticut River American Shad population is iteroparous, which has important implications for both population resilience and reproductive potential, as fish fecundity increases exponentially with fish size (Leggett and Carscaden 1978). The proportion of the annual spawning run determined to be repeat spawners has declined over time from a rate of 49% in the late 1950s, (Walburg and Nichols 1967; Limburg et al. 2003), to a mean of 5% for the period 2006-2015 (Appendix G). Factors leading to the decline of repeat spawners during recent decades are not fully understood. There are no historic data on the composition of repeat spawners prior to the presence of main stem barriers and therefore it is difficult to conclude the full impact of dams on the percentage of repeat spawners in the population. It is likely that the historic shad population was comprised of a more diverse age structure and a greater proportion of repeat spawners. However, observations and newly emerging study data have shown that post-spawn shad may not successfully pass downstream of dams, may be significantly delayed at dams, or may use turbines as a primary passage route. The population impact of these scenarios requires further study both at individual hydropower projects and all hydropower projects collectively (cumulative effects). Agency biologists remain focused on addressing any identified increased fish mortality associated with passing within, through or around dams, canals and hydroelectric stations and facilities (e.g., pumped storage facility). Other factors believed to influence the post-spawning survival include bioenergetic demands of migration, delays in migration, duration of migration, water

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temperature, and distance traveled (Castro-Santos and Letcher 2010). CRASC anticipates improved survival rates of post-spawn shad because of new structural and operational downstream passage measures at Holyoke Dam (2016), and supports future opportunities including hydropower relicensings, partnering or other mechanisms for passage improvements that address migratory delay and other associated project-attributed sources of increased mortality.

Achieving a minimum repeat spawner proportion of at least 15% for each sex as determined by season average from daily samples at Holyoke Fish Lift will help achieve the Plan Goal and Objectives. The mean percentage of repeat spawners for the period 1990-2000 was only slightly greater at 16%. The 15% minimum value in the Plan represents an approximate three-fold increase from the 2006-2015 mean (Appendix F). Addressing in-river sources of mortality that contribute to decreases in the ability of post-spawn adults to successfully migrate back to the ocean are a focus area for management improvements and has been an area of limited available information. In order to address these information gaps, main stem power companies as part of the FERC relicensing process, have recently completed several studies (in review process) which may be used adaptively for this Plan.

The CTDEEP's age structure analysis demonstrates a reduction of the age-6 cohort (males) and loss of older cohorts (both sexes) over recent decades (ASMFC 2007). This Plan seeks to increase representation of these older cohorts to provide reproductive and stock stability resilience in the event of unfavorable environmental conditions.

2. FISHERIES

- 2.1 Improve all aspects of adult shad passage at fishways and adult abundance in the upper basin to support recreational and commercial fisheries, as determined appropriate by the respective State agency and ASMFC; and
- 2.2 Provide access for shore and boat fishing anglers on the main stem and tributaries; develop information and outreach materials to promote these fishery opportunities as appropriate; and
- 2.3 Help ensure monitoring/data requirements for the ASMFC are obtained in a timely and cooperative manner to prevent fisheries closures; and
- 2.4 CRASC Commissioners and the Technical Committee members should maintain their active participation on the ASMFC American Shad and River Herring Management Board, the ASMFC's Technical Committee for those species in state jurisdictional waters. The New England and Mid-Atlantic Fishery Management Councils' activities should also be monitored as federal marine water management decisions could affect Connecticut River American Shad; and
- 2.5 Support the prohibition on mixed stock fisheries of American Shad.

Supporting Narrative

Fish passage at dams was a focus area for the joint state and federal Cooperative Fishery Restoration Program for the Connecticut River basin (1967), to address the restoration and expansion of fisheries. Significant progress on upstream passage came from the agencies' coordinated efforts that later evolved with the CRASC's formation. Under CRASC, measures to address downstream passage and steps to improve upon initial fishway designs and operations resulted in the expansion of shad fisheries into New Hampshire and Vermont (Appendix C). Fish passage technologies and research tools have advanced over time and continue to evolve with improving science and engineering, including evaluation of fish behavior and physiology. The Federal Energy Regulatory Commission's relicensing process at Turners Falls, Northfield Mountain Pump Storage Facility, Vernon Dam, and Bellows Falls projects offers opportunities to address identified issues that may negatively impact adult shad in and around projects

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and their fishways, and subsequently improve fisheries in upstream habitat. The use of new information on shad behavior, physiology, energetics in and around fishways, and related facility operations should be used to update passage measures and management objectives.

According to the ASMFC Interstate Fishery Management Plan for American Shad Management Amendment 3 (2010) a sustainable fishery must “*demonstrate their stock could support a commercial and/or recreational fishery that will not diminish the future stock reproduction and recruitment.*” Only the State of Connecticut and Massachusetts developed and submitted approved Sustainable Fishery Plans for the Connecticut River. The CRASC seeks to achieve a shad population with metrics of abundance and stock structure that will support the development of a Sustainable Fishery Plan as required by the ASMFC for the State of New Hampshire and inclusive of the State of Vermont, allowing recreational harvest. Adult shad passage counts to the habitat upstream of the Turners Falls and Vernon fishways have been variable over the long-term, but in the most recent five years consistent improvement has been demonstrated in the proportion of shad passing Vernon relative to Turners Falls Gatehouse Ladder (Appendix D). However, the agencies will need to document adult passage increases and other population metric objectives before considering the development of criteria for a Sustainable Fishery Plan for the upper basin (New Hampshire and Vermont). Defined target values for passage and other metrics in this Plan will serve as a measure of progress toward achieving the Plan Goal and Objectives.

Recreational fisheries in tributaries may require additional specific considerations. Ultimately, CRASC intends to have recreational fisheries with harvest in all Plan identified tributaries, consistent with Plan Goal and Objectives. The development of recreational fisheries in all basin states and their identified tributaries has the potential to provide extensive recreational opportunities.

American Shad recreational creel survey data had been annually collected for shad by CTDEEP for decades and are provided in reports to ASMFC and other agency publications. Estimated recreational catches for the lower river reached as high as 102,000 fish in 1992, which coincides with the highest estimated run size of 1.63 million fish to the mouth, and the Holyoke Fish Lift passage record of 720,000 shad (CTDEEP 2010). However, studies of recreational fisheries require considerable resources and have become a less common activity since 2000.

Commercial landings data for American Shad in the State of Connecticut began in 1887 with a maximum value of 519,862 kg in 1946 (Appendix G). Currently the only commercial harvest in the basin is a drift gill net fishery in the lower 48 km (30 miles) of the main stem river. In recent decades a decline in in-river commercial fishing effort and landings have been reported by CTDEEP that has been attributed to an aging group of netters with no new license entries (CTDEEP 2012).

The CRASC should continue to work cooperatively with the ASMFC in support of agency efforts to obtain fishery dependent information, including commercial and recreational catch and effort data for required monitoring and assessment purposes. Increased monitoring of small mesh offshore fisheries suggests that American Shad is encountered as bycatch. Support of improved monitoring of bycatch in marine fisheries where bycatch of shad could occur is necessary to evaluate potential management implications under changing marine and climate-related conditions, which are not well understood.

3. ECOLOGICAL

- 3.1 Evaluate and maximize the ecological contributions for all life-stages of shad on the Connecticut River ecosystem; and

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- 3.2 Identify and address impacts to shad habitat for all life stages and life history events, such as river discharge manipulations (e.g., frequency, magnitude, timing, and duration).

Supporting Narrative

The CRASC's Plan goals and objectives seek to restore the ecological roles of both adults and juvenile shad throughout their historic range in the basin, the estuary, and the marine environment. American Shad serve important ecological roles throughout their complex life history and life stages in these environments (Weiss-Glanz et al. 1986; ASMFC 2009; McDermott et al. 2015) (Table 1).

Table 1. Summary of types of ecological contributions made by shad life stage and location (habitat) with corresponding time periods.

Location	Lifestage	Ecological Services	Timing
Freshwater	Adult (prespawn - post spawn)	Prey item (bald eagle, osprey, larger predatory fishes); marine nutrient transfer	April - July
Freshwater	Early life stage to juvenile	Prey item (fishes and fish eating birds)	July - Nov
Estuarine	Juvenile	Prey item (fishes and fish eating birds)	Aug - Dec
Marine	Juvenile through adult	Prey item (fishes, birds, marine mammals)	Year-round

Barriers in the Connecticut River basin that exclude or restrict adults from accessing spawning habitat can reduce or eliminate the ecological roles of adult and subsequent juvenile life stages (Hall et al. 2012; Freeman et al. 2003). Adult shad also contribute marine derived nutrients to freshwater systems (Hanson et al. 2010). In addition, other hydropower operational concerns, such as peaking flows, outdated minimum flows requirements, diversion of flow (canals or pumped storage reservoir), or partial measure, interim protective measures may also negatively impact achieving ecological contributions. Therefore, achieving many strategies previously stated in this Plan for other Objectives will help meet Objective 3 pertaining to Ecological benefits and need not be repeated as strategies for this Objective.

The ecological benefits of restoring the American Shad run are not fully understood and more research will expand our knowledge. For example, there may be species of mussel that rely on upstream shad migration for dispersal or intricate trophic interactions with shad that are unknown. Understanding these relationships will help CRASC set appropriate objectives for future Plans and educate the public on the value of shad restoration.

4. MONITORING AND RESEARCH

- 4.1 Continue enumerating shad at all main stem dams and identified tributaries. Also continue to sample adult shad at the Holyoke Fish Lift to obtain sex specific measures and structures for age and spawning history; and
- 4.2 Continue monitoring juvenile production and explore the need, benefits, options to expand into unmonitored areas; and
- 4.3 Continue monitoring in-river commercial fisheries and explore options for recreational fisheries; and
- 4.4 Work with partners to identify and pursue identified research topics; and
- 4.5 Identify anthropogenic impacts that limit ecological contributions and develop corrective measures.

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Supporting Narrative

American Shad restoration and management requires regular monitoring of fishery dependent and independent metrics to determine population status and trends. Amendment 3 to the ASMFC Interstate Fishery Management Plan for American Shad Management (2010) describes required data for annual state compliance reports as well as data approved for Sustainable Fishery Management Plans. The member agencies of CRASC are responsible for the implementation of current monitoring activities and the means to implement them, as determined appropriate and feasible by each agency. CRASC serves an important coordination role in this regard and may develop new collaborative efforts or mechanisms to develop short-term capacity (e.g., grants). A list of priority annual monitoring information needs and status follow in Table 2.

Table 2. List of priority annual monitoring activities for American Shad in-river.

Activity	Agencies or other	Status
Fishway Counts (main stem and tributaries)	CTDEEP, MADFW, VTDFW, NHFG, Holyoke Gas and Electric, FirstLight Power	Ongoing
Biological sampling, run characterization (size, age, spawning history, by sex)	CTDEEP, from Holyoke Fish Lift	Ongoing
Juvenile Index (lower river)	CTDEEP	Ongoing
Juvenile Index (upper river)	State or federal	Not occurring
Commercial fishery monitoring (catch, effort, by sex, size, age structure)	CTDEEP	Ongoing
Recreational fishery monitoring (catch, effort, by sex, size, age structure)	State or federal	Not occurring

Improved monitoring of recreational fisheries should be considered for a future focal area of management. This type of survey data will aid in providing information on fishing effort, harvest, and biological data to support management decisions and program activities.

The CRASC Technical Committee should continue to assess current information and identify research needs on an annual basis. Determining the number of American Shad that enter the river annually remains a high research priority. Other research priorities include multiple FERC relicensing studies that will provide data on adult and juvenile migration patterns, interaction at dams, fishways, and the Northfield Mountain Pump Storage project (includes larval entrainment study), and passage under varying project operation and river conditions. Study results have started to become available (beginning in 2016) and will provide important information that will require additional review and consideration. The CRASC American Shad Status Report (2015) provides comprehensive details on both research and monitoring needs.

5. PUBLIC EDUCATION AND OUTREACH

- 5.1 Provide regular updates on fishway counts in the spring run period on the U.S. Fish and Wildlife Service Connecticut River Fish and Wildlife Conservation Office's (FWCO) web site, seek

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opportunities to share information with various media outlets, and promote shad as a natural resource; and

- 5.2 Develop information products for a variety of target audiences that communicates the diverse benefits of a restored shad population as defined by this Plan's goals and objectives.

Supporting Narrative

Providing current information on the status of American Shad and how this Plan is relevant to the public will help create and maintain support for management actions and an appreciation for the species. Public awareness on management and research activities and needs can be achieved from CRASC outreach efforts, including identifying principal contacts in each state and by agency. Interested public may be utilized as Citizen Scientists to assist in agency field sampling activities (for adults or juveniles) and other tasks that may be limited by available seasonal staff. The Connecticut River Fish and Wildlife Conservation Office maintains a web site, <https://www.fws.gov/r5csrc/>, that includes: CRASC and ASMFC plans and documents and web links, CRASC meeting minutes, contact information for CRASC announcements, in-season fishway fish counts updates and basin summary fishway counts, and the office's annual report that highlights a wide range of shad management and related activities. The CRASC will support and promote public viewing and educational opportunities at suitable fishways and provide input on messaging at various dams along the Connecticut River.

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Appendix A

A list of legal authorities and select agreements for American Shad management, restoration and related activities (e.g., fish passage) in the Connecticut River basin.

Legal Authorities

- The Fish and Wildlife Coordination Act 1934; as amended
- Federal Power Act 1920; as amended 1935, 1986
- Fish and Wildlife Act 1956
- Federal Aid in Fish Restoration Act 1950 (Dingell-Johnson Act); as amended
- Anadromous Fish Conservation Act 1965
- Clean Water Act 1972
- Connecticut River Atlantic Salmon Compact (Act) 1983
- Silvio Conte National Fish and Wildlife Refuge Act 1991
- State of New Hampshire General Laws, Title XVIII, Chapter 211, Section 211:8
- Commonwealth of Massachusetts, General Laws, Title XIX, Chapter 130,
- Connecticut Gen. Statutes Sec. 26, Chapter 493 and 494
- Connecticut Gen. Statutes Sec. 26-111
- Connecticut Gen. Statutes Sec. 26-115
- Connecticut Gen. Statutes Sec. 26-142(d)

Agreements

- 1967 Statement of Intent for a Cooperative Fishery Restoration Program for the Connecticut River Basin (State and Federal agency Directors; Policy Committee for Fisheries Management of the Connecticut River and Technical Committee)
- 1978 FERC Settlement Agreement(s), Upstream Fish Passage, (formerly New England Power Company and Western New England Power)
- 1990 Memorandum of Agreement(s), CRASC, Connecticut River Downstream Fish Passage, (formerly Northeast Utilities and New England Power Company)

Background on American Shad life history and biology.

American Shad is an anadromous fish species with a native range that extends from the St. Lawrence River, Canada, to the St. John's River, Florida with introductions and range expansion along the Northwest Pacific Coast. American Shad is considered in the marine environment to be pelagic and highly migratory, moving between summer feeding areas and overwintering areas (ASMFC 2009). Mature adults home back to natal rivers to spawn in freshwater habitat typically as males at age-4 and age-5 and as females at age-4 and age-5 for first time spawners. A latitudinal variation in the ability to spawn more than once (iteroparity) occurs from Cape Hatteras, North Carolina and northward, with rates in repeat spawners proportions generally increasing in that direction (Limberg et al. 2003). The spawning run typically last 2-3 months, with the Connecticut River stock entering the river between late March and early April, depending on the environmental conditions. River entry is often associated with river temperatures reaching ~10°C (50°F) (Leggett 1976).

American Shad is a broadcast spawner and eggs are initially semi-buoyant, becoming demersal and gradually sinking to the substrate. Connecticut River female fecundity has been determined to average 303,000 eggs with a standard deviation of 75,000 in a recent NOAA Fisheries study that also described the batch timing of egg maturation (McBride et al. 2016). In addition, the same NOAA study reported a mean of 6.7 batches (spawning frequency) for sampled females that averaged 45,950 eggs. Spawning activity is primarily nocturnal and has been documented occurring in shoal areas and in defined areas such as Windsor Locks (rkm 78), Wilson (rkm 74) and Rocky Hill (rkm 51)(Marcy 1976), but also has been noted as being more widely occurring among habitat types (ASMFC 2009). Other in-river spawning studies have been conducted between the Holyoke Dam and Turners Falls Dam, Massachusetts by the University of Massachusetts Amherst Cooperative Research Unit during the 1970s and 1980s. Recent relicensing study for the Turners Falls Dam/Project, including areas upstream to Vernon Dam, as well as from Vernon Dam to Bellows Falls Dam have been surveyed for spawning activity. American Shad spawn repeatedly, typically occurring in water temperatures ranging from 15 – 23°C, with eggs developing over time in relation to water temperature (ASMFC 2009). Egg development occurs in relation to water temperatures, with hatching in 14 - 20°C water taking approximately 3 days (Marcy 1976). Yolk sac larvae transition to first feeding larvae after a period of 4 - 7 days (water temperature dependent) at a size of 10 - 12mm (ASMFC 2009).

Juvenile shad may use a variety of habitats as they grow and feed on zooplankton and are also opportunistic users of other prey items (ASMFC 2009). The growth rate of juvenile shad has been shown to be consistently faster in upstream areas compared with downstream areas in the Connecticut River main stem and in comparison to the Farmington River (Marcy 1976). Juvenile outmigration has been reported to occur after a period of 80 days, which corresponded to a length of approximately 75mm (O'Donnell and Letcher). Decreasing water temperature has also been correlated with the peak juvenile outmigration, at the Holyoke Dam, initiating at 19°C and peaking from 14 - 9°C, and ending at 10 - 8°C in the study period (O'Leary and Kynard 1986). Information on American Shad in the marine environment is inherently more limited. Three main offshore overwintering areas have been described consisting of; 1) off of the Scotian Shelf/Bay of Fundy, 2) Middle Atlantic Bight, and 3) off the Florida Coast (Dadswell et al. 1987). Summer feeding areas contain mixed stocks that aggregate in the upper Bay of Fundy and Gulf of Maine, the St. Lawrence estuary, and off of Newfoundland and Labrador (Dadswell et al. 1987).

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Appendix C

Estimated number of American Shad entering the Connecticut River from CTDEEP 2010, and CTDEEP Annual Compliance Report to ASMFC (2016).

Year	Estimate	Year	Estimate
1966	695,000	1991	1,196,000
1967	637,000	1992	1,628,000
1968	410,000	1993	749,000
1969	591,000	1994	326,000
1970	488,000	1995	304,000
1971	583,000	1996	667,000
1972	485,000	1997	659,000
1973	613,000	1998	651,000
1974	372,000	1999	475,000
1975	598,000	2000	427,000
1976	740,000	2001	773,000
1977	323,000	2002	687,000
1978	710,670	2003	527,000
1979	632,820	2004	351,000
1980	759,420	2005	226,000
1981	909,270	2006	294,667
1982	939,330	2007	243,755
1983	1,574,000	2008	276,864
1984	1,231,000	2009	321,338
1985	728,000	2010	279,000
1986	748,000	2011	387,000
1987	588,000	2012	778,462
1988	648,000	2013	623,757
1989	979,000	2014	588,105
1990	816,000	2015	687,760

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Appendix D

Existing fishways for American Shad in the Connecticut River basin.

<u>Main stem (rkm)</u>	Project/Dam	Upstream Fishway Design	Status
139	Holyoke	Fish lift	Lifts new in 2004 and 2015 modifications driven by downstream passage requirements, evaluation studies planned for 2016
198	Turners Falls	Modified Ice Harbor and vertical slot	Long standing passage issues, study and modifications; Cabot Station Ladder, Spillway Ladder and Gatehouse Ladder (vertical slot), evaluation studies in 2015 (FERC relicensing)
228	Vernon	Modified Ice Harbor and vertical slot	Evaluation studies in 2015 (FERC relicensing)
280	Bellows Falls	Vertical slot	Historic upstream extent of distribution, with ladder in place, upstream passage is possible
<u>Tributary (name)</u>			
Mattabesset River	StanChem	Denil	First year operation 2013, not evaluated
Farmington River	Rainbow	Vertical slot	Long standing issues with shad passage, CTDEEP owned facility, new fish lift design pending, not evaluated
Westfield River	West Springfield	Denil	Not evaluated
Manhan River	Manhan	Denil	First year of operation 2014, not evaluated
Ashuelot River	Fiske Mill	Fish lift	Not evaluated, known issues with false attraction to tailwater

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Appendix E

Annual counts of American Shad recorded at upstream passage fishways on the main stem dams and select tributaries. No shad have been reported lifted at the Fisk Mill Dam, Ashuelot River, NH or passing the Manhan River, Easthampton, MA.

Year	Holyoke Dam Passed	Turners Falls Dam Passed	Vernon Dam Passed	Bellows Falls Dam Passed	Farmington River, Rainbow Dam Passed	Westfield River, W. Springfield Dam Passed
1955	4,900					
1956	7,700					
1957	8,800					
1958	5,700					
1959	15,000					
1960	15,000					
1961	23,000					
1962	21,000					
1963	31,000					
1964	35,000					
1965	34,000					
1966	16,000					
1967	19,000					
1968	25,000					
1969	45,000					
1970	66,000					
1971	53,000					
1972	26,000					
1973	25,000					
1974	53,000					
1975	111,000					
1976 ^A	346,725				1,189	
1977	202,997				804	
1978	145,136				1,053	
1979	255,753				514	
1980	376,066	298			480	
1981	377,124	200	97		167	
1982	294,842	11	9		737	
1983	528,185	12,705	2,597		1,565	
1984	496,884	4,333	335	1	2,289	
1985	487,158	3,855	833	0	1,042	
1986	352,122	17,858	982	0	1,206	
1987	276,835	18,959	3,459	39	792	
1988	294,158	15,787	1,370	24	378	
1989	354,180	9,511	2,953	*	215	
1990	363,725	27,908	10,894	0	432	
1991	523,153	54,656	37,197	65	591	
1992	721,764	60,089	31,155	103	793	
1993	340,431	10,221	3,652	2	460	

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Year	Holyoke Dam Passed	Turners Falls Dam Passed	Vernon Dam Passed	Bellows Falls Dam Passed	Farmington River, Rainbow Dam Passed	Westfield River, W. Springfield Dam Passed
1994	181,038	3,729	2,681	3	250	
1995	190,295	18,369	15,771	147	246	
1996	276,289	16,192	18,844	1	668	1,413
1997	299,448	9,216	7,384	46	421	1,012
1998	315,810	10,527	7,289	55	262	2,292
1999	193,780	6,751	5,097	110	70	2,668
2000	225,042	2,590	1,548	9	283	3,558
2001	273,206	1,540	1,744	**	153	4,720
2002	374,534	2,870	356	**	110	2,762
2003	286,814	--	268	*	76	1,957
2004	191,555	2,192	653	**	123	913
2005	116,511	1,581	167	3	8	1,237
2006	154,745	1,810	133	0	73	1,534
2007	158,807	2,248	65	0	156	4,497
2008	153,109	4,000	271	0	89	3,212
2009	160,649	3,813	16	0	35	1,395
2010	164,439	16,422	290	0	548	3,449
2011	244,177	16,798	46	1	267	5,029
2012	490,431	26,727	10,386	0	174	10,300
2013	392,967	35,293	18,220	0	84	4,900
2014	370,506	39,914	27,706	0	536	4,787
2015	412,656	58,079	39,771	44	316	3,383
2016	385,930	54,069	35,732	1,973 ^B	141	5,940
Mean	310,975 ^A	15,864	8,055	-	483	3,379
standard deviation	130,295	17,691	11,951	-	472	2,193
minimum	116,511	11	9	-	8	913
maximum	721,764	60,089	39,771	-	2,289	10,300

^A Holyoke shad passage summary statistics only for the period 1976-2016

* Ladder not operated

** No fish count monitoring

^B Bellows Falls is the historic upstream extent of the species range. The Bellows Falls Project fish ladder was, by agreement, operationally triggered on Atlantic Salmon upstream passage needs, so its period of operation was often limited/restricted in the past. In many years no shad were observed passing at this facility. Beginning in 2013, TransCanada agreed to open this ladder based on a trigger of 100 Sea Lamprey passed at Vernon Dam providing an opportunity for upstream habitat access.

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Appendix F

Connecticut Department of Energy and Environmental Protection, Marine Fisheries Division, Juvenile Alosine Seine Survey data for the period 1978-2015. The reported index value is a geometric mean catch of juvenile American Shad from all stations and all dates, annually. Seven sites from Holyoke, MA, to Essex, CT are sampled weekly from mid-July through mid-October.

Year	Index	Year	Index
1978	5.9	1997	6.8
1979	7.8	1998	3.7
1980	9.2	1999	5.5
1981	6.1	2000	4.4
1982	1.8	2001	2.7
1983	5.0	2002	5.6
1984	3.4	2003	6.9
1985	7.1	2004	5.6
1986	6.3	2005	10.1
1987	9.9	2006	1.8
1988	5.7	2007	8.2
1989	4.9	2008	5.1
1990	10.4	2009	3.4
1991	3.9	2010	10.2
1992	7.2	2011	3.1
1993	9.5	2012	3.0
1994	12.2	2013	3.2
1995	1.3	2014	8.0
1996	6.5	2015	8.5

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Appendix G

Connecticut Department of Energy and Environmental Protection, Marine Fisheries Division, proportion of adult American Shad repeat spawners from sample sources transitioning from lower river gillnet (1960s) to primarily Holyoke Fish Lift (1990s-2000s). Data from CTDEEP 2010 and from subsequent annual Compliance reports to the Atlantic States Marine Fisheries Commission.

Year	Repeat	Year	Repeat
1966	0.53	1991	0.15
1967	0.53	1992	0.08
1968	0.34	1993	0.16
1969	0.38	1994	0.39
1970	0.39	1995	0.20
1971	0.45	1996	0.14
1972	0.41	1997	0.12
1973	0.44	1998	0.15
1974	0.22	1999	0.08
1975	0.24	2000	0.15
1976	0.26	2001	0.21
1977	0.10	2002	0.22
1978	0.24	2003	0.05
1979	0.18	2004	0.11
1980	0.19	2005	0.11
1981	0.11	2006	0.02
1982	0.15	2007	0.07
1983	0.20	2008	0.02
1984	0.27	2009	0.05
1985	0.23	2010	0.07
1986	0.21	2011	0.09
1987	0.44	2012	0.04
1988	0.15	2013	0.10
1989	0.21	2014	0.03
1990	0.17	2015	0.02

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Appendix H

Annual commercial landings (in kilograms) of American Shad for Connecticut (NOAA Commercial statistics).

Year	kg	Year	kg	Year	kg
1887	152,861	1930	24,494	1973	116,845
1888	127,913	1931	34,019	1974	112,128
1889	88,904	1932	31,751	1975	75,070
1890	54,431	1933	60,328	1976	177,808
1891	35,380	1934	238,136	1977	150,774
1892	28,576	1935	182,798	1978	138,935
1893	64,864	1936	174,633	1979	93,803
1894	114,305	1937	173,726	1980	140,840
1895	98,883	1938	193,684	1981	147,281
1896	118,388	1939	185,519	1982	128,367
1897	116,120	1940	163,293	1983	193,230
1898	226,343	1941	198,673	1984	180,963
1899	150,139	1942	169,190	1985	182,344
1900	222,260	1943	250,837	1986	146,488
1901	196,859	1944	338,833	1987	151,454
1902	217,724	1945	349,992	1988	85,956
1903	279,413	1946	519,862	1989	82,679
1904	273,516	1947	359,563	1990	119,066
1905	219,992	1948	281,953	1991	68,166
1906	114,759	1949	213,506	1992	65,614
1907	61,689	1950	119,522	1993	43,954
1908	55,338	1951	153,314	1994	48,022
1909	55,338	1952	215,048	1995	27,958
1910	44,452	1953	163,021	1996	66,299
1911	43,545	1954	133,991	1997	85,121
1912	95,254	1955	95,345	1998	82,663
1913	83,461	1956	89,222	1999	65,426
1914	92,079	1957	149,050	2000	98,532
1915	67,132	1958	206,974	2001	26,868
1916	83,461	1959	181,800	2002	49,033
1917	102,512	1960	181,392	2003	50,406
1918	109,316	1961	210,195	2004	30,081
1919	210,013	1962	206,747	2005	31,444
1920	79,832	1963	136,441	2006	17,482
1921	32,659	1964	125,963	2007	23,389
1922	21,319	1965	159,755	2008	12,888
1923	20,865	1966	109,724	2009	12,611
1924	40,370	1967	108,862	2010	11,187
1925	66,224	1968	96,343	2011	12,133
1926	50,349	1969	86,137	2012	19,712
1927	54,431	1970	78,517	2013	18,453
1928	90,265	1971	109,180	2014	15,473
1929	144,242	1972	113,035	2015	23,135

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Appendix I

Summary of estimated habitat

Table A. The estimated spawning and rearing habitat for American Shad by river segment in relation to estimated adult shad production/return potential, and minimum target fish passage numbers by barrier.

Reach	m ²	Ha	Adjustment	Ha	% of total	Adult Shad Return/Production (203 and 111 settings by habitat)	Project	Minimum target number
Main stem - mouth to Holyoke	56,766,060	5,677	0.85	4,825	54.8	979,498		
tributaries (5)		424		424	4.8	47,064		
Main stem - Holyoke to Turners Falls	13,688,717	1,369		1,369	15.5	277,881	Holyoke Fish Lift - passage	687,088
tributaries (2)		109		109	1.2	12,099		
Main stem - Turners to Vernon	7,620,241	762		762	8.7	154,691	Turners Falls Project - passage	397,108
tributaries* (1)		139		139	1.6	15,429		
Main stem - Vernon to Bellows Falls	10,421,641	1,042		1,042	11.8	211,559	Vernon Ladder - passage	226,988
tributary (1)		139		139	1.6	15,429		
Totals		9,661		8,809	100.00	1,713,651		

*Millers River habitat area undefined

Table B. The estimated spawning and rearing habitat for American Shad, by tributary in relation to estimated adult shad production/return potential.

Tributary	Total rkm	Area (est) ha	Adult Shad Return/Production
Mattabesset, CT	36.3	54.5	6,044
Farmington, CT	60.3	211.1	23,427
Pequabuck, CT	12.4	9.9	1,101
Scantic, CT	22.4	31.4	3,481
Westfield, MA	29.4	117.6	13,054
Chicopee, MA ^A		T.B.D.	
Manhan, MA	23.0	23.0	2,553
Deerfield, MA	21.5	86.0	9,546
Millers, MA ^B		T.B.D.	
Ashuelot, NH	60.0	139.0	15,429
West, VT	31.0	139.5	15,485
			90,119
^A - First dam is ~ 1 rkm from confluence with numerous subsequent dams			
^B - Relatively high gradient tributary, more data required			

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CRASC Connecticut River American Shad Management Plan Addendum – Fish Passage Performance (approved February 28, 2020)

Introduction

This Addendum provides American Shad passage performance criteria in support of achieving the goal and objectives of the Connecticut River Atlantic Salmon Commission's (CRASC) Connecticut River American Shad Management Plan (Plan). The Plan, approved in 2017, identified the following three broad objectives for fish passage:

- 1.5 *Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post-spawn adults, and juveniles; and*
- 1.6 *Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency, and delay at these three life stages, as suitable information is available, to support other objectives of this Plan; and*
- 1.7 *Establish downstream performance measures, for adult and juvenile life stages that maximize survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan.*

The state and federal fishery management agencies, through their individual and cooperative authorities (CRASC and ASMFC), are committed to restoring American Shad in the Connecticut River basin, and achieving the Management Plan's goal and objectives. Those goals and objectives are dependent on having safe, effective and timely fish passage for both adult and juvenile American Shad at in-river barriers. Defining fish passage criteria for what is safe, timely and effective is necessary in order to evaluate and manage progress towards these goals and objectives. A FERC Environmental Assessment for the American Tissue Project (2018^A) stated, "*Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities...Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and determining whether effectiveness testing would or would not provide benefits to alosines....*" (FERC 2018^A).

Effectiveness is ultimately the result of both safety and timeliness. Ideally, for a facility/project to have zero effect on migrating fish, 100% of fish that arrive at the station would pass with no delay, injury, or mortality. Here, we attempt to provide realistically achievable performance measures that balance regulatory objectives with feasible monitoring methods.

The following are the Fish Passage Performance Criteria or Objectives for both adult (upstream and downstream) and juvenile (downstream) American Shad for hydroelectric projects in the Connecticut River basin:

1. Upstream adult passage minimum efficiency rate is **75%**, based on the number of shad that approach within 1 kilometer of a project area^A and/or passage barrier. Passage efficiency is $[(\# \text{ passed} / \# \text{ arrived}) * 100]$;

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2. Upstream adult passage time-to-pass (1 kilometer threshold) is **48 hours or less** based on fish that are passed (requires achieving Objective #1);
3. Downstream adult and juvenile project passage minimum efficiency and survival rates are each **95%**, based on the number of shad that approach within 1 kilometer of a project area^A and/or passage barrier and the number that are determined alive post passage (not less than 48 hours evaluation). Passage efficiency is $[(\# \text{ passed} / \# \text{ arrived}) * 100]$ and passage survival is $[(\# \text{ alive downstream of project} / \# \text{ passed}) * 100]$.
4. Downstream adult and juvenile time-to-pass is **24 hours or less**, for those fish entering the project area^A.

^A – Project area shall be defined as comprising the river within 1 km of the up- and downstream extent of a hydropower facility and its footprint components. Where a powerhouse is separated from a dam, e.g. by a power canal, this will also include any bypassed reach of the river. The applied definition for 1 km threshold, in cases whereby a bypassed river reach exists (with regulated/alterd flows) from the development and use of a power canal system, by hydropower operators. In such cases, the location of the dam proper may be several kilometers upstream of the terminus of the power canal system. For upstream passage, the terminus of the power canal and any associated hydropower facility will be the approach basis for the 1 km project area, not the dam. Alternately, for downstream passage, the dam and gatehouse will serve as the basis for the 1 km project approach area, not the generation facilities in the power canal.

Strategies

The efficacy of any fish passage structure, device, facility, operation, or measure depends on a variety of factors including site-specific considerations. The information provided below serves as generic guidance and is not intended to categorically replace site-specific recommendations, limitations, or protocols

The morphology, swimming capability, behavior, and life history of American Shad create challenges for upstream and downstream passage through engineered fishways. The following strategies and best practices provide guidance for the design and operation of efficient fishways for American Shad.

1. Proposed new, and/or modifications to existing, fish passage facilities and any related project operations, should meet or exceed design criteria detailed in the USFWS Fish Passage Engineering Criteria Manual (2017) or its most current version. Proposed variations from USFWS Criteria Manual in either proposed new structures and/or modification to existing structures/operations will require consultation with the federal fish passage engineers (NOAA and/or USFWS). The FERC (2018^B) in its own analyses has stated, “...*designing the upstream anadromous fish passage facility consistent with FWS’s 2017 Design Criteria Manual and in consultation with the resource agencies as stipulated by Interior’s and NMFS’s fishway prescriptions would help guide the design process and ensure the upstream fishway is likely to be effective in timely passing any adult salmon returning to the base of the project’s dam upstream...*”

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2. General Movement

- A. Entrances. Fishways, by necessity, are (relative to the size of the river) narrow pathways that fish must discover. When reaching a stream barrier, shad, in general, do not explore to the degree salmonids do (Larinier and Travade, 2002). Multiple entrances may be necessary where flow conditions are diverse, the river is wide, or sources of false attraction are longitudinally separated (e.g., a bypassed reach between spillway and powerhouse discharge).
- B. Space. Shad move in schools and only reluctantly move as individuals (Larinier and Travade, 2002). Fishways should be as wide as possible to allow the migrants to efficiently move in as a group.
- C. Turns. Shad exhibit rheotaxis and align to the flow field. Shad in particular seem hindered by diverse and shifting flow fields. To the extent possible, fishway designs should ensure that anthropogenic structures do not create large-scale eddies, which can confuse shad and delay passage. Within fishways, sharp turns greater than 90 degrees should be avoided; where necessary, 180-degree turns can be accomplished with two 90-degree turns separated by a sufficient distance.

3. Hydraulic Structures

- A. Orifices. While shad may move through much of the water column, they are typically reluctant to move through submerged orifices. Managers, designers and operators should not expect shad to move through orifices in the weir walls of pool-type fishways (orifices are generally used to drain and maintain hydraulic conditions). Fishway entrance and exit gates should not be operated in an orifice condition; gate lips should be maintained above the waterline during passage season.
- B. Vertical Slots. Shad are reluctant to move through constrictions as individuals, but will do so slowly (compared to salmonids). To promote movement and ensure the opening is wide enough to limit abrasion injuries on concrete walls, the slots for a vertical slot fishway should be no less than 18 inches wide (USFWS 2019).
- C. Denil Baffles. Standard Denil baffles are typically built in 2-foot, 3-foot, and 4-foot widths depending on site constraints, hydrology, population size, and species. Given the shad's reluctance to move individually, and its hesitancy to navigate tighter flow constrictions, Denil fishways for shad should be 4-feet wide (USFWS 2019).
- D. Upstream Fishway Weirs. Shad do not leap like salmonids; accordingly, the nappe of flow over a weir should be non-aerated and submerged (i.e., the water surface on the downstream side should be level with, or above, the weir crest). Additionally, the jet of flow over the weir should produce streaming conditions rather than plunging conditions (USFWS 2019); this promotes a forward roller (i.e., hydraulic) in the downstream pool. An optimal depth of flow over the weir crest is typically in the range of 12 to 18 inches, depending on other conditions.
- E. Downstream Bypass Weirs. Negative rheotaxis guides downstream migrants (adults and juveniles) to the accelerating flow over a weir. However, rapid spatial accelerations (i.e., large changes in velocities over short distances) can spook shad leading the fish to reject the bypass. For this reason, a broad-crested weir is preferable. Bypasses should not approximate a sharp-crested weir (e.g., simple weir boards), if possible. A uniform acceleration weir (UAW) is ideal; UAWs have been shown to moderate this rejection behavior in shad by slowly accelerating the

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flow as it moves over the bypass (Haro et al. 1998). Weirs should be at least 3-feet wide and maintain 2 feet of depth at all times.

- F. Turbine Intakes Racks. Racks or screens should have a 1-inch clear spacing or less. This promotes a behavioral avoidance reaction in adult shad that reduces entrainment and impingement. If feasible, racks should be built at a 45° degree angle to the approach (free stream) velocity and lead to a downstream bypass. This arrangement promotes a sweeping flow (leading to the bypass) that encourages the animal to seek its own escape route. The normal velocity (i.e., velocity measured perpendicular to the plane of the rack) should be maintained at 2 fps or less, measured 1 foot in front of the rack (USFWS 2019).

4. Flow Characteristics

- A. Water Velocity. Shad can sustain burst speeds of 10.2 to 15.4 fps for 6 to 7 seconds. Shad in a 98 foot long flume with velocities ranging from 11.5 fps to 13.6 fps could not reach the end of the flume (Theodore Castro-Santos, personal communication). In general, velocities greater than 6 fps maintained for extended distances can prove challenging (Larinier and Travade, 2002). To limit fatigue, in pools, flumes, and channels, water velocities should be maintained in the 1 to 2 fps range. Localized (short distance) higher velocity regions are necessary to promote movement or attraction: 3 to 5 fps is typical over weir crests; 5 to 6 fps is common through vertical slots; and 4 to 6 fps at fishway entrances has been shown to promote attraction and entry for the suite of anadromous fish on the Connecticut River. For dedicated shad fishways (i.e., where the passage of smaller, weaker fish is neither critical nor desirable), localized entrance velocities of up to 8 fps may be effective.
- B. Turbulence and Air Entrainment. Minimizing turbulence and associated air entrainment is generally considered advantageous in the design of fish passage facilities (Towler et al. 2015). Volumetric energy dissipation correlates to the phenomena of turbulence and aeration in fishways. For shad-specific pool-type fishways, the pool size and flow rate should be designed and operated to limit the dissipation rate to 3.15 ft-lbf/s/ft³ (USFWS 2019; Towler et al. 2015).
- C. Depth of Flow. To promote movement in shoals, fishway pools, exit flumes and entrance channels should maintain a depth of 4 feet at all times (Turek et al. 2016). Note: this does not apply to smaller shad fishways such as the 4-foot wide Denil. To provide sufficient depth for shad to swim normally, the depth of flow should be greater than or equal to two times the largest adult's body depth at all times (USFWS 2019). At fishway entrances, gates and weir boards are used to vertically constrict depth and accelerate flow; however, excessive constrictions may adversely affect entry rates. Denil entrances should always maintain a minimum of 2 feet of depth above the channel invert, gate lip, or weir boards. At large fishways designed to pass American shad, entrances should maintain 3.0 feet of submergence (Mulligan et al., 2018). Submergence depth is calculated as the vertical distance between the tailwater and crest of the entrance gate.

5. Other Considerations

- A. Light and Shadow. Shad are sensitive to sudden changes in light. Generally, fishways should remain uncovered, or covered by grating that allows natural light on the water surface. Where covered and underground sections of fishway are necessary, lighting should be provided (Larinier and Travade, 2002).

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- B. Sounds. American shad have particularly acute hearing. Experience suggests they can be easily stressed by sudden noise (e.g., crowder gate cycling) or influenced by persistent mechanical sound (e.g., powerhouse). To the extent feasible, efforts should be taken to limit artificial sound in, or near, a fishway.
- C. Mechanical and Structural Hazards. Shad often move along walls and in great numbers (Larinier and Travade, 2002). Protuberances, obstacles and moving mechanisms in the fishway can be injurious. Such features should be removed or covered where possible. Vestigial hardware (e.g., bolts, rebar, and antenna connections) on walls should be removed or ground off. Exposed cables in traps should be sheathed in HDPE pipe or hose (or equivalent). Gaps on the sides of gates at counting facilities should be covered with rubber skirts.

Supporting Narrative

Numerous published and unpublished studies have documented American Shad passage and movements in the Connecticut River basin, particularly on the main stem. The recent peer-reviewed publication “A dam passage performance standard model for American Shad” (Stich et al. 2018) utilized a stochastic life-history based model *“to estimate effects of dam passage and migratory delay on abundance, spatial distribution or spawning adults, and demographic structuring in space and time.”* Stich et al. (2018) provides details of the model design, parameters, inputs and R code scripts. The FERC (2004) has concluded, *“...it is important to recognize the significance of modeling tools for assessing fish passage improvements at multiple projects in a river basin. Considering fish passage effectiveness from this level of analysis provides a meaningful approach because cumulative benefits of fish passage and all other restoration measures in the basin can be assessed.”*

For this Addendum, the Stich et al. American Shad Passage Model was programed to run a suite of passage settings specific to the Connecticut River to help inform criteria development based on four model run outputs and the CRASC Management Plan goal and objectives. For each of the three main stem dams (Holyoke, Turners Falls, and Vernon), upstream passage efficiencies were run at 55%, 65%, and 75%. This rate is based on the number of fish that reach within 1 km of the “project”. Time to pass upstream on individual fish arrival was run at 24, 48 and 72 hours. Downstream passage efficiency and survival at the three projects were run at 75%, 85% and 95% (model uses same value for adult and juvenile). Northfield Mountain Pumped Storage, for only juvenile downstream passage efficiencies and survival, were run at 75%, 85%, and 95%. Outputs of the model, that relate to the Plan include; 1) abundance at river mouth, 2) abundance upstream of Turners Falls Dam, 3) abundance upstream of Vernon Dam, and 4) proportion of repeat spawners ($\geq$ age-6). The first model run for “abundance at river mouth” suggested that if managers were only concerned with achieving that minimum target, with no concern for “upper” basin distribution, limiting upstream access could yield the minimum target to the river mouth, but notably only with downstream passage and survival $\geq$ 95%. However, the Plan intends to achieve multiple abundance objectives that reduces the priority of a single target. The second model run examined outputs for shad abundance upstream of Turners Falls, exceeding minimum Plan targets for all three upstream passage rates, with the highest outcomes again tied to 95% downstream passage efficiency and survival and highest upstream passage outputs tied to shortest time to pass (24 hours). The third model run examined abundance upstream of Vernon Dam, exceeding Plan minimum targets for all three upstream passage rates, with the highest outcomes also tied to 95% downstream passage efficiency and survival and upstream passage occurring in a tiered manner (highest outputs are for shortest time to pass [24 hours]). The fourth model run examined outputs for repeat

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spawner component (age-6) at the river mouth, demonstrating a consistent increasing trend in repeats from incrementally improved downstream passage efficiencies and survival (95% highest).

The American Shad Passage Model is one tool for managers to assess the function of fish passage and protection measures required at hydroelectric facilities on the Connecticut River. Results of the Connecticut River model runs are consistent with the findings in Stich et al. (2018), for the multi-dammed Penobscot River. The published article by Stich et al. (2018) and the model run specific to the Connecticut River highlight the importance of high downstream passage efficiency/survival (95%) for adults and juveniles in order to realize actual population gains by providing access upstream at successive dams and maintain a substantial repeat spawner component. Downstream passage was consistently important in all four Connecticut River model run outputs. For upstream passage efficiency rates, abundance outputs were also consistently maximized with shorter time to pass (24 hours), for abundance levels upstream of Turners Falls and Vernon dams.

Downstream passage of adult as well as juvenile shad are a concern in the Connecticut River basin from the perspective of cumulative effects, whereby seemingly modest levels of loss at one hydropower project (e.g., 10-15%) can be compounded at subsequent projects to greater levels affecting both ecological contributions of juveniles and adults, future abundance and population structure/dynamics. Repeat spawner females have an exponential increase in fecundity resulting in substantially greater reproductive potential than smaller virgin females. Given this, a return to >30% repeat spawners for this population has the potential to substantially increase the reproductive potential of the current high proportion of “virgin” female component currently observed in the Connecticut River, while at the same time creating population resilience or buffer against poor recruitment years. Having an age structured population comprised of a substantial proportion of fish age-6 to age-9 will help achieve the Plan’s goals and objectives, but is requisite on managing anthropogenic sources of mortality, such as turbine passage impacts. In addition, recent assessment work has demonstrated density-dependent effects on juvenile shad growth and condition in the Holyoke to Turners Falls reach in contrast to the Vernon to Bellows Falls reach (Mattocks et al. 2019). Management actions that result in a better distribution of juvenile densities will improve juvenile growth and condition. These data further support the complementary need of having high passage efficiency and survival rates for adults (up and down), and juveniles to mitigate for repeated turbine/facility exposures to access and utilize historic upstream habitats.

The question of whether a new hydroelectric project can impact (type and extent) an existing American Shad population has been studied on the Annapolis River, Nova Scotia, Canada. A tidal dam across the Annapolis River was created in 1983 with a spillway/tide gate. A power station with a 7.6 meter (m) diameter turbine, operating at 50 RPMs, under a head range of 1.4 – 6.8 m has operated since 1984 with only upstream passage in place. Dadswell et al. (2018) utilized pre-hydropower fish assessment data for American Shad and other species, to document population impacts largely attributed to this hydropower facility. The researchers provide data demonstrating declines in American Shad adult lengths, mass, age, and percent repeat spawner with a corresponding increase in total annual adult mortality. The authors state that *“these significant changes were largely due to turbine mortality of adult A. Sapidissima during post-spawning outmigration. The tidal turbine is apparently removing larger older adults from the population because they have a higher probability of strike and have passed through the turbine repeatedly during successive, annual spawning runs.”* On the Connecticut River this situation is analogous with repeated successive dam/power stations. The researchers note acoustically tagged adult shad passed via the Annapolis Station turbine had a reported mortality rate of 46.3 (±34.7)% in 1985 and 21.3 (±15.2)% in 1986. Based on adult shad size (400-600mm) the authors note a

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probable blade strike of between 12.5 and 18.7% [rates similar to many estimates for Connecticut River basin turbines].

Adult shad that successfully pass Vernon Dam have access to the most upstream historic extent of their habitat but must later negotiate three main stem barriers on their post-spawn outmigration. For these fish an 85% downstream passage efficiency/survival rate at each project, results in only 61% of the starting number. However, with the exclusion of adult shad from turbine passage and/or other routes of additive project mortality, to achieve a through project target efficiency/survival rate of 95% at each project, the resultant outcome is 86% of the starting number. Thus, a 10% improvement in passage efficiency/survival translates to a 25% increase in bypassed fish to the lower river from this habitat.

Hydroelectric plants dramatically influence the flow fields in a river upstream and downstream of the project. Turbine discharge typically serves as the significant and persistent source of far-field attraction to migrating fish above and below dams. In the context of downstream passage of American shad, turbine passage is hazardous to both juveniles and post-spawn adults; entrainment should generally be avoided. Adult shad are relatively large fish, with females being larger than males (at age and in the annual run composition) and therefore more susceptible to blade strike (Figure 1). The conventional mitigation strategy is to install a dedicated downstream fishway that allows out-migrating juveniles and post-spawn adults to safely bypass the turbines. The efficacy of the bypass depends, in turn, on the same flow fields created by the turbines and any fish guidance structure including how fish are conveyed to a receiving waters and the associated concerns with that process and the receiving pool (USFWS 2019).

Where the efficacy of a downstream bypass is low (or the bypass is non-existent), careful analysis of the mortality of fish entrained through turbines should be made. Field studies (e.g., mark-recapture, balloon-tags) that empirically measure survival of entrained fish are preferred. Moreover, site-specific studies are recommended; extrapolating total entrainment rates from samples of other species or from other sites may be less precise (FERC 1995). Where field studies are impractical, infeasible, or cost prohibitive, desktop analyses may prove useful predictive tools.

Numerous desktop techniques have been documented and generally fall into one of two categories: empirically derived regression equations and fundamental methods that relate fish physiology and turbine physics. The so-called Von Raben method and Franke method are examples of the latter type. Both methods yield equations that predict the probability of blade strike depending largely on turbine geometry and fish length (Franke et al. 1997). The Franke method, an extrapolation and improvement upon Von Raben approach, is the preferred fundamental desktop analyses method. The CRASC recommends the following best practices:

- the Franke method should only be used for Francis, Kaplan, and fixed propeller turbines;
- where possible, use engineering drawings (rather than reports) to determine the inlet and outlet diameters on a Francis turbine;
- in the absence of better information, assume mid-blade paths for fish moving through Kaplan and fixed propeller turbines;
- where accurate turbine efficiency curves for a site are not available, typical turbine efficiency curves can be used and, perhaps, discounted depending on the condition of the runner;

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- care should be taken in selecting a value of the mortality correction factor or correlation coefficient, Lambda; unless Lambda has been calibrated, a conservative value of 0.2 is recommended.

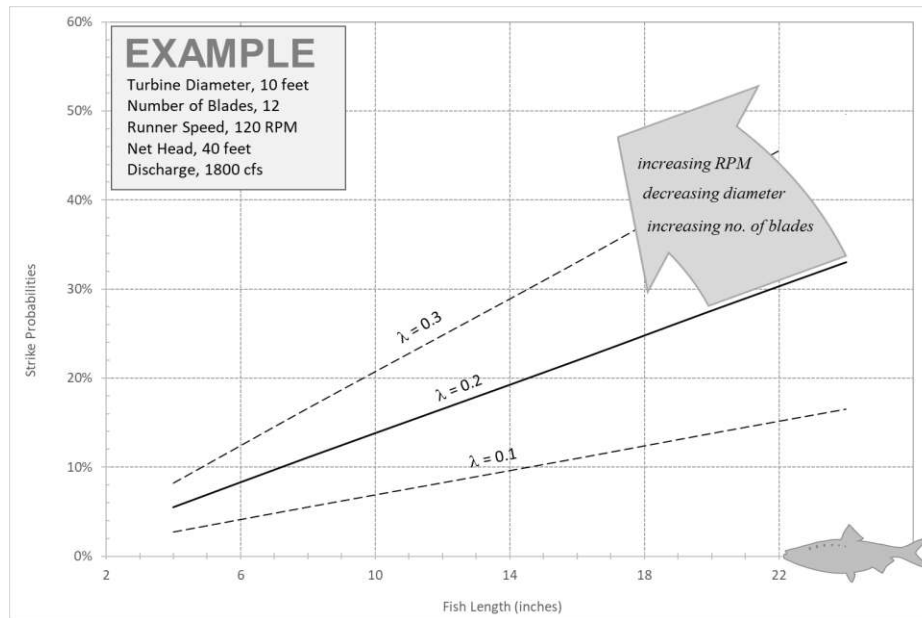


Figure 1. Blade strike probabilities for an example turbine in relation to selected Lambda and responses to increases in turbine RPM, fish length, decreases in turbine diameter, and increases in number of turbine blades.

While the appeal of desktop methods is clear, their application can be computationally complex and is best suited for a spreadsheet solution. To facilitate this, in 2018 the USFWS developed a computer implementation of the Franke method for Microsoft Excel™. This model is a probabilistic Excel-based, VBA application of the methods outlined in INEL's "Development of Environmentally Advanced Hydropower Turbine System Design Concepts" by G. Franke et al. (1997) for evaluating fish mortalities due to turbine entrainment. This model, provided "as is" and without warranty of any kind, is available for download from:

www.fws.gov/northeast/fisheries/fishpassageengineering.html

Juvenile shad mortality based on blade strike model probabilities have shown consistency for short-term (24 hr) mortality with field studies at several hydroelectric projects using balloon tagged juveniles passed through turbines, in a peer-reviewed study design (Heisey et al. 1992). However, juvenile fish field studies have been unable to quantify long-term delayed mortality that may occur from injuries (injury rates are often quantified in study recovered juveniles). The difficulty in retaining control fish for >48 hours is the cause of the issue, resulting in only immediate mortality estimates in recent study results.

Adult shad mortality, based on turbine blade strike model probabilities are increased greatly based on the size of the fish, as noted earlier (Figure 1). Unlike juvenile shad, the ability to use balloon tag methods and pass post spawn shad through turbines has not been successful, attributed to the reduced condition of fish having spent 4-6 weeks in-river without feeding and elevated water temperatures. In recent years, radio tags that can be programed to switch burst signal frequency, based on an internal

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ball bearing movement or lack of movement, has been used to assess mortality. However, several important limiting considerations with this tag type for analyses of “turbine” passed adult shad must be recognized. First, these tags must be programmed for a period of “inactivity” before the tag signal switches from (as an example) an interval of 3 seconds to an interval of 10 seconds. This trigger period has often been set to 24 hours that leads to a complete lack of credibility for a “live signal” following turbine passage, for at least the first 24 hours in the case of immediate mortality. Second, dead fish drift has been studied and documented, including on the Connecticut River with dead radio-tagged adult American Shad, directly inserted into the Holyoke Dam Hadley Falls Station turbine intakes. Bell and Kynard (1985) demonstrated dead turbine-passed adult shad, passed through Hadley Falls Station, drifted between 0.6 and 1.3 km downstream of the project in less than 24 hours of mobile radio tracking. Havin et al. (2017) also provides study results on the drift of dead salmon smolts (2.4 km) and eels (up to 30.1 km). Third, recognizing that dead fish drift, there is the potential that dead tagged individuals will not trigger the mortality switch and/or may alternate between a live signal and mortality signals in areas where drift/movement occurs (e.g., the tailrace of generating turbines).

Castro-Santos et al (2016) determined upstream passage efficiency rates for adult shad using radiotagged fish in 2011 and 2012 from the river mouth to the Holyoke Dam and its two fish lift fishway system (Castro-Santos et al. 2016). These researchers capture and dual tagged American Shad with a radio tag and a PIT tag alone, allowing adjustments for radio tag shedding. Study methods also included deploying a number of stationary radio receivers along the main stem river and also in and around the Holyoke Dam. A PIT reader and antennas were deployed at the Holyoke Fish Lift to document a passed shad. Study results using a Cormack Jolly Seber analyses determined arrival rates ($\pm$ standard error) of tagged shad to Holyoke Dam as $80.5 \pm 6.5\%$ (2011) and $77.1 \pm 7.6\%$ (2012). Passage rates of tagged fish that arrived were $73.8 \pm 7.0\%$ (2011) and $75.8 \pm 6.6\%$ (2012).

The Vernon Dam fish ladder’s passage efficiency also provides a basis for upstream passage efficiency criteria based on the number of shad counted passing at the Turners Falls gatehouse ladder. Since 2012, when USFWS fish passage engineers identified and fixed within ladder passage issues, annual shad passage counts have provided useful, consistent data on passage with a functioning fishway (Table 1). A 2011 radio telemetry study using American Shad tagged and released into the Turners Falls Power Canal, from the exit of the Cabot Station Fish Ladder, provided a least biased estimate (reduced handling/tagging effects with only viable fish passing through Gatehouse) to more accurately determine the proportion of the shad passing Gatehouse that reach the Vernon Dam tailrace (Castro-Santos 2011). Study results demonstrated 90% of the radio tagged shad (36/40) passing the Gatehouse were detected at a stationary receiver located 1 km downstream of Vernon Dam. Tagged fish moved rapidly to the Vernon Dam project area (median of < 2 days). Subsequent year radio tagging studies (FirstLight Power and TransCanada) had results affected by handling/tagging/tag effects (releases within the Turners Falls impoundment) and/or very limited sample sizes of tagged fish passing upstream of the Turners Falls power canal. Applying the 90% arrival rate for viable radio tagged shad to the observed passage counts differentials for the two facilities, results in Vernon’s upstream passage efficiency averaging 67.7% (Table 1). The removal of the first year (2012) following initial fixes at the facility (time series low) increases the mean passage efficiency rate to 72%.

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Table 1. Annual American Shad passage counts for Turners Falls Gatehouse Fish Ladder and the Vernon Dam Fish Ladder for the period 2012 – 2018.

Year	American Shad Passage			At 90% arrival to Vernon, required % passage efficiency for observed counts at Vernon
	TF Gatehouse	Vernon	% Passed from Gatehouse	
2012	26,727	10,386	38.9	43.2
2013	35,293	18,220	51.6	57.4
2014	39,914	27,706	69.4	77.1
2015	58,079	39,771	68.5	76.1
2016	54,069	35,513	65.7	73.0
2017	48,427	28,682	59.2	65.8
2018	43,146	31,724	73.5	81.7
Mean			61.0	67.7
S.D.			12.1	13.5

The CRASC Shad Management Subcommittee anticipates that FERC will issue license articles for Turners Falls, Northfield Mountain Pumped Storage, and Vernon in 2020 and that there will be license articles that address safe, timely and effective passage. Consequently, the improvements to fish passage at each of these facilities will need to be evaluated against the above stated fish passage performance criteria. Licensees of these projects must develop evaluation study plans in coordination with state and federal resource agencies. The results of these studies will allow licensees and resource agencies to consider structural, technical or operational changes if passage performance falls short of the criteria. Considerations for proper study design includes appropriate analytical approaches and adequate sample sizes of test fish to address statistical variability and capture representative variation in project operational and environmental conditions as well as fish movement timing (early, middle, late run) and characteristics of the species life stage (size, physiology). Several peer reviewed studies as well as unpublished evaluations in the Connecticut River have documented the capture, handling, tagging and tag related effects for study fishes using radio or acoustic tags (Frank et al. 2009; Olney et al. 2006; Bailey et. al 2004). Such effects must be taken into consideration when designing, conducting, analyzing and interpreting study results. Tag manufacturers and researchers have made advances in smaller radio tag sizes, tagging methods, analyses, and approaches to describe the type and extent of effects (e.g., PIT only tagged fish vs. radio & PIT tagged fish). Radio and acoustic tags in addition to PIT tags remain a primary evaluation method to understanding underlying behavior and movement, but other approaches may also be applied such as video/acoustic monitoring with caveats based on field of coverage and resolution. The state and federal agencies will provide further guidance during the consultation process.

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Acknowledgements

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Memorandum

Date: February 21, 2020

To: CRASC Commissioners and Alternates, Technical Committee and CRASC email distribution list (individuals submitting review comments)

From: CRASC Technical Committee and American Shad Plan Team

Subject: Review of submitted comments on Draft Addendum to the American Shad Management Plan (approved 2017)

This memorandum captures comments received during the two public comment periods that will be further described in the following text. The Addendum Plan Team worked collaboratively to examine and address submitted comments by the public. Our response is summarized in this memorandum and the attached table which identifies individual comments and responses.

The Connecticut River Atlantic Salmon Commission (CRASC) approved an updated Connecticut River American Shad Management Plan (2017 Plan) at its June 2017 meeting, replacing the 1992 Plan. The 2017 Plan comprises a set of management goals and objectives with supporting narrative. Within the Population Objectives, the Plan identifies the following fish passage objectives:

- 1.5 Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post spawn adults, and juveniles; and
- 1.6 Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency and delay at these three stages, as suitable information is available, to support other objectives of this Plan; and
- 1.7 Establish downstream performance measures, for adult and juvenile life stages that maximizes survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan.

The establishment of performance measures is supported, in part, by the Federal Energy Regulatory Commission's (FERC) draft environmental assessment for the American Tissue Project (FERC No. 2809), which states: *"Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities...Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and*

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determining whether effectiveness testing would or would not provide benefits to alosines...” (FERC 2018^A).

A team of 12 state and federal research and management agency biologists, as well as a senior U. S. Fish and Wildlife Service Fish Passage Engineer, developed the CRASC Shad Plan Addendum – Fish Passage Performance. The Plan Team has extensive expertise working with the monitoring, management, restoration, fish passage design and operation, and research of this species in the Connecticut River and in other systems.

The Plan Team used the following information sources to formulate appropriate and achievable criteria that address the Plan goals and objectives:

- peer reviewed and other publications;
- the 2017 CRASC American Shad Management Plan;
- U.S. Fish and Wildlife Service Fish Passage Criteria (2019);
- American Shad Passage Model (Stich et al. 2018);
- USFWS Turbine Blade Strike Model (2019);
- Atlantic States Marine Fisheries Commission’s Fishery Management Plan for American Shad (Amendment #3);
- ASMFC 2007 American Shad Benchmark Stock Assessment;
- the 1992 CRASC American Shad Management Plan; and
- other sources found in the Literature Cited section of the Addendum; as well as additional references cited in this memorandum and within the attached comments and responses table.

CRASC received written comments on the Draft Addendum from three power companies (Great River Hydro, FirstLight Power and Holyoke Gas and Electric) as well as two individuals (Mr. Karl Meyer and Mr. Robert Stira) during the first 30-day review period (August 9, 2019 through September 9, 2019). The companies and Mr. Stira requested more information on the Shad Passage Model (Stich et al. 2018) along with several other requests. The CRASC granted an additional 45-day comment period (September 12, 2019 through October 28, 2019) and provided, at the request of the power companies, the “R” code and related model details from Dr. Stich as well as model outputs from the Connecticut River model runs described in the Addendum. On October 28, 2019, a second set of review comments were received from FirstLight Power and Great River Hydro (jointly submitted and containing previously submitted review letters), and from Holyoke Gas and Electric. The Plan Team reviewed the submitted comments and organized our responses into a table format. The Plan Team met in mid-November 2019 to review the comments and develop a plan to provide responses.

A dominant topic of the power companies was the Shad Passage Model developed by Dr. Stich and utilized by the Plan Team along with other information (Stich et al. 2018). The companies’ comments suggest that they believe the Shad Passage Model was the primary basis for the development of passage performance criteria. This is not the case. As stated specifically in the Addendum, the model was “*one tool for managers*,” and was used, along with other diverse sources of information, to develop and support the criteria specified in the Addendum.

The companies’ comments also focused on the American Shad Passage Model outputs and the high variability associated with reported mean values. We understand there is high variability in model outputs; that variability is the basis for taking a precautionary approach in interpretation of outputs relative to current “minimum” escapement (number of fish passed at a dam) or population targets. The

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model provides clear and consistent patterns, most notably that high adult downstream survival at hydroelectric projects is critical to achieving management objectives, including long-term population growth, increased repeat spawning fish (i.e., spawners), and upper basin population targets.

Comments received by the companies also suggest they believe the minimum population targets defined in the 2017 Plan and used to help interpret model outcomes are long-term static figures. This is not the case. The 2017 Plan (page 6) states: *"This [return/production] estimate likely underestimates the full return/production potential due to problems of reduced passage issues (up and downstream) that were known to exist at each dam. CRASC may increase the minimum adult production target values as improvements to habitat quantity and quality and fish passage occur in the future with pending hydropower relicensing opportunities and other advances in technologies and regulatory or partnering opportunities."* CRASC's strategy is to address the constraints on the population that these minimum targets were derived under and, over time, update the management goals and objectives, as necessary, based on new information and improvements to passage. The CRASC intends to update the 2017 Plan at a 5-7 year interval, similar to the approach used by the Atlantic States Marine Fisheries Commission.

In the near future, there will be key fish passage and restoration opportunities, particularly in the upper Connecticut River basin, that will facilitate progress on achieving the 2017 Plan goals and objectives. The FERC relicensing process allows a rare opportunity to work with the utilities to mitigate the impacts of hydroelectric generation by improving upstream and downstream passage. These efforts will significantly and positively influence the status of shad populations over the long-term. Cumulative impacts of impediments to shad passage are particularly acute for the upper basin states, that have had to implement shad harvest restrictions, including closing the fishery to harvest (VT and NH) and reducing bag limits (MA). The restoration and development of sustainable fisheries, currently closed to the public in the upper basin, is a high priority for CRASC members that necessitates the upstream passage efficiency criteria described in the Addendum.

A concern expressed by the companies is how the Addendum passage performance criteria may be utilized in a regulatory context. We note that CRASC does not have any statutory authority within the Federal Power Act (i.e., FERC) or Clean Water Act (i.e., 401 water quality certification). However, the agencies charged with developing fish passage prescriptions and conditions through FERC relicense proceedings and/or 401 Water Quality Certification need management information to guide their recommendations. The extent to which the passage performance criteria are used in the regulatory processes will be up to the agencies, as will the design of evaluations to determine if those criteria are being met.

It is an increasing practice to incorporate fish passage performance criteria into fisheries management plans. The first CRASC American Shad Management Plan (1992) provided clear objectives for upstream fish passage. The 1992 Plan states, *"Achieve annual passage of 40-60% of the spawning run (based on a five-year running average) at each successive upstream barrier on the Connecticut River mainstem."* That criterion is similar to the proposed revised upstream passage efficiency criterion, which focuses on passing 75% of the shad that arrive at a project (as opposed to what has passed at the preceding dam). Based on a theoretical arrival of 80% of the shad from the previous dam,¹ with 75% passage efficiency of

¹ Previous upstream passage studies conducted on the Connecticut River have documented arrival rates in-line with this 80% target at the Holyoke (FERC No. 2004) and Vernon (FERC No. 1904) projects; refer to Addendum.

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those arrivals, an outcome of 60% passage is achieved. This aligns with the high end of the original 1992 criterion. As noted in the 2017 Plan and the Addendum, both Holyoke and Vernon projects have at times demonstrated achievement of 75% passage efficiency for fish arriving at a project.

The Addendum criteria also includes a 48-hour time period for shad to pass upstream (upon arriving within 1km of a project), to address negative impacts of delayed passage. Although a 24-hour time period for shad to pass in the Passage Model runs was shown to provide the best outcomes (for that setting, highlighting model sensitivity), we do not expect that the 24-hour time to pass criterion is achievable based on past field studies. Results from field studies indicate that a 48-hour time to pass criterion can be achieved; therefore, a higher upstream passage efficiency rate (75% as noted), as well as downstream passage survival (95% through project), are necessary in order to achieve minimum target population Management Plan goals and objectives among all basin areas, particularly for the upper basin (upstream of Vernon).

The companies provided their own Passage Model runs noting that “many” of the 81 scenarios they ran could achieve stated goals and objectives. However, the Plan Team’s review of the model output provided suggest that often only a subset of all management objectives are met. In some runs that met objectives, unrealistic parameter settings were used such as the 24-hour time to pass criterion discussed above. The companies contend that model outputs that fall within a very wide range (upper portion) of 95% confidence intervals may indicate achievement. We recognize there is a great deal of variability and thus uncertainty with the model outputs. We are cautious in the interpretation of the model results, using the mean as one guide for relative comparative responses and sensitivities (e.g., upstream passage delay and downstream passage survival at projects).

We contend that the companies’ (e.g., Figure 1) do not demonstrate achievement of the minimum population target and Plan goals and objectives using low upstream and downstream passage efficiency settings. The model output (e.g., Figure 1) is limited to the river mouth minimum target and does not meet the full scope of the management goals and objectives. Figures 23 to 32 suggest that minimum targets can be achieved with less than 75% upstream efficiency, but only with fish arriving and passing in 24 hours. We maintain the 24-hour ‘time to pass’ is not achievable and our 48-hour ‘time to pass’ is both reasonable and achievable. ‘Time to pass’ is likely linked to passage efficiency for fish arriving at a project. It is not reasonable to suggest a ‘time to pass’ expectation for arrivals at the “highest” level of effectiveness (24 hours) and then suggest concurrent passage efficiency in the “very poor” 25% to “low” 55% range as provided. The achievable 48-hour ‘time to pass’ requires 75% passage efficiency (achievable) as well as 95% downstream passage survival (achievable) to provide the best likelihood of achieving minimum targets and other Plan goals and objectives upstream of Vernon. Our conclusion that the efficiency targets are achievable is based on other supporting information and that when those targets are met the model results show minimum population targets can be met. In fact, the companies own model runs, shown in their Figure 28, in the top right panel, support the proposed criteria of the Addendum.

Support for the performance criteria in the Addendum is provided by a number of additional management plans, publications and other supporting information, as well as additional references listed below (Haro and Castro-Santos 2012; Noonan et al. 2012; Groux et al. 2015). Specific examples include:

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- The Migratory Fish Management and Restoration Plan for the Susquehanna River Basin establishes an 85% upstream shad passage criterion for fish reaching a project (SRAFRFC 2010).
- The U. S. Fish and Wildlife Service's Modified Prescription for Fishways (June 7, 2016) for the Conowingo Hydroelectric Project (FERC No. 405) states the licensee "shall" operate the project to achieve the SRAFRFC (2010) criteria and provides evaluation measures for those criteria (USFWS 2016).
- Parties to the Offer of Settlement for the York Haven Project (FERC No. 1888) agreed to the SRAFRFC Plan (2010) 85% upstream passage criterion for project arrivals and to the criterion of 95% through-project survival of juvenile shad and provides evaluation measures for those criteria (Patrizia 2014).
- The State of Maine's American Shad passage criteria specifies that, *"...the number of adult fish that need to be passed upstream at each fishway is estimated by dividing spawning escapement needed in all waters above the facility by an assumed passage efficiency (a goal of 90% is typically used)"* (MEDMR and MEDIFW 2008).
- Noonan et al. (2012) concluded *"To mitigate habitat fragmentation caused by anthropogenic barriers, upstream, passage facilities should allow 90-100% of migrating adult fish to pass in a safe and rapid manner (with citations)."* The researchers continued, *"...it was clear that current fishways are not achieving their primary conservation goal of restoring the connectivity of freshwater ecosystems."*
- In Silva et al. (2017), passage needs are discussed at length and include the following quote, *"Lucas and Baras (2001), similarly recommend attraction and passage efficiency targets of 90-100% for diadromous fishes, recognizing the cumulative impact, through reduced net passage across multiple sites, for effective restorative or population maintenance."*

We disagree with the companies' comments critical of passing more shad upstream of Holyoke in light of declines in repeat spawners citing information from Leggett et al. (2004). That paper's hypotheses have since been rejected in favor of more recent research that included a comprehensive analysis of published data on energetics and related data to model the shad population with respect to migration range, spawning success, and post spawn survival (Castro-Santos and Letcher 2010). Castro-Santos and Letcher concluded that delay, rather than energetics, was responsible for the loss of repeat spawners,

"...with migratory delay, rather than distance, being a dominate feature... delays incurred at dams are artificial consequences of human activities and can be mitigated for through improvements to design and operation of those dams and their associated fish passage structures (Kynard and Buerkett 1997; Haro et al. 1998; Kemp et al. 2006). Such mitigation would not be possible if the energetic costs of migration were driven primarily by migratory range, as proposed by Leggett et al. (2004)."

We also note in our table of responses that a number of iteroparous American Shad populations have native ranges penetrating much farther upstream than the Connecticut River shad population (280 km);

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the Susquehanna River (1,000 km to Otsego Lake) and James River (570 km) being just two examples (Limburg et al. 2003). However, shad in those systems have been severely depleted to a small fraction of their historical population sizes and have been restricted from significant reaches of historical habitat by dam construction and/or ineffective fish passage. This is similar to the situation on other rivers with dams and inadequate fish passage measures (Limburg et al. 2003; Limburg and Waldman 2009; Brown et al. 2013). Lastly, recent monitoring of juvenile American Shad production in the dammed habitat segments of the Connecticut River main stem has revealed density dependent effects on juvenile growth between Holyoke and Turners Falls dams that is not occurring with juveniles in habitats farther upstream (Mattocks et al. 2019). These examples are some of the justifications for, and benefits of, restoring access throughout the species' historical range that can be achieved most rapidly with the proposed criteria. This conclusion is based on the comprehensive, diverse sources of information and the Plan Team member's extensive knowledge, expertise and experience.

While the companies did not specifically comment on the topic of adult downstream passage performance, it is an issue directly linked to several management goals and objectives, such as increasing repeat spawner abundance. USFWS (2019) developed the Turbine Blade Strike Model that now provides a valuable tool to understand the potential impacts of passage at hydroelectric projects in the context of cumulative impacts and demonstrates the increased impact to larger/older female shad that have exponentially greater fecundity than virgin fish (covered in Addendum).

The previous CRASC American Shad Management Plan (1992) did not set specific criteria for downstream passage but did contain an objective to *"Maximize outmigrant survival for juvenile and spent adult shad."* The Addendum states that shad can be excluded from turbine passage and bypass facilities can be developed where absent or improved where needed to achieve 95% through project survival, helping to address the impact of cumulative project effects in this basin.

The USFWS Fish Passage Engineering Design Criteria (2019) documents a number of significant improvements to fishway designs, facility operational conditions, understanding of fish behavior, options for fish exclusion from turbines, and bypass designs that can address the challenges of designing effective passage facilities. The science of fish passage has experienced a rapid development in recent years, and there is widespread acknowledgement that fisheries managers must now incorporate new technologies to counter changing environmental conditions. The assertion by Silva et al. (2017) that *"Designing efficient fishways, with minimal passage delay and post-passage impacts, requires adaptive management and continued innovation"* is particularly relevant to the challenges faced by American Shad populations on the Connecticut River.

Without effective fish passage to provide access to historical spawning and nursery habitat, the species will not be able to achieve the abundance, size and age structure, and within-system range distribution that define population restoration goals in agency management plans. Mitigating the impacts of hydroelectric facilities and restoring runs of diadromous fish is achievable through the consistent application of science-based criteria. Developing performance criteria as a means of verifying the success of fish passage facilities is appropriate and has been explicitly requested by FERC. The CRASC, its constituent organizations, and the Plan Team relied on peer-reviewed population models (Stitch et al. 2018; Castro-Santos & Letcher 2010), recent research, assessments, plans, and fishway design guidelines

(summarized in USFWS 2019) in developing the fish passage performance criteria contained in the CRASC Shad Plan Addendum.

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Letter reference	Comment #	Comment	Response
FLP/GRH, 10/28/19, page 1	1	According to its developer (D. Stich personal communication), the model is neither final or stable at the present time nor was it when used to output population projections in the Draft Addendum.	The developer version on the master branch is used for ongoing research. Dr. Stich provided access to the legacy version of the model (used for these runs) that is frozen (final and stable). Dr. Stich states “I did not say this specifically I simply said that we are continually developing it (as is clearly stated on the software development page.” It is well-known that these models are based on incomplete and imperfect data. However they do represent the best available knowledge at the time they were developed. The intent of these models is to be a living document, such that they can be updated and refined as new information comes available. As such these models should never be considered 'final'. They are, however, stable in that they perform consistently and without error.
FLP/GRH, 10/28/19, page 1	2	...it was intended to be used as a tool in an iterative and collaborative approach to examine population trends as a result of various combinations of passage performance measures. Therefore, its application in developing very specific passage performance criteria is premature and inappropriate until such time as all parties agree that it is stable and how it should be applied	Dr. Stich has developed the SHADIA model to a state whereby the output it generates has served as a decision making support for the CRASC technical committee (TC). With input from the TC, Dr. Stich did indeed iteratively develop the model on the back end (e.g. temperature, flow, fecundity) and on the front end (various passage and mortality rates at each project). The passage model is <u>one tool</u> , one piece of information, that was used to inform criteria decisions (refer to page 5 of the Addendum). See comment response #6 regarding model stability. Further, all parties need not agree on how the model should be applied. This is a resource management tool. How the state and federal agencies use this tool, if at all, is within their regulatory and management discretion.
FLP/GRH, 10/28/19, page 1	3	The Draft Addendum focus on mean population values projected by the model was inappropriate. It should focus on use of the model as a tool to examine options for increasing the Connecticut River shad population by looking for positive trends through a variety of mitigation schemes and approaches	The model does produce a full range of user-specified confidence intervals. The mean was used for simplicity and illustration, but the consequences of management actions are true across the range of likely responses. Lower confidence limits show the same trends as the means, just at different magnitudes. We agree that managers should be concerned with lower confidence intervals, because these represent the risk of spawning failure. This is adequately captured by the model and should be included in the report. We agree that managers should be concerned with lower confidence intervals, because these represent the risk of spawning failure. This is adequately captured by the model and should be included in the report.

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FLP/GRH, 10/28/19, page 1	4	Draft Addendum failed to represent and account for the projected variability in model output suggesting substantial uncertainty in population projections. Therefore, there is substantial uncertainty and imprecision in the effect of passage performance measures specified in the Draft Addendum.	Same as previous response. For fishery managers it is important to hedge against variability (precautionary approach is the term commonly applied) in projections to minimize risk of stock failure, other undesirable outcomes that would reduce the rate or ability to achieve management objectives (such as opening closed fisheries in VT and NH).
FLP/GRH, 10/28/19, page 1	5	The model should include separate functions for adult and juvenile downstream passage effectiveness/survival. Currently the model includes a single downstream passage effectiveness/survival input value for both adult and juvenile shad. This is problematic because passage induced (and natural) mortality differs substantially among those life stages and the effects on population should be examined separately. It is therefore illogical to conclude a common passage performance criterion	We agree. This issue is acknowledged directly in the software. As new data come available we intend to update this. Already Castro-Santos and Letcher (2010) have demonstrated the likely consequences of migratory delay to downstream migrant adults and its effects on spawning and survival. The model as presented is conservative. Adult survival is the greater challenge, but is also the more important driver of patterns. Future refinements are unlikely to change these impacts except to emphasize the importance of adult survival. See Boreman and Friedland (2003).
FLP/GRH, 10/28/19, page 2	6	The model continues to be improved and it is imperative that the Companies and CRASC work together to 1.) Agree on a final version of the model; 2.) Apply the model as a tool in guiding mitigation options; 3.) Agree on inputs (fixed or variable) and their relative effects on the modeled population.	The CRASC approach was to work with the partners identified as necessary to develop the population model tool, one of many pieces of information used to develop and support the performance criteria. There will be no fixed inputs, outside of management controls in the model. CRASC agency members decided who would be appropriate to include in that process of model development, as well as broader discussions on the available information used and cited in the Addendum, to achieve initially identified " <u>minimum</u> " restoration population targets as well as other priorities (increase repeat spawners and restore upper basin adult run size - for fisheries and ecological objectives) (CRASC 2017). The agency's approach is driven by our intent to develop information tools (such as the USFWS Turbine Blade Strike Model) and use many other sources of information to restore the American Shad population and achieve the 2017

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			CRASC Shad Plan goals and objectives. The "stable" version of the model has been provided to the companies.
FLP/GRH, 10/28/19, page 2	7	Mitigation options based on modeled populations should focus on the most cost-effective measures that result in enhancing the Connecticut River shad population.	Mitigation options can be judged on many criteria and all the criteria have importance and must be considered using a wide range of available information not only the model. We again state the model was one tool used by the Team. The focus for CRASC is to identify mitigation options that support management goals and objectives. The primary focus for CRASC is to identify options that provide the most restoration benefit.
FLP/GRH, 10/28/19, page 2	8	The development of passage performance criteria should be a transparent and collaborative process including the Companies.	The resource agencies have management authority for the protection and conservation of public trust resources. We have addressed this comment in several ways. We maintained an open process throughout the development of this plan addendum. We extended the comment period and provided requested information, and having company representatives speak before the CRASC Commission. Company representatives are free to attend our public meetings. The model design, parameter values and opportunities for use are all covered in other responses (#11, 12, 15, 16 etc.).
FLP/GRH, 10/28/19, page 2	9	Although the model is publicly available, the Companies independent review of it revealed problems and limitations noted herein which were not addressed in the Draft Addendum. A more collaborative approach may have prevented this	Despite the claim of problems and limitations, the TC model consistently suggested that in order to restore the adult shad population to the Connecticut River, low rates of mortality had the best chance for the population to meet management goals and objectives for whole basin restoration.
FLP/GRH, 10/28/19, page 3	10	Given the implications of the Draft Addendum on the Companies' FERC licenses, the Companies have a significant interest in ensuring that the Draft Addendum is supported by sound scientific principles and existing scientific information regarding Connecticut River American Shad. The Companies do not believe the Draft Addendum, as prepared, meets that standard.	The Draft Addendum integrates all the information available at the time and is based on sound scientific principles. The Shad plan and all the components will use adaptive management as more information becomes available. We include responses to specific comments below and reject the assertion that the Draft Addendum does not meet the standard described by the companies. In addition to the Stich model, we have incorporated the best available science to restore the American shad population.

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FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	11	CRASC should facilitate a presentation and workshop for interested parties, ideally led by Dr. Stich or a surrogate who is highly familiar with the model development and implementation to address, at a minimum, questions regarding model design, variable inputs and distributions, and output variability	The CRASC has used a publically available, peer reviewed model developed by Dr. Stich. The model design and parameters are all fully transparent, there are no black boxes or hidden parameters. The model design is explained in Stich et al. (2018) where it is noted that the model has the design flexibility for other river applications. The "Legacy" code posted on the Shadia web site provides those model details used for Connecticut River model runs. Dr. Stich has provided input to the companies on the R code and made the CT River Model run setting available on the publically accessible Shadia web site.
FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	12	CRASC should share specific input and output datasets it used to adapt the model for the Connecticut River. This information must be made available to interested parties in order to assess the relative predicted effects of modeled input variables	These are available in the software package. This was one of the big reasons for its development. The only system-specific considerations are information about growth and mortality, spawning dynamics, max age, starting population size, temperature data, and the actual configuration of the hydrosystem (including carrying capacity). Vignettes are also provided with the software that document the data.
FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	13	CRASC should institute a minimum 90-day review and comment period beginning after the presentation/workshop and after CRASC has disseminated requested data	The CRASC has provided what it has determined is a sufficient period of review time. The initial 30-day period, August 9 to September 9, was noted as insufficient by some reviewers based on the comments received to have the model code provided along with many other requests (note in this response document) The CRASC agreed to an additional 45 days of review September 12 to October 28 and provided the R model code and related files from Dr. Stich on the Connecticut River.
FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	14	CRASC should clarify its review and revision process and timing, commit to addressing any comments received, and ensure that a summary of responsiveness to those comments received is published and distributed to interested parties prior to presenting a final version to the CRASC for approval and adoption	CRASC has provided responses to reviewers comments, beginning with the extension of the review and comment period (following the first 30 day period), initiated on September 12. CRASC reviewed its plan to respond to submitted comments at the December 11, 2019 CRASC. It was noted at that meeting that CRASC Plan Team members were responding to comments in an internal process and that the next CRASC meeting in February 2020 would be when response would be publically provided.

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FLP/GRH, 10/28/19 Attachment B 9/9/19 letter page 4	15	the Companies were informed by CRASC that the “R” program code used to generate the model outputs described in the Draft Addendum and a PowerPoint presentation (Presentation) on the referenced model runs and a 45-day comment period with an October 28, 2019 deadline would be provided. CRASC’s response did not address the Companies requests to facilitate a workshop wherein interested parties could work collaboratively to understand the model and investigate its utility to develop passage performance criteria, or to clarify the review process and timing	The model is open and available for use by anyone as noted in the response comments. The resource agency group comprised of state, federal, research, academic biologists contained all the necessary expertise to develop the model, using the best available science. The power companies have the ability to run the model with different values. The model was just one tool used to inform the development of passage.
FLP/GRH, 10/28/19, page 4	16	<u>The intent of the extended review period could not be fulfilled.</u> The Companies’ incorporated model input code provided by CRASC and the publicly available Shadia model for the Connecticut River, downloaded from the GitHub site as directed by CRASC. However, model output differed significantly from that provided by CRASC. On October 9, 2019 the Companies conferred with Shadia’s originator, Dr. Dan Stich (SUNY Oneonta), who confirmed that the publicly available model version had been revised from the version used to produce the output used by CRASC to inform the Draft Addendum.	The CRASC believes a significant amount of time and information has been provided to any persons/entities that had an interest in providing review comments on the Addendum. The companies did reach out to Dr. Stich who provided what has been identified as the "Legacy Code" used for the Connecticut River model runs on October 9, 2019. The companies did complete a large number of model runs of their own and submitted those in the letter dated October 28, 2019. The dam passage performance standards models are updated as new data become available. The version the companies attempted to use during fall 2019 to reproduce previous results was the most recent and included climate predictions that were still under review at the time. For this reason, the legacy version (referenced in comment 17) that was used for the CRASC request was provided publicly through the software website to promote transparency and reproducibility.

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FLP/GRH, 10/28/19, page 4	17	Dr. Stich was able to make available a 'legacy' version of the model code which was expected to replicate that used to inform the Draft Addendum. At that point, 26 days of the 45-day review period had elapsed and there was insufficient time remaining to complete our intended sensitivity analyses	The TC has reviewed a sufficient number of modeled output and it has coordinated with Dr. Stich extensively. We have a good understanding of the inputs to which the model is most sensitive. We reiterate that the model was not the sole source of information for which we based our performance standard.
FLP/GRH, 10/28/19, page 4	18	the intended use of the model was to provide a tool for all parties to use to collaboratively assess the relative effects of various passage performance scenarios. The model was in development when used to inform the Draft Addendum, is still in development and the most current version is not considered stable, and new scientific information that may improve the model's predictive accuracy has become available	The companies understanding of the term "stable", in the context of modeling, is not accurate. By stable, Dr. Stich did not mean that the model was not performing well or had an inherent flaw, but rather that it was no longer being modified in any way. The model does not need to be stable and the broad thrust of the Companies' comments capture this very idea, the model should be constantly revised as new information becomes available. To that end, Dr. Stich and the CRASC team are constantly looking for and receptive to new data sources to incorporate into the model. The current ASMFC Benchmark Stock Assessment is still more than 6 months from completion and is focused on coast wide stocks, incorporating information from individual systems (e.g., the Connecticut River) as well as coast wide surveys of various life stages. Additionally, the companies' expectations for the results of the Stock Assessment are the inverse of how the management system functions in this case. Rather than producing new information that could be used in the model or other important aspects of the Draft Addendum, the Stock Assessment will incorporate much of the data that has already been considered on the Connecticut River for coast wide management. It is possible that some aspect of the Assessment process will provide new information or tools that can be brought into this or future Addendums and CRASC looks forward to any opportunity to benefit shad restoration on the Connecticut River. We are unsure where the companies reference to the model being a tool "for all parties to use collaboratively" comes from, but the resource agencies have found it a useful piece of additional information in developing passage performance criteria working towards achieving goals and objectives of the CRASC Plan.

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FLP/GRH, 10/28/19, page 4	19	...the Companies recommend that CRASC support the development and validation of the model to a more stable state and then work collaboratively with the Companies and stakeholders in its use as a tool to help evaluate projected effects of passage performance criteria.	The TC states again that the model was one piece of information for the criteria development. As new peer-reviewed information becomes available, determination can be made on next steps. Other sources of information (research) and data (fishery dependent and independent) have been and will continue to be used to assess stock status and trends (CRASC 2017; ASMFC 2012). It will be adjusted over time as we gain more information and test the assumptions on which it is based. It represents our current understanding of the Connecticut River shad population.
FLP/GRH, 10/28/19, page 4 & 5	20	<u>Development of Passage Performance Criteria as Described in the Draft Addendum was Premature,</u> revisions to the model have been made to include the best available scientific information, including updated age and growth and mortality data derived from an ongoing stock assessment⁴, and climate information The model currently includes a common downstream passage effectiveness/survival input value for adult and juvenile shad. This is problematic because passage induced (and natural) mortality differs substantially among those life stages. It is therefore illogical to conclude a common passage performance criterion. The model should include separate functions for adult and juvenile downstream passage effectiveness/survival, and the sensitivity of the model to those functions and the projected effects on the population should be examined separately. The model was very	See earlier responses. The model will continue to be developed to help serve the management community, however the version provided is appropriate for management purposes. We agree that adult and juvenile mortality estimates should be considered separately and this will be included in future versions of the model. Available data indicate that shad populations are most sensitive to adult survival. Therefore we do not expect the outcome of future models to differ greatly, even when adult and juvenile mortality are separated.

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		sensitive to downstream passage and this change may substantially change output.	
FLP/GRH, 10/28/19, page 5	21	The Draft Addendum Incorrectly Focused on Mean Population Values Projected by The Model Rather Than Focusing on Population Trends, and Did Not Consider Confidence Around Model Projections	The Draft Addendum focused on using a wide variety of information sources to inform the performance criteria and target population goals, not just the model outputs. The Plan Team used the population model and described model outputs to help inform criteria with an understanding the mean outputs exhibit wide confidence intervals. The mean was used for simplicity and illustration, but the consequences of management actions are true across the range of likely responses. The Team also contends the mean output values do provide context for projected outcomes among differing scenarios for passage efficiency and survival. As such, the Team applied a precautionary approach (commonly applied in fishery conservation dealing with uncertainty) as part of the discussion on the model outputs and other information sources. The mean is just the average likely outcome. Some are better, but some are worse. In principle, managers want to minimize risk (this is the precautionary principle). By focusing in means we are providing the least biased predictor of success, however this means that greater protections would improve likelihood of success. Note that the models run by the companies also confirm this--to get better than 50% likelihood of success requires that both upstream and downstream passage rates be maximized, with a minimum of delay. This is the basis of the requirements we have called for.
FLP/GRH, 10/28/19, page 5	22	That approach is misapplied because it undermines the inherent stochasticity of the model and considers the result as deterministic. The model incorporates environmental stochasticity and inter-annual variability by drawing from parameterized distributions for many input variables (see Stich et al. 2018).	We disagree. Although means are discussed the model is in fact stochastic, not deterministic. Managers must consider likely outcomes of decisions and that is what the model is intended to support

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FLP/GRH, 10/28/19, page 5	23	The Draft Addendum failed to present, discuss and seemingly consider the confidence intervals around modeled population projections. In the Presentation of model output provided in support of the Draft Addendum, figures depict the annual population as an average of approximately 123 iterations per scenario, but no information regarding the variability around those projections. It is therefore important to demonstrate and evaluate model results in the context of that variability. For example, Figure 1 depicts ~120 iterations of a single model run. The mean projected annual population falls roughly in the middle of a large amount of variability.	The model confidence intervals are wide for outputs, there is uncertainty around the parameter settings bounded by the best science available in an approach peer reviewed by the Canadian Journal of Fisheries and Aquatic Science. As such, the CRASC position is to take a precautionary approach in model output interpretations. Our Team's interpretation of model outputs is based upon the design and parameterization of the model through discussions with Dr. Stich and each member's background working with American Shad management, restoration and passage (include Dr. Ted Castro-Santos and his published modeling work with shad). This is the rationale for the agencies being conservative in their interpretation of the model outputs that are viewed as informative for trends and relative shifts in parameter settings reflected in the mean value. However the model outputs is/are not the sole driver for the development of the passage criteria, a fact that is clearly stated in the Addendum. It was not the intent of the CRASC to suggest the model is the primary informational factor in our criteria development, we contend that is clearly expressed in the plan (page 5) and also covered in the memorandum.
FLP/GRH, 10/28/19, page 6	24	Figures 3-11 represent the same output but with 95% confidence intervals for each modeled scenario. The wide confidence intervals demonstrate a high level of variability and calls into question the validity of specific passage performance criteria with regards to the Plan objective. While the mean of few scenarios approached the Plan objective, the confidence limits of many scenarios exceeded it⁵.	Variability within complex models is inherent, especially those which examine and incorporate any level of environmental stochasticity, as Shadia does. The model is a tool used to help support criteria development that included consideration of numerous other supporting sources of information. It is important to consider that all plan thresholds are clearly defined as minimum targets and expectations these levels would be exceeded, partly attributed to needed improvements in passage (greater upstream passage efficiencies) and survival. Means allow us to 1) graphically explore the potential consequences of different management actions; and 2) precautionary approach requires that we consider minimum likely returns, not maximum likely returns, and to ensure that those minimum likely returns meet management goals. Note that we do not consider 24 h maximum delay to be a realistic or achievable goal. Within realistic parameters everything in these models points to minimizing delay and maximizing safe passage in both directions as the management strategy that is most likely to achieve targets. We had noted mean values in outputs in our consideration of model outputs we ran but that does not mean variability was not examined or considered by the CRASC. It would be irresponsible for the agencies to consider managing a population solely on wide ranging confidence interval of a

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			model - at the estimated upper 95% level, for a population considered under restoration. Additionally, the plan is not static nor concerned solely with minimum thresholds or model outputs, especially when considered over the full lifespan of a 40 year operating license. Figures 3-11 only consider the minimum target to the river mouth, it does not provide any information relative to potential outcomes for the upper basin, and has <u>zero</u> examples for achievement of the minimum target with the mean output.
FLP/GRH, 10/28/19, page 6	25	The trend in population growth was generally similar among scenarios with the most rapid population growth occurring over approximately the first two generations (~10 years). Similarly, output for modeled populations above Turners Falls (Figures 12-21) and Vernon (Figures 22-31) Dams demonstrated high variability with upper confidence limits well above the targets and lower confidence limits below the targets in all scenarios	We fully acknowledge variability in the model's output. Having acknowledged that, as managers, we have taken a conservative approach to reaching our management goals and objectives with other information for criteria utilized. Model runs for Vernon (<u>minimum adult population target</u>), the referenced figures 22-31) supports our position that high upstream passage efficiency is necessary when using the achievable criteria of 48-hour time to pass and that high downstream passage survival is also required to help achieve the goals and objectives to the upper basin. Further, among our many specified management goals and objectives, we seek to open closed fisheries in NH and VT and reestablish ecological roles among all life stages that have been severely depleted in the upper basin and that can be addressed by attainable upstream fish passage efficiencies and time-to pass (refer to memorandum). Also refer to response in #25.
FLP/GRH, 10/28/19, page 6	26	Both the summary of results in the Presentation provided by CRASC and in the Companies' independent assessment of passage performance using the model indicated that there are multiple scenarios that can result in projected population growth toward meeting Plan objectives and there are trade-offs in terms of management objectives relative to passage performance	The Plan is clear in using the most upstream river segment as the central component of the standard. Having the necessary upstream passage and downstream measures become a necessity as a result of achieving the many objectives of opening fisheries, restoring ecological functions, and ensuring long-term population resilience and health (% repeats). We have made the decision to take a precautionary approach to restoring the shad population relative to criteria. Given the uncertainty in ocean conditions, bycatch, water quality, timing of flows, and other factors, the decision to implement high performance standards provides the highest likelihood for achieving management goals. We reiterate that the model is not the only tool upon which we made our performance standard decision.

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FLP/GRH, 10/28/19, page 6	27	To demonstrate that many scenarios could achieve the objectives, the Companies performed model runs using the same suite of passage performance criteria as above, but with an upstream passage rate of 25% (Figures 32-41). Based on the results of this analysis, there is a suite of scenarios that could be used to meet population and upriver distribution goals, even with such a low upstream passage rate.⁶ These include scenarios with lower proportions of downstream passage times, greater times to passage, and/or a combination of both.	The companies' letter states 25% upstream passage efficiencies applied to the model can achieve agency goals. The provided company model runs show that the mean population model does not achieve the "minimum" population target currently set for shad passage upstream of Vernon Dam for Figures 32, 39, 40, and 41. It seems that the companies have misunderstood the meaning of the confidence intervals. Just because there is a slight possibility of achieving a management goal is no justification for pursuing a given strategy. Our responsibility is to ensure that restoration has a good chance of success, and none of the models shown here support that goal. On the contrary, this very argument supports what we have proposed as the most appropriate and reasonable suite of criteria. The agency identified Vernon minimum target is critical to achievement of the 2017 CRASC Plan goals, and is the most sensitive to poor passage efficiency settings, higher delays, and increased impacts from poor downstream survival. The companies appear to be pointing to the fact the upper 95% confidence interval is located above that "minimum" target for Vernon. The TC refutes the suitability of using an "upper 95% CI" as a determination of achieving the noted minimum passage value. The precautionary approach, reasonably applied to a this population, is the logical choice for a species that remains in restoration status as other East Coast populations are all considered at "all-time" low levels of abundance (ASMFC 2007). The 24 hour time to pass used by the company is unrealistic based on field data, we chose an achievable 48 hour time to pass. We used other numerous other sources of information, not just model based, to inform our decisions. The criteria identified in the draft addendum are based on a holistic administrative record, are feasible, and are realistic. The precautionary approach requires that we at minimum provide strategies that have a greater than 50% chance of success (this is indicated by the mean predicted outcome meeting or exceeding population targets...e.g. the mean predicted outcome must be above the target threshold indicated by the dotted lines on the plots). To that end we have identified strategies that meet this requirement. These criteria will provide the best likelihood, given the breadth of information considered and discussed, to achieving <u>initial minimum</u> management goals and objectives.
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FLP/GRH, 10/28/19, page 6	28	studies produced results that should be considered in future model runs and management strategies. For example, recently conducted shad telemetry studies conducted for the relicensing of the Turners Falls Project indicate that 80% of the early tagged shad released at Holyoke arrive at Cabot Station while less than half (35%) of those tagged later in the season arrive at the Project.	If fish arrive at the project (80% or 35% can be time varying,) they should be passed, it is addressed by the definition of the criteria.
FLP/GRH, 10/28/19, page 7	29	The upstream relocation of the shad population has resulted in higher total energy expenditure and increased adult mortality leading to a dramatic reduction in the repeat spawning component of the population and in the mean size and age of adult fish.... The loss of larger repeat spawning females is estimated to have resulted in a 20% reduction in mean population fecundity and could account for a 14% reduction in annual recruitment to the population (Leggett et al. 2004 ⁷). This most likely has contributed to the failure of the population to respond numerically to the increased access to upriver spawning habitat. A prudent management strategy would be to adjust the passage of shad during the latter part of the annual run to ensure the restoration and the maintenance of an age and repeat spawning structure more consistent with historic	This decrease can also be explained by increased exposure to downstream turbine or other ineffective downstream passage which is known to have occurred and is occurring as well as delays in both upstream and downstream passage. If one assigns a conservative through project survival rates of 0.85 for outmigrating adults, applied to the third power (for passage of fish by three main stem projects– VT/NH fish), that leaves 61% of starting number (no modeling required). That degree of loss, is not acceptable for this population (under restoration - most notably in upper river basin habitats) given solutions exist to prevent such a loss from power company facilities. The USFWS turbine blade strike model is a useful tool to demonstrated the magnitude of the loss by turbine type and operations with routing data (refer to addendum). It is also important to note that turbine mortality is related to fish size, that larger females are selectively more impacted by turbine passage - exacerbating management concerns for the component of repeat spawners and the contributions larger females with their increased fecundity and potential contribution to production potential. We disagree with the companies' comments critical of passing more shad upstream of Holyoke in light of declines in repeat spawners citing information from Leggett et al. (2004). That paper's hypotheses were carefully considered and refuted by more recent research that included a comprehensive analysis of published data on energetics and related data to model the shad population with respect to migration range, spawning success, and post spawn survival (Castro-Santos and Letcher 2010). Castro-Santos and Letcher concluded that delay, rather than energetics, was responsible for the loss of repeat spawners. CRASC is seeking to effectively address poor upstream passage efficiencies, associated delays tied to inefficiencies, and also turbine/project route mortality of the commercial hydro power operators. On the matter of distance as a concern, Limberg et al. (2003) provides examples of numerous iteroparous (repeat spawner) shad population that were

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		levels. Failure to do so could further erode the proportion of repeat spawners and the number of individuals of older age classes, thereby placing the population at risk of recruitment failure in the event of a period of several years of successive poor recruitment.	documented to penetrate much greater distances up rivers than the Connecticut River. Examples of "long distance" migrating populations (greater than the Connecticut 280 km) historically used by these "repeat" spawner populations include; St John River, New Brunswick (300 km), Hudson River (320 km), Delaware River, NJ/NY (380 km), Susquehanna River, MD/PA/NY (>800 km), Potomac River MD/WV (310 km), Roanoke River NC/VA (375 km), and James River, VA (575 km). Castro-Santos and Letcher (2010) note "<i>delays incurred at dams are artificial consequences of human activities and can be mitigated for through improvements to design and operation of those dams and their associated fish passage structures (Kynard and Buerkett 1997; Haro et al. 1998; Kemp et al. 2006)...</i>"such mitigation would not be possible if the energetic costs of migration were driven primarily by migratory range, as proposed by Leggett et al. (2004)." Finally, the intent to allow the population to access a diversity of habitat over its full range for spawning and nursery habitat will 1) help reduce the occurrence of density dependent effects on juveniles (if constrained to select habitats - as detected currently); 2) help reduce potential negative impacts from more localized events (high rain events in one portion of the basin, other localized impacts); and 3) achieve the ecological benefits derived from the timing and magnitude of juvenile production that should be occurring among all the habitats - it not simply about adult fish only (refer to CRASC 2017).
FLP/GRH, 10/28/19, page 7	30	The Companies reiterate that use of modeled population projections should consider variability in output and focus on trends, rather than a deterministic interpretation of results.	This has been addressed in previous comment responses.
FLP/GRH, 10/28/19, page 7	31	Model revision is necessary to incorporate the best available data and include separation of juvenile and adult downstream passage, and the model should be verified as stable and agreed upon as final for the purpose of assessing passage performance.	The separation of juvenile and adult downstream passage survival is not necessary to evaluate the management questions of interest. Having both adults and juvenile downstream passage survival track for outcomes at 75%, 85%, and 95% are both logical and supported by available evidence to be representative to commonly expected ranges for some larger and mid-size project turbines on the main stem river. Please also refer to the response to comment #5, essentially the same question. The stability of the model was addressed in previous comment responses (#1, etc.).

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FLP/GRH, 10/28/19, page 7	32	we recommend that a working group, including the Companies and HG&E be convened to collaboratively apply the model as a tool to assess the sensitivity of passage performance criteria broadly, then more specifically investigate those criteria that have the greatest affects with consideration for cost-effective measures	The TC has provided opportunity for public comment during the development of the model scenarios and inputs. It is the responsibility of the resource agencies to apply the model within the context of numerous other sources of information (cited and discussed), to inform management and restoration decisions.
FLP/GRH, 9/9/19		The following comments were not included in the 10/28/19 FLP/GRH letter that referenced the 9/9/19 letter and included that letter as Attachment A. There were some instances of 9/9/19 letter comments that were placed directly in the 10/28/19 letter by the companies and were addressed earlier in this summary.	

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FLP/GRH, 9/9/19, page 2	33	In page 1, paragraph 3, CRASC states that “Ideally, for a facility/project to have zero effect on migrating fish, 100% of fish that arrive at the station would pass with no delay, injury, or mortality...” This assumes that in an un-dammed system, 100% of fish arriving at a point would pass with no delay, injury, or mortality. Such a statement suggests natural impediments to fish migration should be ignored or either do not or would not exist otherwise. It does not account for natural physical barriers (e.g. velocity, falls), which may have induced delays or passage failure: many at the same locations as present day Connecticut River main stem dams. It also ignores natural variation in temperatures, flows, or behavioral (e.g., spawning activity, predation), factors that can induce natural delay or termination of upstream migration. Lastly, it artificially establishes hydroelectric project passage zones that range from a minimum of one kilometer to several kilometers rather than a point. These factors potentially contributing to migratory extent and duration should be acknowledged in the Draft Addendum.	The TC acknowledges that no hydroelectric project is capable of such an ideal but the TC contends with the numerous citations, discussion on the topics in the Addendum as well as in the memorandum that <u>these criteria are achievable</u>. The precedent for criteria has been established on the Susquehanna River for American Shad (USFWS section 18 prescription cited in memo) after decades of failed passage measures in that basin, without any passage criteria in place. Other examples of precedent on similar passage criteria are in place for the State of Maine with Atlantic Salmon and on the West Coast with Pacific salmon stocks, through NOAA section 18 prescriptions. We note again that the FERC has identified the lack of defined passage criteria as an issue (citation in Addendum). The model does not ignore variation in temperature or flows. It selects from a distribution of temperatures and flows. Refer to page 2 of the Addendum as it clearly describes that arrival is based on fish migrating to 1 km from project. The 24-hour time to pass downstream of a project is supported by results of a juvenile shad tagging study in 2015 at the Vernon Dam/project, that suggest this rate is achievable and can be evaluated as a criteria. Results from the juvenile radio tagged shad released upstream of the project, passed the project in 0.7 hours (median) and that “approximately 87% of the shad that passed Vernon did so in 12 hours or less” (TransCanada 2017).
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FLP/GRH, 9/9/19, page 3	34	A significant upriver relocation of the main spawning activity by American shad in the Connecticut River to date has failed to produce the anticipated increase in total population size from the increase in total spawning habitat available. This upriver displacement of spawning has resulted in an increase in the length of the spawning migration and a corresponding increase in the energy expended to reach the spawning grounds. Fish are bioenergetically adapted to the length of their spawning migration. As the distance covered by a migrating shad increases, energy requirements also increase. Shad do not feed during migration and added energy demands for an extended migration may cause shad to exceed their limit of endurance. Prior to upriver relocation of the spawning activity, Glebe and Leggett (1981)³ found that energy allocated to migration was close to the minimum required for adult survival. Improvements to the Holyoke Dam fish lift in 1976 increased lifting capacity from 5-10% to about 50% of the annual run (Moffitt et al 1982)⁴. Additional upstream fish passage improvements at Holyoke after relicensing resulted in an estimate of over 70% of the shad run being passed	The coast wide decline in American Shad stocks is describe in the 2007 ASMFC Benchmark Assessment with annual updates from ASMFC demonstrating a continuation of this status for many populations through 2018 (ASMFC 2018). As a result of this well described coast wide decline, it is CRASC's contention that the opening of habitat in the Connecticut River has in fact mitigated non-riverine causes of population decline while numerous other shad systems have observed significant declines (e.g., adjacent Hudson River Shad fishery closed in 2009, remains closed). CRASC is seeking to address poor upstream passage efficiencies, associated delays tied to passage inefficiencies and turbine/project route mortality. The company incorrectly states that over 70% of the shad run passed over Holyoke in 2011 and 2012 (citing the CRASC Plan Addendum). The Draft Plan states on page 9 that 73.8% (2011) and 75.8% (2012) <u>of the shad that arrive (that is 1 km from Holyoke)</u>, passed at Holyoke. On the matter of migration distance, Limberg et al. (2003) provides examples of numerous iteroparous (repeat spawners) shad population documented to reach much greater distances up river than the Connecticut River, which have succumbed to dams and absent or inadequate fish passage. CRASC does not consider the artificial restrictions to migration on the Connecticut population to represents limitations of their energetic ability or biological ability. Anthropogenic limitations from interactions at projects (delay, inefficiency and mortality) are artificial impositions. With the draft addendum, we seek to correct the negative impacts/effects of hydropower development on the population. See response to #29 regarding energetics and distance.
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		over Holyoke in 2011 and 2012 (see CRASC Shad Plan Addendum).	
FLP/GRH, 9/9/19, page 3	35	Mortality of post-spawn adult shad has increased along with the increase of migratory range (Crecco et al. 1982)⁵. The increased use of body reserves due to migratory range extension may be a major cause of increased mortality of emigrating shad. Although the weight loss that results in death is unknown, Chittenden (1976)⁶ suggests that death may occur when somatic weight loss exceeds 40% of initial weight. A result of increased post-spawn mortality was a dramatic reduction in the repeat spawning component of the population and in the mean size and age of adult fish. In addition, an increase in the variance in annual population abundance followed this reduction in population age structure. The loss of larger repeat spawning females is estimated to have resulted in a 20% reduction in mean population fecundity and could account for a 14% reduction in annual recruitment to the population Leggett et al. 2004)⁷. This may have contributed to the failure of the population to respond numerically to the increased access to upriver spawning habitat. Reduced iteroparity	Refer to the response of comment #29 and #34 as it covers the incorrect assumptions on "distance" migrated as a possible main hypothesis. Response in question 31 also covers the downstream passage protection of adult shad which has only been developed in very limited areas as of this date as a driving factors coupled with the "delay" of fish passage covered by Castro-Santos and Letcher 2010. The fact that a higher proportion of shad tagged earlier at Holyoke arrived at Cabot (80%) versus 35% later in the season is not surprising and has no bearing on the application of the upstream passage criteria. The proposed criteria are based only on fish arriving at a project (1 km), and does not affect fish remaining in lower portions of a river reach. Seasonality as interpreted in the context of the comment is accounted for in the criteria. The performance criteria is applied to fish that arrive at a dam. This number will naturally vary throughout the migration season. Please note that here and elsewhere the company refers to Leggett et al. (2004), which as we have already stated has been refuted with respect to these and other points.

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		can deter restoration efforts because of the reduction of the effective population size and reproductive rate and because iteroparity serves as a buffer against environmental stochasticity. To mitigate for this effect, Leggett et al. (2004) recommended that migratory range be restricted by limiting the number of shad passed above Holyoke Dam. In addition, recent shad telemetry studies conducted for the relicensing of the Turners Falls Project indicated that 80% of the early tagged shad released at Holyoke arrive at the next upstream Project (Cabot Station) while less than half (35%) of those tagged later in the season arrive at the Project. This suggests that seasonality should be considered as well.	
FLP/GRH, 9/9/19, page 3	36	A prudent management strategy would be to adjust the passage of shad during the latter part of the annual run to ensure the restoration and the maintenance of an age and repeat spawning structure more consistent with historic levels...historic levels until the anticipated positive effects of increased spawning area created by fishway construction is reflected in the size of the population entering the river to spawn. Failure to do so could further erode the proportion of repeat spawners and the number of	Fish that arrive at the project (within 1 km) should have the opportunity to pass in a safe, timely and effective manner. Downstream migrating adult and juvenile should likewise have safe, timely and effective downstream passage. CRASC goals include improving the age structure of the population and increasing repeat spawning without restricting access to historic spawning and nursery habitats. Mitigating the known impacts of hydropower facilities would address management goals and objectives that don't ignore the biological and instinctual behavior of migratory fish. Refer to comment #29 for benefits of increasing access to historic spawning and nursery habitats and recruitment along with other ecological benefits noted in goals and objectives of the Management Plan (CRASC 2017).

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		individuals of older age classes, thereby placing the population at risk of recruitment failure in the event of a period of several years of successive poor recruitment.. Therefore, the Companies recommend that CRASC run a model scenario with reduced shad passage at Holyoke Dam during the latter part of the season.	
FLP/GRH, 9/9/19, page 4	37	How does CRASC rectify the criteria for minimum upstream adult passage efficiency of 75% within 48 hours with the potential for natural physical features to impose delay or obstruction to migration and the potential for shad to spawn within a project area without passing upstream? Recent studies have demonstrated velocity and physical barriers to shad passage at Rawson's Island / Rock Dam in the Turners Falls bypass as well as spawning activity there and in various reaches of the Connecticut River including below Vernon Dam.	Passage at Rawson Island and adjacent areas relative to shad movement has not been fully examined relative to a full range of potential discharge (Dam and Cabot) options that should be considered to achieve shad passage in that project area. The agencies are not limited to flows provided for earlier studies relative to their timing, duration, frequency, and magnitude. Higher discharges than those studied with less competing attraction by the Cabot Power Station, for sustained periods (rather than shifting study treatments), are expected to provide more suitable passage conditions and routes in the bypassed river reach. The power canal diverts up to 15,000 CFS of river flow - from the river in the bypassed reach during the upstream passage season, denying that section of the river (bypassed reach) those flow characteristics present since the last ice age. Fish that are not allowed to pass project areas (in this case to zone of passage flows and fishway efficiency issues) would be expected to start to spawn at some point.

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FLP/GRH, 9/9/19, page 4	38	What is the model sensitivity to specific input values, including upstream passage efficiency, upstream passage duration, downstream adult passage efficiency and duration and downstream juvenile passage efficiency and duration? It is not evident in the Draft Addendum how sensitive the outputs were to inputs and therefore it is impossible to draw conclusions about the relative benefits of defined passage performance criteria compared to other user input options.	Sensitivities are addressed in Stich et al (2018). Similar analyses were performed by Castro-Santos and Letcher (2010) indicating that models are indeed sensitive to some inputs. Downstream passage, marine survival, and movement parameters continue to dominate models, regardless of errors in other inputs.
FLP/GRH, 9/9/19, page 4	39	What is the effect of modeling the same input values for adult and juvenile downstream passage survival (75%, 85%, and 95%)? As described above, natural mortality of post spawned adults increases with migration distance. Additionally, juvenile turbine passage survival is generally high. The Companies recommend separate inputs for juvenile and adult passage survival.	Since receiving these comments we have provided the company with up-to-date versions of the model which allow them to address these questions. The companies were able to conduct there own model runs and comments on those outputs were addressed earlier in the table. Also refer to comment # 20 response to the matter of juvenile survival.

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FLP/GRH, 9/9/19, page 5	40	What is the expected natural mortality of outmigrating post-spawn adults and juveniles and how is that rectified with performance criteria? Stich et al. (2018) incorporated an input distribution for post-spawning survival “with a mean of about 0.80 (95% CI: 0.79– 0.87)”, referencing Raabe and Hightower (2014)8. It is unclear how this is manifested in the Draft Addendum criteria for downstream passage of adult American Shad. If natural post-spawn mortality within a production unit were approximately 20%, downstream passage survival of 95% could be numerically unattainable.	Natural and anthropogenic mortality sources are already included in the model. The point is to separate those processes to provide managers with tools they can use to make decisions.
FLP/GRH, 9/9/19, page 6	41	What was the variability in the various model run outputs? What is the overlap of probabilistic model output among the various input values for upstream and downstream passage survival and duration? Stich et al. (2018) noted that “the modeling approach was stochastic and thus incorporated uncertainty in input parameters, either through estimated precision of empirically derived parameters or by imposing a wide range of potential values over point-estimates where no estimate of precision was available.” As a result, model outputs would be expected to vary both intra- and inter-annually,	Models are available for anyone to run. When the models are run you get variability in the output. This was addressed in the more recent company comment letters following their use of the model and the comments that were responded to earlier (please refer to comments and responses #23 and #24).

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		depending on the range of those input values and the amount of replication in simulations.	
FLP/GRH, 9/9/19, page 6	42	What is the model sensitivity to production potential? Stich et al. (2018) used calculated production potential and presumably the Connecticut River adaptation of the model used production potential as described in Table A1 of CRASC (2017). What is the effect of altering those values?	Ongoing efforts are looking into this. We can assert that the model is sensitive to carrying capacity, because that creates a 'ceiling' above which the population cannot penetrate. As developed we have adopted a conservative value for carrying capacity based on current population sizes. If this were increased to approach theoretical potentials we would expect the model to continue to be sensitive to downstream adult passage, but the importance of expedited upstream passage would likely increase. Mattocks et al (2019) has shown density dependent effects of juvenile shad growth when comparing juveniles from the Holyoke Impoundment to juveniles in either the Turners Falls or Vernon Dam Impoundments.
FLP/GRH, 9/9/19, page 6	43	The Companies' August 30, 2019 comment letter and request for additional information remains our primary response to your solicitation for comments on the Draft Addendum to the CRASMP and it should not be perceived as being replaced by this letter and comments herein. We appreciate the opportunity to comment on the Draft Addendum and urge you and the CRASC to grant our August 30, 2019 request for extension and additional information.	An extension was granted via an email to all parties on September 12, 2019 from Ken Sprankle, providing the very R Code used in the modelling and the power point presentation output of the modeled runs, referenced in the Addendum. The new comment deadline was noted as October 28, 2019. The files were successfully electronically transferred to the companies by the end of the day, September 12, 2019. That would allow 45 days of additional review time.

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FLP/GRH, 8/30/19		The following comments were not included in the 10/28/19 FLP/GRH letter that referenced the 8/30/19 letter and included that letter as Attachment B. There were some instances of 8/30/19 letter comments that were placed directly in the 10/28/19 letter by the companies and were addressed earlier in this summary.	
FLP/GRH, 8/30/19, page 2	44	Request for Additional Time to Comment on Draft Addendum and Improved Transparency Regarding Review Process...it is imperative that the Connecticut River model be fully evaluated by Connecticut River stakeholders, including the Companies, with regard to the sensitivities of the various parameters, along with the values and sources of the parameters included in it.	This was addressed with time extensions and provided data, models, and other information

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FLP/GRH, 8/30/19, page 2	45	..based on the information provided in the Draft Addendum, it is not possible to assess the sensitivity of the model and the variability in output predictions derived from the Commission's application of the model. The supporting narrative section of the Draft Addendum concludes that the second model run showed "the highest upstream passage outputs were tied to the shortest time to pass (24 hours)." However, it is not evident in the Draft Addendum how sensitive the outputs were to changes in time to pass, and therefore it is impossible to make a conclusion about the relative benefit of the 24-hour criteria compared to other user input options. The question of sensitivity to this and other input values is critical to the application of this particular model because the precision of the model's output is a function of the distributions from which the input data are drawn.	This was addressed with time extensions and provided data, models, and other information. We considered other information that is cited and discussed in the Addendum and the memo relative to adult time to pass. The TC approach was to use all available information and determine criteria that would provide the best opportunities to achieve the suite of goals and objective in the Management Plan, given there is uncertainty in many aspects of information (model, environmental in future) that require a precautionary approach but were "achievable". We have numerous references supporting the fact our criteria are achievable and that precedent exists for such criteria, especially in light of preceding decades of shad passage issues in the Northeast (Brown et al. 2013). As mentioned in our response to comment #38, in response to this and similar questions we provided the company with the model and allowed them to explore these questions. The results of their access to this is evident from various other questions that they have posed. Thus we consider this question to be obsolete.
FLP/GRH, 8/30/19, page 2	46	...model outputs would be expected to vary both intra- and inter-annually, depending on the range of those input values and the amount of replication in Monte-Carlo simulations. It is not possible to assess the relative benefits of modeled passage criteria inputs without the context of the stochastic variability and uncertainty projected in the output data.	See comment responses #7, 21, 23, and 24, among others, to address this comment.

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FLP/GRH, 8/30/19, page 2 & 3	47	At the August 8, 2019 Commission meeting, it was noted that the proposed criteria set forth in the Draft Addendum are aspirational, and that CRASC cannot enforce the performance criteria. However, this characterization of the role of the Draft Addendum and the authority of the Commission obscures and minimizes the role of such performance criteria when applied in the various regulatory processes applicable to FERC licensees. The Draft Addendum (page 10) obliquely acknowledges this reality when it states that "...improvements to fish passage at each of these facilities will need to be evaluated against the above stated fish passage performance criteria. Licensees of these projects must develop evaluation study plans in coordination with state and federal resource agencies. The results of these studies will allow licensees and resource agencies to <i>consider structural, technical or operational changes if passage performance falls short of the criteria.</i>" (emphasis added). This statement implies the Commission anticipates iterative physical and operational changes may be required throughout a license term if the criteria described in the Draft Addendum are not met. Given the consequential role of performance criteria and the need	We note that CRASC does not have any statutory authority within the Federal Power Act (i.e., FERC) or Clean Water Act (i.e., 401 water quality certification). However, the agencies charged with developing fish passage prescriptions and conditions (through FERC relicensing proceedings) and or 401 Water Quality Certification need management information to guide their recommendations and to be used in those regulatory processes. The extent to which the performance criteria are used will be up to the conditioning agencies, as will the design of evaluations to determine if those criteria are being met. While CRASC cannot enforce performance criteria, agencies within CRASC are free to indicate to FERC that a performance standard is needed. Indeed, FERC is on record stating the following in its Environmental Assessment for the American Tissue project that it issued on June 29, 2018 (Accession # 20180629-3008): "Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities...Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and determining whether effectiveness testing would or would not provide benefits to alosines..." (FERC 2018). The Addendum represents topics and measures managers have studied, documented, developed, and deliberated on as necessary to achieve Management Plan goals and objectives (as currently described, i.e., "minimum population targets").
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		for measures in regulatory proceedings to be based on substantial evidence, it is imperative that any performance criteria adopted in the Draft Addendum are based on an accurate application of the model to the Connecticut River, accepted scientific principles associated with fish passage (including enhancing stock and not merely passage counts and timing), and existing scientific information about American Shad populations in the Connecticut River to ensure that such performance criteria are reasonably attainable and reasonably demonstrable.	
FLP/GRH, 8/30/19, page 3	48	First part of this comment is repeated in #43. If natural post-spawn mortality within a production unit is approximately 20%, downstream passage survival of 95% could be numerically unattainable . Thus, without further clarification from the Commission regarding its adaptations of the model for use on the Connecticut River, the assumption in the Draft Addendum that the performance criteria support safe, timely, and effective passage of American Shad is unsubstantiated	It appears there is confusion on the applied survival rate, that for the model runs was set as "project" passage specific. It does not reflect the applied distance based rate of natural mortality. The project passage survival rate is designed to reflect what is attributed to the "effect" of the project, which may include turbine passage, spill, bypass or other possible routes. Those sources of mortality from encountering a project on outmigration are considered additive. It is the additive sources of project encountered mortality, attributable to for example turbine passage, that can be addressed.

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HGE, 10/28/19, page 1	49	HGE submitted a request for CRASC to implement an extended review/comment period to ensure full consideration of all data and questions presented before the draft Plan is finalized. In addition, HG&E requested a presentation and workshop to address questions regarding the Stich model design, variable inputs and distributions and output variability.	Please refer to comment responses for #11, #12, #13, #14, #15.
HGE, 10/28/19, page 1	50	CRASC's response <i>[refers to providing R code, PowerPoint, and additional 45 days review]</i> did not fully address our questions, nor did it respond to our request to facilitate a workshop so that interested parties could work collaboratively to understand the model. HG&E reattaches its September 9, 2019 letter (Attachment A) to this submission and requests that CRASC address the comments and questions in that submittal as well as those below	Please refer to comment responses for #11, #12, #13, #14, #15.
HGE, 10/28/19, page 1	51	HG&E recommends that CRASC not approve the draft addendum to the Connecticut River American Shad Management Plan for the following specific reasons. 1) The model <i>Shadia</i> is not final or stable at the present time, nor was it final or stable when it was used to develop population projections in the Draft Addendum, according to the model's developer (D. Stich per. comm.). Thus, using it	Please refer to comment responses for #1, #2, and others. We again state the model was one of many pieces of information used by the TC to develop the criteria. It is not accurate to suggest the model was the primary driver for criteria. We have discussed and referenced many additional sources of information (in addition to what is provided in the addendum) that informed the development of the criteria.

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		that model to develop specific passage performance measures is premature and not appropriate, at least until it is final and stable.	
HGE, 10/28/19, page 2	52	The Draft Addendum inaccurately focused on mean population values projected by the model, rather than more appropriately using those projected values to identify population trends (D. Stich per comm.).	Refer to the response of comment #2, #3, and #23.
HGE, 10/28/19, page 2	53	The Draft Addendum failed to represent and account for variability in model output that suggests considerable uncertainty in population projections. Consequently, there is substantial uncertainty and imprecision in the effect of passage performance measures specified in the Draft Addendum.	Refer to the response of comment #3, #4.
HGE, 10/28/19, page 2	54	The model currently includes an unrealistic single, common downstream passage effectiveness/survival input value for both adult and juvenile shad. It should include separate effectiveness/survival input values for each life stage.	Refer to the response of comment #5.

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HGE, 10/28/19, page 2	55	The Draft Addendum failed to present, discuss and seemingly consider the confidence intervals around modeled population projections. Wide confidence intervals indicate both the variability in the model and uncertainty in population projections.	Refer to the response of comment #23 and #24.
HGE, 10/28/19, page 2	56	HG&E understands that FirstLight Power and Great River Hydro have spent considerable time and effort to run the <i>Shadia</i> model and they have concluded that there are multiple scenarios that could result in projected population growth toward meeting the Plan's objectives. For example , as HG&E understand that analysis, the Draft Addendum identified that upstream passage of 75% of adults arriving within 1 km downstream of a hydroelectric project and within 48 hours of arrival, and downstream passage and survival of 95% of adults and juveniles arriving within 1 km upstream of a project within 24 hours of arrival, were necessary to meet the Plan objectives. HG&E understand that FirstLight Power and Great River Hydro's model runs demonstrated that many scenarios could achieve the Plan's objectives. On that basis, HG&E agrees with FirstLight Power and Great River Hydro's conclusions that the <i>Shadia</i> model does not support	Refer to the response of comment #23, #24 and #27. HGE comments that along with the other companies the model does not support the criteria in the plan. We disagree as the model has shown that population is most sensitive to downstream passage survival when considering achieving upstream passage "minimum" passage targets to upstream of Vernon. In addition, the model was sensitive to "time to pass" for upstream passage. We have covered these topics in other previous responses - most notably that the model was one of many pieces of information used by the TC to develop the criteria. It is not accurate to suggest the model was the primary driver for criteria. We have discussed and referenced many additional sources of information (in addition to what is provided in the addendum) that informed the development of the criteria. Additionally the company outputs are based on "minimum" levels currently in the Plan (also discussed at length in earlier responses). Given wide confidence intervals we also as managers seeking to restore this population must take a precautionary approach in interpreting both data and model outputs (refer to comment response #24 and #27).

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		passage performance criteria in the Plan.	
HGE, 10/28/19, page 2	57	HG&E believes that going forward there is a need for transparency by the establishment of a working group to collaboratively assess relative value of modeled scenarios that includes HG&E, FirstLight Power and Great River Hydro.	Refer to the response of comment #8 and #19.
HGE, 10/28/19, page 2	58	Over the past 18 years, HG&E has spent tens of millions of dollars on American shad passage and has a significant interest in ensuring that the Draft Addendum is supported by sound scientific principles and existing scientific information regarding Connecticut River American Shad - before it is approved and finalized.	We agree that HGE has taken important and appropriate steps to improve up- and downstream fish passage and has done so in a collaborative approach. We also agree that all measures undertaken to improve passage should supported by sound scientific principles. See comment response #47.
HGE, 10/28/19, page 3	59	As indicated in the August 30, 2019 letters from all three Project owners (HG&E, FirstLight Power and Great River Hydro) directly impacted by this Plan, transparency is needed in regards to the Stich model design, variable inputs and distributions, and output variability. Therefore, HG&E renews its request for a model workshop and	Refer to the response of comment #6, # 8, #11, and #44.

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		further requests a full review and response to the questions in this letter.	
Stira, 9/5/19, page 1	60	Operators of fish passage facilities would be faced with demonstrating that the performance of their facilities meets the criteria presented in the Addendum. In some cases that would likely be impossible, given the limitations of current evaluation technologies. For example, the criteria for downstream passage of juvenile American shad stipulate that a minimum of 95% of emigrating juveniles that enter a hydro project area pass downstream through the project within 24 h and survive passage. To my knowledge there is no method available to verify that a project's facilities meet these criteria. Because of the small size and 'fragility' of juvenile shad, telemetric methods cannot be used with confidence since those methods would likely alter the behavior of tagged fish and bias the results of an evaluation. Another approach would be to estimate survival after turbine passage, which may exceed 95%, but researchers have had difficulty holding 'control' fish for	We disagree that the company could not design and conduct studies to demonstrate whether they are meeting passage criteria, it can be done and those studies can provide the necessary information as referenced in our memo with recent examples for Conowingo fish passage and York Haven fish passage (USFWS 2016; Patrizia 2014). The use of radio tagging technology includes micro tags (JSATS) and other smaller tag types in addition to PIT tags (balloon tags for turbine studies) may all be used (have been and are being used) to design suitable studies to obtain necessary data to assess project arrival, passage and survival (TransCanada 2017) . The FERC supports the use of such technologies and approaches to evaluate fish passage performance and fish survival as they should. Criteria on juvenile downstream passage may be also be assessed on the USFWS Turbine Blade Strike model, with discussion on the need for additional balloon tagging studies as a means to obtain additional information. Balloon tagging studies for juvenile shad have been routinely approved by FERC. However, as noted, the ability to determine delayed mortality (>24 hr) with balloon tag juvenile fish has not been successful due to the inability maintain controls beyond 24 hours. There are design and technology limitations in all aspects of fishery science management and research, an understanding of those limitations is important in the interpretation of the data and analyses that can be and has been part of the process of dealing with hydropower's impacts to our nation's diadromous fishery resources.

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		long periods. Without control survival, survival of fish after passage through the turbines cannot be calculated. In addition, a survival study would not yield data relative to the 24-h criterion. Why include criteria with which operators will not be able to demonstrate compliance?	
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Stira, 9/5/19, page 1	61	There are other issues raised by the criteria, such as the question of the declining condition of adult shad the farther they migrate upriver and the effect longer migration may have on post-spawning mortality and the likelihood of repeat spawning. The poorer the condition of the fish the less likely it may be to survive downstream passage through open river, much less through even a highly efficient passage facility. Operators should not be held accountable for 'natural' mortality.	CRASC's interest is reducing anthropogenic sourced mortality to the extent practicable to allow population restoration and achieve Management Plan goals and objectives. We do not suggest that companies should be accountable for natural mortality, only project related mortality impacts (immediate/short term and delayed from injury) that are know to occur. American Shad population exhibit varied life history characteristics. Population dynamics modeling and the use of parameter based on best information are better informing our understanding of the repeated exposure to delays on upstream passage as well as additive project specific mortality from downstream project passage. It is clear from those data that delay and whole river survival are serious management concerns for successful restoration (CRASC 2017, ASMFC 2007, ASMFC 2010). However, we have advanced significantly in our understanding of biological and engineering requirements for upstream and downstream fish passage of shad. We agree spent downrunning adults are on reduced energy reserves. This fact provides support for establishing the stringent downstream safety standards and preventing turbine passage
Stira, 9/5/19, page 2	62	The Addendum does not indicate how an operator would verify that it meets the criteria. Would one evaluation in one year showing the criteria have been met be sufficient, or would verification be required annually? The latter might impose an unreasonable burden on the operator.	That would be best left to the agencies in charge of conditioning and prescription authorities. An example of how this has been answered can be found in several examples, the first from York have Project on the Susquehanna River, within the Settlement Agreement that details responses to this for American Shad criteria (Patrizia 2014). A second includes the USFWS (2016) Fish Passage Prescriptions for the Conowingo Hydroelectric Project, also requiring achievement of shad passage criteria of the Susquehanna River Anadromous Fish Restoration Committee with details on evaluations. Other examples of criteria use and evaluations exist within the State of Maine FERC projects where anadromous Atlantic Salmon occur (NOAA) as well as the West Coast where Pacific Salmonids occur (NOAA).

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Stira, 9/5/19, page 2	63	Meeting the passage criteria would depend on the interplay of all factors, so failure to meet the criteria, especially for upstream passage, might have more to do with factors outside of a facility operator's control than with facility design and/or operation.	The TC understands that some factors are outside of project control and will need to be addressed by the regulatory agencies, FERC and owner operators in processes outside of the CRASC authority. We provided a number of examples and references in the memo for this table regarding the ability to achieve this passage rate and the fact criteria are in place for several species including shad (Susquehanna 85% upstream passage efficiency required) as well as noting the USFWS Section 18 for Conowingo (USFWS 2016) and the Settlement Agreement for York Haven (Patrizia 2014) that include evaluations of these. Also refer to response to comment #64.
Stira, 9/5/19, page 2	64	At the CRASC meeting of 8 August, one of the writers/reviewers said that the Addendum was "aspirational" in nature. If that's the case, an explicit statement to that effect should be included in the document. The Addendum will likely be used in regulatory proceedings, and all parties should be clear on the intent of the criteria.	We note that CRASC does not have any statutory authority within the Federal Power Act (i.e., FERC) or Clean Water Act (i.e., 401 water quality certification). However, the agencies charged with developing fish passage prescriptions and conditions (through FERC relicense proceedings) and or 401 Water Quality Certification need management information to guide their recommendations and to be used in those regulatory processes. The extent to which the performance criteria are used will be up to the conditioning agencies, as will the design of evaluations to determine if those criteria are being met

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Stira, 9/5/19, page 3	65	Development of documents such as the Addendum would benefit from more representation from the private sector. The operators themselves may employ biologists to support fish passage at their facilities, and there are many biologists working for companies contracted to evaluate fish passage. These individuals have accumulated decades of experience in evaluating facilities relative to passage criteria and could have contributed to the development of the Addendum. Private sector involvement might also help avoid ‘groupthink’, a hazard for all organizations. At the very least, if Trout Unlimited is asked to contribute, shouldn’t the operators have been asked to do the same?	The CRASC Shad Plan Team was developed by the CRASC agency members and additional individuals that were considered to be helpful in advancing the CRASC Plan goals and objectives were asked to contribute in this effort.
Stira, 9/5/19, page 3	66	As an aside, hydro operator involvement in the workings of CRASC has declined steadily over time. In the past, operator representatives had a seat at the table at meetings of CRASC and its predecessor (though without ‘official’ recognition), and operators were asked to participate on CRASC Technical Committee subcommittees. At present, there is no similar interaction between the operators and CRASC, which seems odd given the major role the operators have in meeting CRASC’s goals for fish passage.	CRASC Commission and TC meetings are open to the public.

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Meyer, 9/9/19, page 1	67	Results from long-range studies and annual fish passage totals across more than four decades of fishway monitoring underscore the failures of restoration at key ecosystem sites—particularly in the Turners Falls Pool. Thus, Vermont, New Hampshire and northern Massachusetts have never benefited to any meaningful extent in the migratory fisheries restoration of shad on the Connecticut.	Fish passage had been established through earlier agency actions in the 1970s (primarily) and also in the 1980 and 1990s, and have since included FERC relicensing and Settlement Agreements (e.g., Holyoke). Initial fishway designs were approved using in some cases the approaches and information available at that time from West Coast designs (e.g., Ice Harbor design). We agree it is time to fully utilize all available information to better address those factors that are negatively impacting the resource and that includes using performance criteria for improved passage and protections that are achievable and can address project related impacts that impact the agencies ability to achieve management plan goals and objectives.
Meyer, 9/9/19, page 1	68	The time for facilities operators to comply with fish passage statutes has come due, given the federal relicensing of 5 main stem operations on the Connecticut currently underway	The FERC process is underway for the noted projects. Other projects are also soon to be up for relicensing.
Meyer, 9/9/19, page 2	69	The Anadromous Fish Conservation Act, Public Law 89-304, was adopted by Congress in 1965, two years before the states and federal fish agencies signed the “1967 <i>Statement of Intent for a Cooperative Fishery Restoration Program for the Connecticut River Basin.</i> ” The first species mentioned in that document is <i>Alosa sapidissima</i> , American shad. Original restoration targets for the species were: “one million fish at Holyoke; 850,000 at Turners Falls; and 750,000 at Vernon.”	The agencies have adjusted projected adult run sizes from the initial Program years (1960s), but as we have noted in our responses, we believe our current targets to be minimum population targets and that as habitat access is provided and the population is allowed to respond, assessments and more current data may justify increases to current plan minimum targets (as discussed in the Plan and in previous responses).

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Meyer, 9/9/19, page 2	70	Shad populations on many East Coast Rivers have plummeted over the past half century. Fortunately, with the long-term success of the very basic fish lifts at Holyoke Dam, the Connecticut has shown some resilience and tenacity in retaining shad runs in the lower parts of the basin. But, ecosystem restoration for American shad and other migratory species has essentially failed across those same decades in all the upstream pools—commencing with the choke point at the Turners Falls dam, canal, and by pass reach of river.	The Addendum and its criteria are not project specific, it is to be applied to the basin in support of achieving Management Plan goals and objectives. The TC concurs that both upstream and downstream passage needs to be addressed and have provided a number of responses supporting these statements in addition to the memo.
Meyer, 9/9/19, page 2	71	...studies and ongoing investigations of the habitat and impoundments upstream of Turners Falls Dam point to the critical loss of millions of eggs and juveniles due to entrainment at the Northfield Mountain Pumped Storage Station. Couple this with upstream passage failures and downstream mortality estimates for adult shad—leading to the critical loss of repeat spawners that are necessary to bolster spawning success and grow the shad population as these robust recruits return to spawn in successive seasons, and you have a recipe for another failing shad population on another US River.	The Addendum does not address egg and larval fish entrainment. Study results at Northfield Mountain Pumped Storage does show entrainment of shad eggs, shad larvae, and juvenile shad. Fish passage designs and criteria have not been applied to eggs and larvae. The CRASC Plan does note the importance and ecological value of juvenile shad (not simply adult abundance alone). The TC does believe downstream passage protections for juveniles at NMPS are necessary and should be developed, to meet the 95% "through project" - passing survival. Pumped storage does not fall under "entrainment" regulations that are applied to other river users that pull water from the river (such as cooling water) that does require permits and possible considerations for losses at those early life stages.

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Meyer, 9/9/19, page 2	72	I am fully in support of the CRASC's science and results-based <i>American Shad Passage Performance Plan.</i>	
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CONNECTICUT RIVER AMERICAN SHAD MANAGEMENT PLAN



**Connecticut River Atlantic Salmon Commission
103 East Plumtree Road
Sunderland, Massachusetts 01375**

*Management Plan Approved June 9, 2017
Addendum on Fish Passage Performance Approved February 28, 2020*

INTRODUCTION

The Connecticut River population of American Shad has been cooperatively managed by the basin state and federal fishery agencies since 1967. In that year the “Policy Committee for Fishery Management of the Connecticut River Basin” was formed in response to the passage of the 1965 Anadromous Fish Conservation Act (Public Law 89-304) by the U.S. Congress. This committee was replaced by the more formal “Connecticut River Atlantic Salmon Commission” (CRASC), which was created by act of Congress (P.L. 98-138) in 1983 (Gephard and McMenemy 2004) and coordinates restoration and management activities with American Shad (<http://www.fws.gov/r5csrc/>). The CRASC American Shad Management Plan had a stated objective of 1.5 to 2.0 million fish entering the river mouth annually (CRASC 1992). Diverse legislative authorities for the basin state and federal fish and wildlife agencies, including formal agreements to restore and manage American Shad, have been approved over time and are listed in Appendix A. The following Plan updates the existing CRASC Management Plan for American Shad in the Connecticut River Basin (1992), in order to reflect current restoration and management priorities and new information. An overview of American Shad life history and biology is provided in Appendix B.

Annual estimates of adult returns to the river mouth for the period 1966-2015 have ranged from 226,000 to 1,628,000, with an annual mean of 638,504 fish (Appendix C). Access to historical habitat has increased since 1955 when the first modern-era fishlift was constructed at Holyoke Dam, with significant passage improvements made when the fishlift was rebuilt in 1976 and again in 2004. Since 1980, access to additional habitat has increased through the deterioration of the Enfield Dam and fishway construction at three main stem and four tributary dams. Bellows Falls, Vermont (river kilometer-rkm 280) has been identified as the historic extent of the species’ range on the main stem river, but a fishway completed in 1984 to pass Atlantic Salmon upstream at that barrier now allows shad to migrate beyond that dam (Figure 1; Appendix D and E).

The size of the annual shad run increased from 1967 to 1992 concurrent with the installation of fishways at main stem dams but the population experienced a dramatic and unexpected decline beginning after 1992 (Crecco and Savoy 2004). Some recovery has occurred from 2012-2016 as the number of shad lifted at Holyoke has exceeded the mean annual count for the period 1976-2011, in each of these recent years (Appendix E). At this time, the Connecticut River American Shad population is considered stable, but at reduced levels of abundance, according to the Atlantic States Marine Fisheries Commission’s (ASMFC) American Shad Benchmark Stock Assessment (ASMFC 2007).

In the Connecticut River, fishway passage counts (Appendix E) are an important metric to help determine adult abundance and trends over time, although many factors can influence fish passage rates and counts within and among years. Additional long-term population monitoring information includes stock structure data (e.g., age, spawning history) for Holyoke Fish Lift and downstream areas, as well as a juvenile shad seine survey, conducted by the Connecticut Department of Energy and Environment (CTDEEP) (Appendix F and G). Other long-term monitoring data compiled by the CTDEEP include landings and effort data for the lower river commercial gill net fishery (Appendix G).

Beginning in 2013, commercial (in-river only) and/or recreational harvest of American Shad by a state required a Sustainable Fishery Management Plan approved by the Atlantic States Marine Fisheries Commission (Amendment 3 to the ASMFC Interstate Fishery Management Plan for Shad and River Herring, 2010). Subsequently, the State of Connecticut developed an ASMFC approved Sustainable Fishery Management Plan (2012) that maintained both its commercial and recreational fisheries, with harvest. Massachusetts also received approval to maintain a recreational fishery with allowed harvest (MADMF 2012). The State of New Hampshire chose not to develop a sustainability plan and therefore its fisheries are limited to catch-and-release. Vermont is not a member of ASMFC and is free to maintain a recreational fishery without a sustainability plan but has followed New Hampshire’s regulations. In

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addition, ASMFC required development of a Habitat Plan for American Shad, which was completed by both the State of Connecticut for its portion of the basin and CRASC for the entire basin. Both were approved in 2014 (ASMFC 2014).

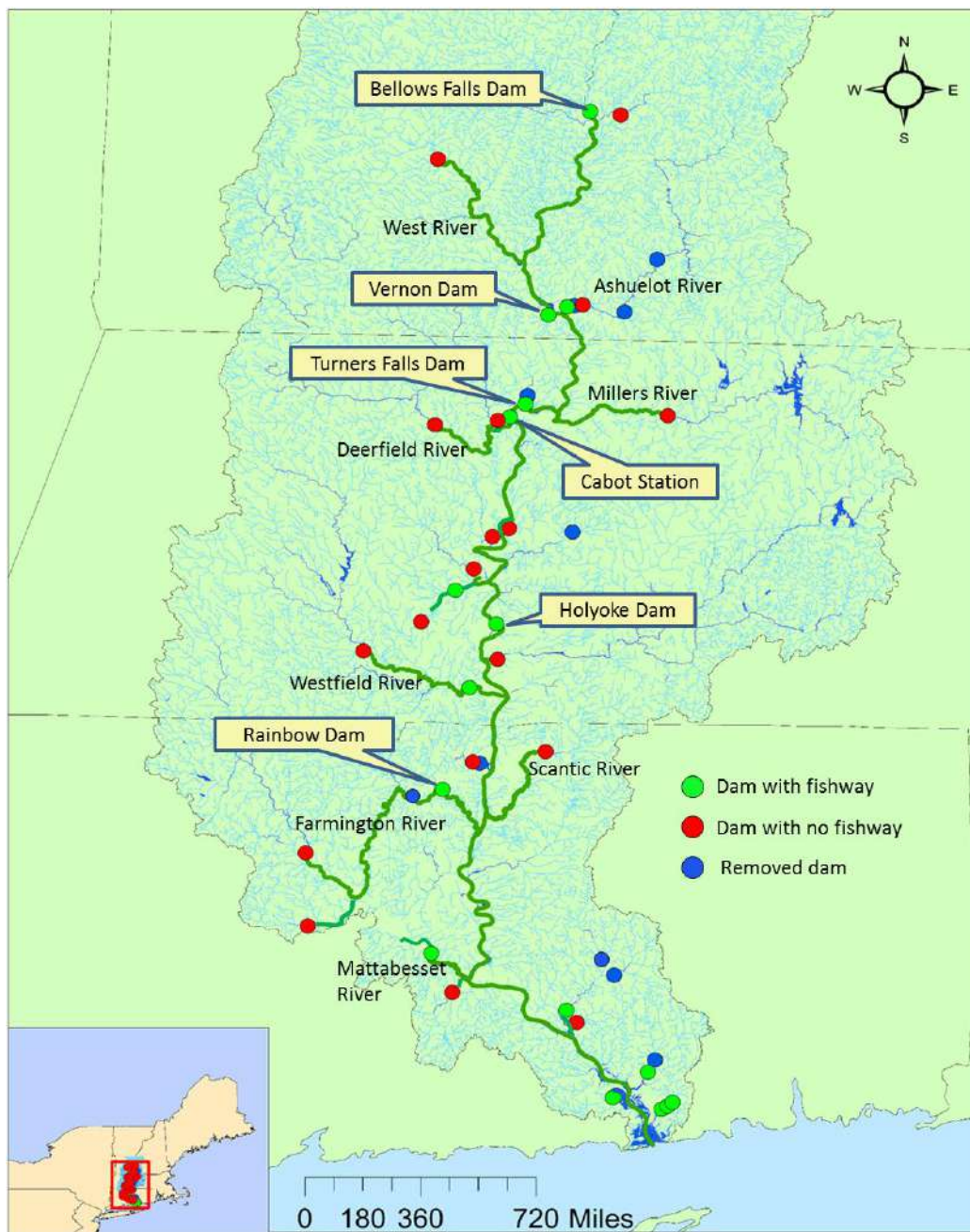


Figure 1. Restored habitat access within the historical range of American Shad in the Connecticut River.

American Shad have also been designated as a “Species of Greatest Conservation Need,” as stated in the comprehensive State Wildlife Action Plan(s), in each of the four basin states (TWW 2015). This designation recognizes the need to develop and implement conservation strategies and actions to improve American Shad’s status in the Connecticut River basin.

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This Plan reflects knowledge gained since the development of the 1992 American Shad Plan, which includes advances on shad population status and dynamics, physiology and energetics, reproduction, movement/behavior, fishway use/passage, fishway design/modification, and both fishway and facility operation and flow management.

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GOALS

To restore and maintain a naturally reproducing American Shad population to its historic range in the Connecticut River basin at targeted management levels of both abundance and stock structure, to provide and maintain recreational fisheries in the four basin states and the traditional in-river commercial fisheries for the species in Connecticut, and provide for the diverse ecological benefits derived from all life stages of shad in freshwater, estuarine and marine habitats.

OBJECTIVES

1. POPULATION

- 1.1 Achieve and sustain a minimum population of **1.7** million adult American Shad entering the mouth of the Connecticut River annually based on **8,800 hectares** (ha) of spawning and nursery habitat in the main stem and identified tributaries (Appendix I); and
- 1.2 Achieve and sustain a management target adult return rate of a minimum of **203 adults per hectare in the main stem** (Appendix I); and
 - 1.2.1 Achieve a run of > 1,027,000 shad downstream of Holyoke;
 - 1.2.2 Pass > 687,000 shad at Holyoke Dam; and
 - 1.2.3 Pass >397,000 shad at Turners Falls Dam; and
 - 1.2.4 Pass >227,000 shad at Vernon Dam; and
- 1.3 Achieve and sustain a management target adult return rate of a minimum of **111 adults per hectare in targeted tributaries** (Appendix I); and
- 1.4 Achieve an adult stock structure that over a five-year running average has a repeat spawner component minimum of **15%** for each sex; maintains a sex ratio close to 1:1, and is composed of a diverse age structure, including fish age-6 and older; and
- 1.5 Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post spawn adults, and juveniles [Refer to Addendum]; and
- 1.6 Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency and delay at these three stages, as suitable information is available, to support other objectives of this Plan [Refer to Addendum]; and
- 1.7 Establish downstream performance measures, for adult and juvenile life stages that maximizes survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan [Refer to Addendum].

2. FISHERIES

- 2.1 Maintain and/or establish a sustainable spring shad recreational fishery with harvest opportunities throughout its historical range on the main stem and on targeted tributaries guided by population size and fish passage objectives from this Plan; and
- 2.2 Enhance and promote recreational fishing opportunities throughout the species' historical range; and
- 2.3 Maintain a sustainable spring in-river commercial fishery in the lower main stem river in Connecticut; and

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- 2.4 Participate in other fisheries management organizations to support science-based management of Connecticut River American Shad fisheries.

3. ECOLOGICAL

- 3.1 Maintain an American Shad population to provide the diverse ecological contributions of American Shad, at all life stages, in the freshwater, estuarine, and marine environments, based upon population targets listed under 1.2 and 1.3.

4. MONITORING AND RESEARCH

- 4.1 Conduct fishery independent and dependent monitoring programs to assess population status and trends; and
- 4.2 Periodically determine long and short-term research needs to achieve or evaluate the Plan Goal and Objectives; and
- 4.3 Identify anthropogenic impacts that limit achieving the other Objectives of this Plan and develop corrective measures.

5. PUBLIC OUTREACH AND EDUCATION

- 5.1 Provide communications and education for the public on the CRASC Plan, and the benefits and ecological values of American Shad in the Connecticut River, Long Island Sound, and the East Coast in the Atlantic Ocean.

STRATEGIES

1. POPULATION

- 1.1 Increase American Shad access to spawning and nursery habitat in both the main stem and the targeted tributaries when possible; and
- 1.2 Determine if fish passage measures are safe, timely, and effective for upstream migrating adult and downstream migrating adults and juveniles, at individual dams, hydropower projects, for cumulative project effects, and assess whether Plan Goals and Objectives are being achieved. Develop corrective action plans as needed; and
- 1.3 Monitor hydropower operations and facilities for any detrimental effects that may impact Plan Goals and Objectives. Develop corrective action plans as needed; and
- 1.4 Conduct annual pre-season, in-season, and post season inspections of fishways, by qualified fish passage specialists (biologist and engineers), to ensure they are functioning within design criteria; and
- 1.5 Evaluate annually information for stock status, trends of metrics and special study results to determine if adaptive management approaches should be developed.

Supporting Narrative

The adult American Shad production target(s), which are based on accessible and potentially accessible spawning and nursery habitat area and future mixed age class spawning stock returns (within year), have been utilized in other recent American Shad plans and studies including the Roanoke River, Virginia (Harris and Hightower 2015); Susquehanna River, Maryland, Pennsylvania, New York (SRAFR 2010); Merrimack River, Massachusetts, New Hampshire (USFWS 2010); and Penobscot River, Maine (MDMR 2008). The CRASC Management Plan for River Herring in the Connecticut River Basin (2004) provides river surface areas in hectares (ha) for the main stem to determine habitat estimates for this Plan. CRASC biologists reduced the estimated available habitat from the River Herring Plan by 15% (or 852 ha) to account for the brackish water habitat in the lower Connecticut River, which is unsuitable spawning and nursery habitat for American Shad.

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This Plan has a minimum target annual adult return/production rate of 203 adults/ha for the main stem, derived from Connecticut River specific estimates for adult returns and composed of multiple age classes of both sexes to the river mouth in relation to available habitat. The highest estimated adult shad return to the river mouth (1992), when divided by the number of hectares of all available main stem habitat to Bellows Falls, Vermont yields a return/production of 203 adults/ha (Appendices E and I). This estimate likely underestimates the full return/production potential due to problems of reduced passage issues (up and downstream) that were known to exist at each dam. CRASC may increase the minimum adult production target values as improvements to habitat quantity and quality and fish passage occur in the future with pending hydropower relicensing opportunities and other advances in technologies and regulatory or partnering opportunities.

The adult return/production rate in identified tributaries was adjusted to 55% (111 adults/ha) of the main stem production and is consistent with tributary adult shad targets identified by each State agency. Research in the Delaware River supports the hypothesis that American Shad home to tributary spawning grounds (Hendricks et al. 2002) so we expect that the abundance of adults entering the Westfield and other rivers are largely independent of abundance trends in the main stem population. Adult production potential from tributaries can be inferred from shad passage counts at the West Springfield Fishway on the Westfield River, Massachusetts operating since 1996, that had a record high passage of 10,300 (2012) into an estimated 92 ha of habitat, yielding an estimate of 111 adults/ha.

Resilience based approaches to population management through actions that protect and promote diverse age structure, life histories, and habitat use will support Population, Fishery, and Ecological objectives identified in this Plan. A population maintained among many river segments and tributaries may have greater reproductive potential to buffer against negative impacts from environmental perturbations over space and time (Hillborn et al. 2003, Schindler et al. 2010). Likewise, diverse age structure and behavioral patterns within a population of migratory fish can help mitigate against stochastic or anthropomorphic effects and capitalize on ideal conditions for population recruitment (Kerr et al. 2010, Secor 2007).

The Connecticut River American Shad population is iteroparous, which has important implications for both population resilience and reproductive potential, as fish fecundity increases exponentially with fish size (Leggett and Carscaden 1978). The proportion of the annual spawning run determined to be repeat spawners has declined over time from a rate of 49% in the late 1950s, (Walburg and Nichols 1967; Limburg et al. 2003), to a mean of 5% for the period 2006-2015 (Appendix G). Factors leading to the decline of repeat spawners during recent decades are not fully understood. There are no historic data on the composition of repeat spawners prior to the presence of main stem barriers and therefore it is difficult to conclude the full impact of dams on the percentage of repeat spawners in the population. It is likely that the historic shad population was comprised of a more diverse age structure and a greater proportion of repeat spawners. However, observations and newly emerging study data have shown that post-spawn shad may not successfully pass downstream of dams, may be significantly delayed at dams, or may use turbines as a primary passage route. The population impact of these scenarios requires further study both at individual hydropower projects and all hydropower projects collectively (cumulative effects). Agency biologists remain focused on addressing any identified increased fish mortality associated with passing within, through or around dams, canals and hydroelectric stations and facilities (e.g., pumped storage facility). Other factors believed to influence the post-spawning survival include bioenergetic demands of migration, delays in migration, duration of migration, water

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temperature, and distance traveled (Castro-Santos and Letcher 2010). CRASC anticipates improved survival rates of post-spawn shad because of new structural and operational downstream passage measures at Holyoke Dam (2016), and supports future opportunities including hydropower relicensings, partnering or other mechanisms for passage improvements that address migratory delay and other associated project-attributed sources of increased mortality.

Achieving a minimum repeat spawner proportion of at least 15% for each sex as determined by season average from daily samples at Holyoke Fish Lift will help achieve the Plan Goal and Objectives. The mean percentage of repeat spawners for the period 1990-2000 was only slightly greater at 16%. The 15% minimum value in the Plan represents an approximate three-fold increase from the 2006-2015 mean (Appendix F). Addressing in-river sources of mortality that contribute to decreases in the ability of post-spawn adults to successfully migrate back to the ocean are a focus area for management improvements and has been an area of limited available information. In order to address these information gaps, main stem power companies as part of the FERC relicensing process, have recently completed several studies (in review process) which may be used adaptively for this Plan.

The CTDEEP's age structure analysis demonstrates a reduction of the age-6 cohort (males) and loss of older cohorts (both sexes) over recent decades (ASMFC 2007). This Plan seeks to increase representation of these older cohorts to provide reproductive and stock stability resilience in the event of unfavorable environmental conditions.

2. FISHERIES

- 2.1 Improve all aspects of adult shad passage at fishways and adult abundance in the upper basin to support recreational and commercial fisheries, as determined appropriate by the respective State agency and ASMFC; and
- 2.2 Provide access for shore and boat fishing anglers on the main stem and tributaries; develop information and outreach materials to promote these fishery opportunities as appropriate; and
- 2.3 Help ensure monitoring/data requirements for the ASMFC are obtained in a timely and cooperative manner to prevent fisheries closures; and
- 2.4 CRASC Commissioners and the Technical Committee members should maintain their active participation on the ASMFC American Shad and River Herring Management Board, the ASMFC's Technical Committee for those species in state jurisdictional waters. The New England and Mid-Atlantic Fishery Management Councils' activities should also be monitored as federal marine water management decisions could affect Connecticut River American Shad; and
- 2.5 Support the prohibition on mixed stock fisheries of American Shad.

Supporting Narrative

Fish passage at dams was a focus area for the joint state and federal Cooperative Fishery Restoration Program for the Connecticut River basin (1967), to address the restoration and expansion of fisheries. Significant progress on upstream passage came from the agencies' coordinated efforts that later evolved with the CRASC's formation. Under CRASC, measures to address downstream passage and steps to improve upon initial fishway designs and operations resulted in the expansion of shad fisheries into New Hampshire and Vermont (Appendix C). Fish passage technologies and research tools have advanced over time and continue to evolve with improving science and engineering, including evaluation of fish behavior and physiology. The Federal Energy Regulatory Commission's relicensing process at Turners Falls, Northfield Mountain Pump Storage Facility, Vernon Dam, and Bellows Falls projects offers opportunities to address identified issues that may negatively impact adult shad in and around projects

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and their fishways, and subsequently improve fisheries in upstream habitat. The use of new information on shad behavior, physiology, energetics in and around fishways, and related facility operations should be used to update passage measures and management objectives.

According to the ASMFC Interstate Fishery Management Plan for American Shad Management Amendment 3 (2010) a sustainable fishery must “*demonstrate their stock could support a commercial and/or recreational fishery that will not diminish the future stock reproduction and recruitment.*” Only the State of Connecticut and Massachusetts developed and submitted approved Sustainable Fishery Plans for the Connecticut River. The CRASC seeks to achieve a shad population with metrics of abundance and stock structure that will support the development of a Sustainable Fishery Plan as required by the ASMFC for the State of New Hampshire and inclusive of the State of Vermont, allowing recreational harvest. Adult shad passage counts to the habitat upstream of the Turners Falls and Vernon fishways have been variable over the long-term, but in the most recent five years consistent improvement has been demonstrated in the proportion of shad passing Vernon relative to Turners Falls Gatehouse Ladder (Appendix D). However, the agencies will need to document adult passage increases and other population metric objectives before considering the development of criteria for a Sustainable Fishery Plan for the upper basin (New Hampshire and Vermont). Defined target values for passage and other metrics in this Plan will serve as a measure of progress toward achieving the Plan Goal and Objectives.

Recreational fisheries in tributaries may require additional specific considerations. Ultimately, CRASC intends to have recreational fisheries with harvest in all Plan identified tributaries, consistent with Plan Goal and Objectives. The development of recreational fisheries in all basin states and their identified tributaries has the potential to provide extensive recreational opportunities.

American Shad recreational creel survey data had been annually collected for shad by CTDEEP for decades and are provided in reports to ASMFC and other agency publications. Estimated recreational catches for the lower river reached as high as 102,000 fish in 1992, which coincides with the highest estimated run size of 1.63 million fish to the mouth, and the Holyoke Fish Lift passage record of 720,000 shad (CTDEEP 2010). However, studies of recreational fisheries require considerable resources and have become a less common activity since 2000.

Commercial landings data for American Shad in the State of Connecticut began in 1887 with a maximum value of 519,862 kg in 1946 (Appendix G). Currently the only commercial harvest in the basin is a drift gill net fishery in the lower 48 km (30 miles) of the main stem river. In recent decades a decline in in-river commercial fishing effort and landings have been reported by CTDEEP that has been attributed to an aging group of netters with no new license entries (CTDEEP 2012).

The CRASC should continue to work cooperatively with the ASMFC in support of agency efforts to obtain fishery dependent information, including commercial and recreational catch and effort data for required monitoring and assessment purposes. Increased monitoring of small mesh offshore fisheries suggests that American Shad is encountered as bycatch. Support of improved monitoring of bycatch in marine fisheries where bycatch of shad could occur is necessary to evaluate potential management implications under changing marine and climate-related conditions, which are not well understood.

3. ECOLOGICAL

- 3.1 Evaluate and maximize the ecological contributions for all life-stages of shad on the Connecticut River ecosystem; and

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- 3.2 Identify and address impacts to shad habitat for all life stages and life history events, such as river discharge manipulations (e.g., frequency, magnitude, timing, and duration).

Supporting Narrative

The CRASC's Plan goals and objectives seek to restore the ecological roles of both adults and juvenile shad throughout their historic range in the basin, the estuary, and the marine environment. American Shad serve important ecological roles throughout their complex life history and life stages in these environments (Weiss-Glanz et al. 1986; ASMFC 2009; McDermott et al. 2015) (Table 1).

Table 1. Summary of types of ecological contributions made by shad life stage and location (habitat) with corresponding time periods.

Location	Lifestage	Ecological Services	Timing
Freshwater	Adult (prespawn - post spawn)	Prey item (bald eagle, osprey, larger predatory fishes); marine nutrient transfer	April - July
Freshwater	Early life stage to juvenile	Prey item (fishes and fish eating birds)	July - Nov
Estuarine	Juvenile	Prey item (fishes and fish eating birds)	Aug - Dec
Marine	Juvenile through adult	Prey item (fishes, birds, marine mammals)	Year-round

Barriers in the Connecticut River basin that exclude or restrict adults from accessing spawning habitat can reduce or eliminate the ecological roles of adult and subsequent juvenile life stages (Hall et al. 2012; Freeman et al. 2003). Adult shad also contribute marine derived nutrients to freshwater systems (Hanson et al. 2010). In addition, other hydropower operational concerns, such as peaking flows, outdated minimum flows requirements, diversion of flow (canals or pumped storage reservoir), or partial measure, interim protective measures may also negatively impact achieving ecological contributions. Therefore, achieving many strategies previously stated in this Plan for other Objectives will help meet Objective 3 pertaining to Ecological benefits and need not be repeated as strategies for this Objective.

The ecological benefits of restoring the American Shad run are not fully understood and more research will expand our knowledge. For example, there may be species of mussel that rely on upstream shad migration for dispersal or intricate trophic interactions with shad that are unknown. Understanding these relationships will help CRASC set appropriate objectives for future Plans and educate the public on the value of shad restoration.

4. MONITORING AND RESEARCH

- 4.1 Continue enumerating shad at all main stem dams and identified tributaries. Also continue to sample adult shad at the Holyoke Fish Lift to obtain sex specific measures and structures for age and spawning history; and
- 4.2 Continue monitoring juvenile production and explore the need, benefits, options to expand into unmonitored areas; and
- 4.3 Continue monitoring in-river commercial fisheries and explore options for recreational fisheries; and
- 4.4 Work with partners to identify and pursue identified research topics; and
- 4.5 Identify anthropogenic impacts that limit ecological contributions and develop corrective measures.

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Supporting Narrative

American Shad restoration and management requires regular monitoring of fishery dependent and independent metrics to determine population status and trends. Amendment 3 to the ASMFC Interstate Fishery Management Plan for American Shad Management (2010) describes required data for annual state compliance reports as well as data approved for Sustainable Fishery Management Plans. The member agencies of CRASC are responsible for the implementation of current monitoring activities and the means to implement them, as determined appropriate and feasible by each agency. CRASC serves an important coordination role in this regard and may develop new collaborative efforts or mechanisms to develop short-term capacity (e.g., grants). A list of priority annual monitoring information needs and status follow in Table 2.

Table 2. List of priority annual monitoring activities for American Shad in-river.

Activity	Agencies or other	Status
Fishway Counts (main stem and tributaries)	CTDEEP, MADFW, VTDFW, NHFG, Holyoke Gas and Electric, FirstLight Power	Ongoing
Biological sampling, run characterization (size, age, spawning history, by sex)	CTDEEP, from Holyoke Fish Lift	Ongoing
Juvenile Index (lower river)	CTDEEP	Ongoing
Juvenile Index (upper river)	State or federal	Not occurring
Commercial fishery monitoring (catch, effort, by sex, size, age structure)	CTDEEP	Ongoing
Recreational fishery monitoring (catch, effort, by sex, size, age structure)	State or federal	Not occurring

Improved monitoring of recreational fisheries should be considered for a future focal area of management. This type of survey data will aid in providing information on fishing effort, harvest, and biological data to support management decisions and program activities.

The CRASC Technical Committee should continue to assess current information and identify research needs on an annual basis. Determining the number of American Shad that enter the river annually remains a high research priority. Other research priorities include multiple FERC relicensing studies that will provide data on adult and juvenile migration patterns, interaction at dams, fishways, and the Northfield Mountain Pump Storage project (includes larval entrainment study), and passage under varying project operation and river conditions. Study results have started to become available (beginning in 2016) and will provide important information that will require additional review and consideration. The CRASC American Shad Status Report (2015) provides comprehensive details on both research and monitoring needs.

5. PUBLIC EDUCATION AND OUTREACH

- 5.1 Provide regular updates on fishway counts in the spring run period on the U.S. Fish and Wildlife Service Connecticut River Fish and Wildlife Conservation Office's (FWCO) web site, seek

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opportunities to share information with various media outlets, and promote shad as a natural resource; and

- 5.2 Develop information products for a variety of target audiences that communicates the diverse benefits of a restored shad population as defined by this Plan's goals and objectives.

Supporting Narrative

Providing current information on the status of American Shad and how this Plan is relevant to the public will help create and maintain support for management actions and an appreciation for the species. Public awareness on management and research activities and needs can be achieved from CRASC outreach efforts, including identifying principal contacts in each state and by agency. Interested public may be utilized as Citizen Scientists to assist in agency field sampling activities (for adults or juveniles) and other tasks that may be limited by available seasonal staff. The Connecticut River Fish and Wildlife Conservation Office maintains a web site, <https://www.fws.gov/r5csrc/>, that includes: CRASC and ASMFC plans and documents and web links, CRASC meeting minutes, contact information for CRASC announcements, in-season fishway fish counts updates and basin summary fishway counts, and the office's annual report that highlights a wide range of shad management and related activities. The CRASC will support and promote public viewing and educational opportunities at suitable fishways and provide input on messaging at various dams along the Connecticut River.

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Appendix A

A list of legal authorities and select agreements for American Shad management, restoration and related activities (e.g., fish passage) in the Connecticut River basin.

Legal Authorities

- The Fish and Wildlife Coordination Act 1934; as amended
- Federal Power Act 1920; as amended 1935, 1986
- Fish and Wildlife Act 1956
- Federal Aid in Fish Restoration Act 1950 (Dingell-Johnson Act); as amended
- Anadromous Fish Conservation Act 1965
- Clean Water Act 1972
- Connecticut River Atlantic Salmon Compact (Act) 1983
- Silvio Conte National Fish and Wildlife Refuge Act 1991
- State of New Hampshire General Laws, Title XVIII, Chapter 211, Section 211:8
- Commonwealth of Massachusetts, General Laws, Title XIX, Chapter 130,
- Connecticut Gen. Statutes Sec. 26, Chapter 493 and 494
- Connecticut Gen. Statutes Sec. 26-111
- Connecticut Gen. Statutes Sec. 26-115
- Connecticut Gen. Statutes Sec. 26-142(d)

Agreements

- 1967 Statement of Intent for a Cooperative Fishery Restoration Program for the Connecticut River Basin (State and Federal agency Directors; Policy Committee for Fisheries Management of the Connecticut River and Technical Committee)
- 1978 FERC Settlement Agreement(s), Upstream Fish Passage, (formerly New England Power Company and Western New England Power)
- 1990 Memorandum of Agreement(s), CRASC, Connecticut River Downstream Fish Passage, (formerly Northeast Utilities and New England Power Company)

Background on American Shad life history and biology.

American Shad is an anadromous fish species with a native range that extends from the St. Lawrence River, Canada, to the St. John's River, Florida with introductions and range expansion along the Northwest Pacific Coast. American Shad is considered in the marine environment to be pelagic and highly migratory, moving between summer feeding areas and overwintering areas (ASMFC 2009). Mature adults home back to natal rivers to spawn in freshwater habitat typically as males at age-4 and age-5 and as females at age-4 and age-5 for first time spawners. A latitudinal variation in the ability to spawn more than once (iteroparity) occurs from Cape Hatteras, North Carolina and northward, with rates in repeat spawners proportions generally increasing in that direction (Limberg et al. 2003). The spawning run typically last 2-3 months, with the Connecticut River stock entering the river between late March and early April, depending on the environmental conditions. River entry is often associated with river temperatures reaching ~10°C (50°F) (Leggett 1976).

American Shad is a broadcast spawner and eggs are initially semi-buoyant, becoming demersal and gradually sinking to the substrate. Connecticut River female fecundity has been determined to average 303,000 eggs with a standard deviation of 75,000 in a recent NOAA Fisheries study that also described the batch timing of egg maturation (McBride et al. 2016). In addition, the same NOAA study reported a mean of 6.7 batches (spawning frequency) for sampled females that averaged 45,950 eggs. Spawning activity is primarily nocturnal and has been documented occurring in shoal areas and in defined areas such as Windsor Locks (rkm 78), Wilson (rkm 74) and Rocky Hill (rkm 51)(Marcy 1976), but also has been noted as being more widely occurring among habitat types (ASMFC 2009). Other in-river spawning studies have been conducted between the Holyoke Dam and Turners Falls Dam, Massachusetts by the University of Massachusetts Amherst Cooperative Research Unit during the 1970s and 1980s. Recent relicensing study for the Turners Falls Dam/Project, including areas upstream to Vernon Dam, as well as from Vernon Dam to Bellows Falls Dam have been surveyed for spawning activity. American Shad spawn repeatedly, typically occurring in water temperatures ranging from 15 – 23°C, with eggs developing over time in relation to water temperature (ASMFC 2009). Egg development occurs in relation to water temperatures, with hatching in 14 - 20°C water taking approximately 3 days (Marcy 1976). Yolk sac larvae transition to first feeding larvae after a period of 4 - 7 days (water temperature dependent) at a size of 10 - 12mm (ASMFC 2009).

Juvenile shad may use a variety of habitats as they grow and feed on zooplankton and are also opportunistic users of other prey items (ASMFC 2009). The growth rate of juvenile shad has been shown to be consistently faster in upstream areas compared with downstream areas in the Connecticut River main stem and in comparison to the Farmington River (Marcy 1976). Juvenile outmigration has been reported to occur after a period of 80 days, which corresponded to a length of approximately 75mm (O'Donnell and Letcher). Decreasing water temperature has also been correlated with the peak juvenile outmigration, at the Holyoke Dam, initiating at 19°C and peaking from 14 - 9°C, and ending at 10 - 8°C in the study period (O'Leary and Kynard 1986). Information on American Shad in the marine environment is inherently more limited. Three main offshore overwintering areas have been described consisting of; 1) off of the Scotian Shelf/Bay of Fundy, 2) Middle Atlantic Bight, and 3) off the Florida Coast (Dadswell et al. 1987). Summer feeding areas contain mixed stocks that aggregate in the upper Bay of Fundy and Gulf of Maine, the St. Lawrence estuary, and off of Newfoundland and Labrador (Dadswell et al. 1987).

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Appendix C

Estimated number of American Shad entering the Connecticut River from CTDEEP 2010, and CTDEEP Annual Compliance Report to ASMFC (2016).

Year	Estimate	Year	Estimate
1966	695,000	1991	1,196,000
1967	637,000	1992	1,628,000
1968	410,000	1993	749,000
1969	591,000	1994	326,000
1970	488,000	1995	304,000
1971	583,000	1996	667,000
1972	485,000	1997	659,000
1973	613,000	1998	651,000
1974	372,000	1999	475,000
1975	598,000	2000	427,000
1976	740,000	2001	773,000
1977	323,000	2002	687,000
1978	710,670	2003	527,000
1979	632,820	2004	351,000
1980	759,420	2005	226,000
1981	909,270	2006	294,667
1982	939,330	2007	243,755
1983	1,574,000	2008	276,864
1984	1,231,000	2009	321,338
1985	728,000	2010	279,000
1986	748,000	2011	387,000
1987	588,000	2012	778,462
1988	648,000	2013	623,757
1989	979,000	2014	588,105
1990	816,000	2015	687,760

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Appendix D

Existing fishways for American Shad in the Connecticut River basin.

<u>Main stem (rkm)</u>	Project/Dam	Upstream Fishway Design	Status
139	Holyoke	Fish lift	Lifts new in 2004 and 2015 modifications driven by downstream passage requirements, evaluation studies planned for 2016
198	Turners Falls	Modified Ice Harbor and vertical slot	Long standing passage issues, study and modifications; Cabot Station Ladder, Spillway Ladder and Gatehouse Ladder (vertical slot), evaluation studies in 2015 (FERC relicensing)
228	Vernon	Modified Ice Harbor and vertical slot	Evaluation studies in 2015 (FERC relicensing)
280	Bellows Falls	Vertical slot	Historic upstream extent of distribution, with ladder in place, upstream passage is possible
<u>Tributary (name)</u>			
Mattabesset River	StanChem	Denil	First year operation 2013, not evaluated
Farmington River	Rainbow	Vertical slot	Long standing issues with shad passage, CTDEEP owned facility, new fish lift design pending, not evaluated
Westfield River	West Springfield	Denil	Not evaluated
Manhan River	Manhan	Denil	First year of operation 2014, not evaluated
Ashuelot River	Fiske Mill	Fish lift	Not evaluated, known issues with false attraction to tailwater

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Appendix E

Annual counts of American Shad recorded at upstream passage fishways on the main stem dams and select tributaries. No shad have been reported lifted at the Fisk Mill Dam, Ashuelot River, NH or passing the Manhan River, Easthampton, MA.

Year	Holyoke Dam Passed	Turners Falls Dam Passed	Vernon Dam Passed	Bellows Falls Dam Passed	Farmington River, Rainbow Dam Passed	Westfield River, W. Springfield Dam Passed
1955	4,900					
1956	7,700					
1957	8,800					
1958	5,700					
1959	15,000					
1960	15,000					
1961	23,000					
1962	21,000					
1963	31,000					
1964	35,000					
1965	34,000					
1966	16,000					
1967	19,000					
1968	25,000					
1969	45,000					
1970	66,000					
1971	53,000					
1972	26,000					
1973	25,000					
1974	53,000					
1975	111,000					
1976 ^A	346,725				1,189	
1977	202,997				804	
1978	145,136				1,053	
1979	255,753				514	
1980	376,066	298			480	
1981	377,124	200	97		167	
1982	294,842	11	9		737	
1983	528,185	12,705	2,597		1,565	
1984	496,884	4,333	335	1	2,289	
1985	487,158	3,855	833	0	1,042	
1986	352,122	17,858	982	0	1,206	
1987	276,835	18,959	3,459	39	792	
1988	294,158	15,787	1,370	24	378	
1989	354,180	9,511	2,953	*	215	
1990	363,725	27,908	10,894	0	432	
1991	523,153	54,656	37,197	65	591	
1992	721,764	60,089	31,155	103	793	
1993	340,431	10,221	3,652	2	460	

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Year	Holyoke Dam Passed	Turners Falls Dam Passed	Vernon Dam Passed	Bellows Falls Dam Passed	Farmington River, Rainbow Dam Passed	Westfield River, W. Springfield Dam Passed
1994	181,038	3,729	2,681	3	250	
1995	190,295	18,369	15,771	147	246	
1996	276,289	16,192	18,844	1	668	1,413
1997	299,448	9,216	7,384	46	421	1,012
1998	315,810	10,527	7,289	55	262	2,292
1999	193,780	6,751	5,097	110	70	2,668
2000	225,042	2,590	1,548	9	283	3,558
2001	273,206	1,540	1,744	**	153	4,720
2002	374,534	2,870	356	**	110	2,762
2003	286,814	--	268	*	76	1,957
2004	191,555	2,192	653	**	123	913
2005	116,511	1,581	167	3	8	1,237
2006	154,745	1,810	133	0	73	1,534
2007	158,807	2,248	65	0	156	4,497
2008	153,109	4,000	271	0	89	3,212
2009	160,649	3,813	16	0	35	1,395
2010	164,439	16,422	290	0	548	3,449
2011	244,177	16,798	46	1	267	5,029
2012	490,431	26,727	10,386	0	174	10,300
2013	392,967	35,293	18,220	0	84	4,900
2014	370,506	39,914	27,706	0	536	4,787
2015	412,656	58,079	39,771	44	316	3,383
2016	385,930	54,069	35,732	1,973 ^B	141	5,940
Mean	310,975 ^A	15,864	8,055	-	483	3,379
standard deviation	130,295	17,691	11,951	-	472	2,193
minimum	116,511	11	9	-	8	913
maximum	721,764	60,089	39,771	-	2,289	10,300

^A Holyoke shad passage summary statistics only for the period 1976-2016

* Ladder not operated

** No fish count monitoring

^B Bellows Falls is the historic upstream extent of the species range. The Bellows Falls Project fish ladder was, by agreement, operationally triggered on Atlantic Salmon upstream passage needs, so its period of operation was often limited/restricted in the past. In many years no shad were observed passing at this facility. Beginning in 2013, TransCanada agreed to open this ladder based on a trigger of 100 Sea Lamprey passed at Vernon Dam providing an opportunity for upstream habitat access.

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Appendix F

Connecticut Department of Energy and Environmental Protection, Marine Fisheries Division, Juvenile Alosine Seine Survey data for the period 1978-2015. The reported index value is a geometric mean catch of juvenile American Shad from all stations and all dates, annually. Seven sites from Holyoke, MA, to Essex, CT are sampled weekly from mid-July through mid-October.

Year	Index	Year	Index
1978	5.9	1997	6.8
1979	7.8	1998	3.7
1980	9.2	1999	5.5
1981	6.1	2000	4.4
1982	1.8	2001	2.7
1983	5.0	2002	5.6
1984	3.4	2003	6.9
1985	7.1	2004	5.6
1986	6.3	2005	10.1
1987	9.9	2006	1.8
1988	5.7	2007	8.2
1989	4.9	2008	5.1
1990	10.4	2009	3.4
1991	3.9	2010	10.2
1992	7.2	2011	3.1
1993	9.5	2012	3.0
1994	12.2	2013	3.2
1995	1.3	2014	8.0
1996	6.5	2015	8.5

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Appendix G

Connecticut Department of Energy and Environmental Protection, Marine Fisheries Division, proportion of adult American Shad repeat spawners from sample sources transitioning from lower river gillnet (1960s) to primarily Holyoke Fish Lift (1990s-2000s). Data from CTDEEP 2010 and from subsequent annual Compliance reports to the Atlantic States Marine Fisheries Commission.

Year	Repeat	Year	Repeat
1966	0.53	1991	0.15
1967	0.53	1992	0.08
1968	0.34	1993	0.16
1969	0.38	1994	0.39
1970	0.39	1995	0.20
1971	0.45	1996	0.14
1972	0.41	1997	0.12
1973	0.44	1998	0.15
1974	0.22	1999	0.08
1975	0.24	2000	0.15
1976	0.26	2001	0.21
1977	0.10	2002	0.22
1978	0.24	2003	0.05
1979	0.18	2004	0.11
1980	0.19	2005	0.11
1981	0.11	2006	0.02
1982	0.15	2007	0.07
1983	0.20	2008	0.02
1984	0.27	2009	0.05
1985	0.23	2010	0.07
1986	0.21	2011	0.09
1987	0.44	2012	0.04
1988	0.15	2013	0.10
1989	0.21	2014	0.03
1990	0.17	2015	0.02

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Appendix H

Annual commercial landings (in kilograms) of American Shad for Connecticut (NOAA Commercial statistics).

Year	kg	Year	kg	Year	kg
1887	152,861	1930	24,494	1973	116,845
1888	127,913	1931	34,019	1974	112,128
1889	88,904	1932	31,751	1975	75,070
1890	54,431	1933	60,328	1976	177,808
1891	35,380	1934	238,136	1977	150,774
1892	28,576	1935	182,798	1978	138,935
1893	64,864	1936	174,633	1979	93,803
1894	114,305	1937	173,726	1980	140,840
1895	98,883	1938	193,684	1981	147,281
1896	118,388	1939	185,519	1982	128,367
1897	116,120	1940	163,293	1983	193,230
1898	226,343	1941	198,673	1984	180,963
1899	150,139	1942	169,190	1985	182,344
1900	222,260	1943	250,837	1986	146,488
1901	196,859	1944	338,833	1987	151,454
1902	217,724	1945	349,992	1988	85,956
1903	279,413	1946	519,862	1989	82,679
1904	273,516	1947	359,563	1990	119,066
1905	219,992	1948	281,953	1991	68,166
1906	114,759	1949	213,506	1992	65,614
1907	61,689	1950	119,522	1993	43,954
1908	55,338	1951	153,314	1994	48,022
1909	55,338	1952	215,048	1995	27,958
1910	44,452	1953	163,021	1996	66,299
1911	43,545	1954	133,991	1997	85,121
1912	95,254	1955	95,345	1998	82,663
1913	83,461	1956	89,222	1999	65,426
1914	92,079	1957	149,050	2000	98,532
1915	67,132	1958	206,974	2001	26,868
1916	83,461	1959	181,800	2002	49,033
1917	102,512	1960	181,392	2003	50,406
1918	109,316	1961	210,195	2004	30,081
1919	210,013	1962	206,747	2005	31,444
1920	79,832	1963	136,441	2006	17,482
1921	32,659	1964	125,963	2007	23,389
1922	21,319	1965	159,755	2008	12,888
1923	20,865	1966	109,724	2009	12,611
1924	40,370	1967	108,862	2010	11,187
1925	66,224	1968	96,343	2011	12,133
1926	50,349	1969	86,137	2012	19,712
1927	54,431	1970	78,517	2013	18,453
1928	90,265	1971	109,180	2014	15,473
1929	144,242	1972	113,035	2015	23,135

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Appendix I

Summary of estimated habitat

Table A. The estimated spawning and rearing habitat for American Shad by river segment in relation to estimated adult shad production/return potential, and minimum target fish passage numbers by barrier.

Reach	m ²	Ha	Adjustment	Ha	% of total	Adult Shad Return/Production (203 and 111 settings by habitat)	Project	Minimum target number
Main stem - mouth to Holyoke	56,766,060	5,677	0.85	4,825	54.8	979,498		
tributaries (5)		424		424	4.8	47,064		
Main stem - Holyoke to Turners Falls	13,688,717	1,369		1,369	15.5	277,881	Holyoke Fish Lift - passage	687,088
tributaries (2)		109		109	1.2	12,099		
Main stem - Turners to Vernon	7,620,241	762		762	8.7	154,691	Turners Falls Project - passage	397,108
tributaries* (1)		139		139	1.6	15,429		
Main stem - Vernon to Bellows Falls	10,421,641	1,042		1,042	11.8	211,559	Vernon Ladder - passage	226,988
tributary (1)		139		139	1.6	15,429		
Totals		9,661		8,809	100.00	1,713,651		

*Millers River habitat area undefined

Table B. The estimated spawning and rearing habitat for American Shad, by tributary in relation to estimated adult shad production/return potential.

Tributary	Total rkm	Area (est) ha	Adult Shad Return/Production
Mattabesset, CT	36.3	54.5	6,044
Farmington, CT	60.3	211.1	23,427
Pequabuck, CT	12.4	9.9	1,101
Scantic, CT	22.4	31.4	3,481
Westfield, MA	29.4	117.6	13,054
Chicopee, MA ^A		T.B.D.	
Manhan, MA	23.0	23.0	2,553
Deerfield, MA	21.5	86.0	9,546
Millers, MA ^B		T.B.D.	
Ashuelot, NH	60.0	139.0	15,429
West, VT	31.0	139.5	15,485
			90,119
^A - First dam is ~ 1 rkm from confluence with numerous subsequent dams			
^B - Relatively high gradient tributary, more data required			

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CRASC Connecticut River American Shad Management Plan Addendum – Fish Passage Performance (approved February 28, 2020)

Introduction

This Addendum provides American Shad passage performance criteria in support of achieving the goal and objectives of the Connecticut River Atlantic Salmon Commission's (CRASC) Connecticut River American Shad Management Plan (Plan). The Plan, approved in 2017, identified the following three broad objectives for fish passage:

- 1.5 *Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post-spawn adults, and juveniles; and*
- 1.6 *Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency, and delay at these three life stages, as suitable information is available, to support other objectives of this Plan; and*
- 1.7 *Establish downstream performance measures, for adult and juvenile life stages that maximize survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan.*

The state and federal fishery management agencies, through their individual and cooperative authorities (CRASC and ASMFC), are committed to restoring American Shad in the Connecticut River basin, and achieving the Management Plan's goal and objectives. Those goals and objectives are dependent on having safe, effective and timely fish passage for both adult and juvenile American Shad at in-river barriers. Defining fish passage criteria for what is safe, timely and effective is necessary in order to evaluate and manage progress towards these goals and objectives. A FERC Environmental Assessment for the American Tissue Project (2018^A) stated, "*Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities...Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and determining whether effectiveness testing would or would not provide benefits to alosines....*" (FERC 2018^A).

Effectiveness is ultimately the result of both safety and timeliness. Ideally, for a facility/project to have zero effect on migrating fish, 100% of fish that arrive at the station would pass with no delay, injury, or mortality. Here, we attempt to provide realistically achievable performance measures that balance regulatory objectives with feasible monitoring methods.

The following are the Fish Passage Performance Criteria or Objectives for both adult (upstream and downstream) and juvenile (downstream) American Shad for hydroelectric projects in the Connecticut River basin:

1. Upstream adult passage minimum efficiency rate is **75%**, based on the number of shad that approach within 1 kilometer of a project area^A and/or passage barrier. Passage efficiency is $[(\# \text{ passed} / \# \text{ arrived}) * 100]$;

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2. Upstream adult passage time-to-pass (1 kilometer threshold) is **48 hours or less** based on fish that are passed (requires achieving Objective #1);
3. Downstream adult and juvenile project passage minimum efficiency and survival rates are each **95%**, based on the number of shad that approach within 1 kilometer of a project area^A and/or passage barrier and the number that are determined alive post passage (not less than 48 hours evaluation). Passage efficiency is $[(\# \text{ passed} / \# \text{ arrived}) * 100]$ and passage survival is $[(\# \text{ alive downstream of project} / \# \text{ passed}) * 100]$.
4. Downstream adult and juvenile time-to-pass is **24 hours or less**, for those fish entering the project area^A.

^A – Project area shall be defined as comprising the river within 1 km of the up- and downstream extent of a hydropower facility and its footprint components. Where a powerhouse is separated from a dam, e.g. by a power canal, this will also include any bypassed reach of the river. The applied definition for 1 km threshold, in cases whereby a bypassed river reach exists (with regulated/alterd flows) from the development and use of a power canal system, by hydropower operators. In such cases, the location of the dam proper may be several kilometers upstream of the terminus of the power canal system. For upstream passage, the terminus of the power canal and any associated hydropower facility will be the approach basis for the 1 km project area, not the dam. Alternately, for downstream passage, the dam and gatehouse will serve as the basis for the 1 km project approach area, not the generation facilities in the power canal.

Strategies

The efficacy of any fish passage structure, device, facility, operation, or measure depends on a variety of factors including site-specific considerations. The information provided below serves as generic guidance and is not intended to categorically replace site-specific recommendations, limitations, or protocols

The morphology, swimming capability, behavior, and life history of American Shad create challenges for upstream and downstream passage through engineered fishways. The following strategies and best practices provide guidance for the design and operation of efficient fishways for American Shad.

1. Proposed new, and/or modifications to existing, fish passage facilities and any related project operations, should meet or exceed design criteria detailed in the USFWS Fish Passage Engineering Criteria Manual (2017) or its most current version. Proposed variations from USFWS Criteria Manual in either proposed new structures and/or modification to existing structures/operations will require consultation with the federal fish passage engineers (NOAA and/or USFWS). The FERC (2018^B) in its own analyses has stated, “...*designing the upstream anadromous fish passage facility consistent with FWS’s 2017 Design Criteria Manual and in consultation with the resource agencies as stipulated by Interior’s and NMFS’s fishway prescriptions would help guide the design process and ensure the upstream fishway is likely to be effective in timely passing any adult salmon returning to the base of the project’s dam upstream...*”

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2. General Movement

- A. Entrances. Fishways, by necessity, are (relative to the size of the river) narrow pathways that fish must discover. When reaching a stream barrier, shad, in general, do not explore to the degree salmonids do (Larinier and Travade, 2002). Multiple entrances may be necessary where flow conditions are diverse, the river is wide, or sources of false attraction are longitudinally separated (e.g., a bypassed reach between spillway and powerhouse discharge).
- B. Space. Shad move in schools and only reluctantly move as individuals (Larinier and Travade, 2002). Fishways should be as wide as possible to allow the migrants to efficiently move in as a group.
- C. Turns. Shad exhibit rheotaxis and align to the flow field. Shad in particular seem hindered by diverse and shifting flow fields. To the extent possible, fishway designs should ensure that anthropogenic structures do not create large-scale eddies, which can confuse shad and delay passage. Within fishways, sharp turns greater than 90 degrees should be avoided; where necessary, 180-degree turns can be accomplished with two 90-degree turns separated by a sufficient distance.

3. Hydraulic Structures

- A. Orifices. While shad may move through much of the water column, they are typically reluctant to move through submerged orifices. Managers, designers and operators should not expect shad to move through orifices in the weir walls of pool-type fishways (orifices are generally used to drain and maintain hydraulic conditions). Fishway entrance and exit gates should not be operated in an orifice condition; gate lips should be maintained above the waterline during passage season.
- B. Vertical Slots. Shad are reluctant to move through constrictions as individuals, but will do so slowly (compared to salmonids). To promote movement and ensure the opening is wide enough to limit abrasion injuries on concrete walls, the slots for a vertical slot fishway should be no less than 18 inches wide (USFWS 2019).
- C. Denil Baffles. Standard Denil baffles are typically built in 2-foot, 3-foot, and 4-foot widths depending on site constraints, hydrology, population size, and species. Given the shad's reluctance to move individually, and its hesitancy to navigate tighter flow constrictions, Denil fishways for shad should be 4-feet wide (USFWS 2019).
- D. Upstream Fishway Weirs. Shad do not leap like salmonids; accordingly, the nappe of flow over a weir should be non-aerated and submerged (i.e., the water surface on the downstream side should be level with, or above, the weir crest). Additionally, the jet of flow over the weir should produce streaming conditions rather than plunging conditions (USFWS 2019); this promotes a forward roller (i.e., hydraulic) in the downstream pool. An optimal depth of flow over the weir crest is typically in the range of 12 to 18 inches, depending on other conditions.
- E. Downstream Bypass Weirs. Negative rheotaxis guides downstream migrants (adults and juveniles) to the accelerating flow over a weir. However, rapid spatial accelerations (i.e., large changes in velocities over short distances) can spook shad leading the fish to reject the bypass. For this reason, a broad-crested weir is preferable. Bypasses should not approximate a sharp-crested weir (e.g., simple weir boards), if possible. A uniform acceleration weir (UAW) is ideal; UAWs have been shown to moderate this rejection behavior in shad by slowly accelerating the

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flow as it moves over the bypass (Haro et al. 1998). Weirs should be at least 3-feet wide and maintain 2 feet of depth at all times.

- F. Turbine Intakes Racks. Racks or screens should have a 1-inch clear spacing or less. This promotes a behavioral avoidance reaction in adult shad that reduces entrainment and impingement. If feasible, racks should be built at a 45° degree angle to the approach (free stream) velocity and lead to a downstream bypass. This arrangement promotes a sweeping flow (leading to the bypass) that encourages the animal to seek its own escape route. The normal velocity (i.e., velocity measured perpendicular to the plane of the rack) should be maintained at 2 fps or less, measured 1 foot in front of the rack (USFWS 2019).

4. Flow Characteristics

- A. Water Velocity. Shad can sustain burst speeds of 10.2 to 15.4 fps for 6 to 7 seconds. Shad in a 98 foot long flume with velocities ranging from 11.5 fps to 13.6 fps could not reach the end of the flume (Theodore Castro-Santos, personal communication). In general, velocities greater than 6 fps maintained for extended distances can prove challenging (Larinier and Travade, 2002). To limit fatigue, in pools, flumes, and channels, water velocities should be maintained in the 1 to 2 fps range. Localized (short distance) higher velocity regions are necessary to promote movement or attraction: 3 to 5 fps is typical over weir crests; 5 to 6 fps is common through vertical slots; and 4 to 6 fps at fishway entrances has been shown to promote attraction and entry for the suite of anadromous fish on the Connecticut River. For dedicated shad fishways (i.e., where the passage of smaller, weaker fish is neither critical nor desirable), localized entrance velocities of up to 8 fps may be effective.
- B. Turbulence and Air Entrainment. Minimizing turbulence and associated air entrainment is generally considered advantageous in the design of fish passage facilities (Towler et al. 2015). Volumetric energy dissipation correlates to the phenomena of turbulence and aeration in fishways. For shad-specific pool-type fishways, the pool size and flow rate should be designed and operated to limit the dissipation rate to 3.15 ft-lbf/s/ft³ (USFWS 2019; Towler et al. 2015).
- C. Depth of Flow. To promote movement in shoals, fishway pools, exit flumes and entrance channels should maintain a depth of 4 feet at all times (Turek et al. 2016). Note: this does not apply to smaller shad fishways such as the 4-foot wide Denil. To provide sufficient depth for shad to swim normally, the depth of flow should be greater than or equal to two times the largest adult's body depth at all times (USFWS 2019). At fishway entrances, gates and weir boards are used to vertically constrict depth and accelerate flow; however, excessive constrictions may adversely affect entry rates. Denil entrances should always maintain a minimum of 2 feet of depth above the channel invert, gate lip, or weir boards. At large fishways designed to pass American shad, entrances should maintain 3.0 feet of submergence (Mulligan et al., 2018). Submergence depth is calculated as the vertical distance between the tailwater and crest of the entrance gate.

5. Other Considerations

- A. Light and Shadow. Shad are sensitive to sudden changes in light. Generally, fishways should remain uncovered, or covered by grating that allows natural light on the water surface. Where covered and underground sections of fishway are necessary, lighting should be provided (Larinier and Travade, 2002).

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- B. Sounds. American shad have particularly acute hearing. Experience suggests they can be easily stressed by sudden noise (e.g., crowder gate cycling) or influenced by persistent mechanical sound (e.g., powerhouse). To the extent feasible, efforts should be taken to limit artificial sound in, or near, a fishway.
- C. Mechanical and Structural Hazards. Shad often move along walls and in great numbers (Larinier and Travade, 2002). Protuberances, obstacles and moving mechanisms in the fishway can be injurious. Such features should be removed or covered where possible. Vestigial hardware (e.g., bolts, rebar, and antenna connections) on walls should be removed or ground off. Exposed cables in traps should be sheathed in HDPE pipe or hose (or equivalent). Gaps on the sides of gates at counting facilities should be covered with rubber skirts.

Supporting Narrative

Numerous published and unpublished studies have documented American Shad passage and movements in the Connecticut River basin, particularly on the main stem. The recent peer-reviewed publication “A dam passage performance standard model for American Shad” (Stich et al. 2018) utilized a stochastic life-history based model *“to estimate effects of dam passage and migratory delay on abundance, spatial distribution or spawning adults, and demographic structuring in space and time.”* Stich et al. (2018) provides details of the model design, parameters, inputs and R code scripts. The FERC (2004) has concluded, *“...it is important to recognize the significance of modeling tools for assessing fish passage improvements at multiple projects in a river basin. Considering fish passage effectiveness from this level of analysis provides a meaningful approach because cumulative benefits of fish passage and all other restoration measures in the basin can be assessed.”*

For this Addendum, the Stich et al. American Shad Passage Model was programed to run a suite of passage settings specific to the Connecticut River to help inform criteria development based on four model run outputs and the CRASC Management Plan goal and objectives. For each of the three main stem dams (Holyoke, Turners Falls, and Vernon), upstream passage efficiencies were run at 55%, 65%, and 75%. This rate is based on the number of fish that reach within 1 km of the “project”. Time to pass upstream on individual fish arrival was run at 24, 48 and 72 hours. Downstream passage efficiency and survival at the three projects were run at 75%, 85% and 95% (model uses same value for adult and juvenile). Northfield Mountain Pumped Storage, for only juvenile downstream passage efficiencies and survival, were run at 75%, 85%, and 95%. Outputs of the model, that relate to the Plan include; 1) abundance at river mouth, 2) abundance upstream of Turners Falls Dam, 3) abundance upstream of Vernon Dam, and 4) proportion of repeat spawners ($\geq$ age-6). The first model run for “abundance at river mouth” suggested that if managers were only concerned with achieving that minimum target, with no concern for “upper” basin distribution, limiting upstream access could yield the minimum target to the river mouth, but notably only with downstream passage and survival $\geq$ 95%. However, the Plan intends to achieve multiple abundance objectives that reduces the priority of a single target. The second model run examined outputs for shad abundance upstream of Turners Falls, exceeding minimum Plan targets for all three upstream passage rates, with the highest outcomes again tied to 95% downstream passage efficiency and survival and highest upstream passage outputs tied to shortest time to pass (24 hours). The third model run examined abundance upstream of Vernon Dam, exceeding Plan minimum targets for all three upstream passage rates, with the highest outcomes also tied to 95% downstream passage efficiency and survival and upstream passage occurring in a tiered manner (highest outputs are for shortest time to pass [24 hours]). The fourth model run examined outputs for repeat

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spawner component (age-6) at the river mouth, demonstrating a consistent increasing trend in repeats from incrementally improved downstream passage efficiencies and survival (95% highest).

The American Shad Passage Model is one tool for managers to assess the function of fish passage and protection measures required at hydroelectric facilities on the Connecticut River. Results of the Connecticut River model runs are consistent with the findings in Stich et al. (2018), for the multi-dammed Penobscot River. The published article by Stich et al. (2018) and the model run specific to the Connecticut River highlight the importance of high downstream passage efficiency/survival (95%) for adults and juveniles in order to realize actual population gains by providing access upstream at successive dams and maintain a substantial repeat spawner component. Downstream passage was consistently important in all four Connecticut River model run outputs. For upstream passage efficiency rates, abundance outputs were also consistently maximized with shorter time to pass (24 hours), for abundance levels upstream of Turners Falls and Vernon dams.

Downstream passage of adult as well as juvenile shad are a concern in the Connecticut River basin from the perspective of cumulative effects, whereby seemingly modest levels of loss at one hydropower project (e.g., 10-15%) can be compounded at subsequent projects to greater levels affecting both ecological contributions of juveniles and adults, future abundance and population structure/dynamics. Repeat spawner females have an exponential increase in fecundity resulting in substantially greater reproductive potential than smaller virgin females. Given this, a return to >30% repeat spawners for this population has the potential to substantially increase the reproductive potential of the current high proportion of “virgin” female component currently observed in the Connecticut River, while at the same time creating population resilience or buffer against poor recruitment years. Having an age structured population comprised of a substantial proportion of fish age-6 to age-9 will help achieve the Plan’s goals and objectives, but is requisite on managing anthropogenic sources of mortality, such as turbine passage impacts. In addition, recent assessment work has demonstrated density-dependent effects on juvenile shad growth and condition in the Holyoke to Turners Falls reach in contrast to the Vernon to Bellows Falls reach (Mattocks et al. 2019). Management actions that result in a better distribution of juvenile densities will improve juvenile growth and condition. These data further support the complementary need of having high passage efficiency and survival rates for adults (up and down), and juveniles to mitigate for repeated turbine/facility exposures to access and utilize historic upstream habitats.

The question of whether a new hydroelectric project can impact (type and extent) an existing American Shad population has been studied on the Annapolis River, Nova Scotia, Canada. A tidal dam across the Annapolis River was created in 1983 with a spillway/tide gate. A power station with a 7.6 meter (m) diameter turbine, operating at 50 RPMs, under a head range of 1.4 – 6.8 m has operated since 1984 with only upstream passage in place. Dadswell et al. (2018) utilized pre-hydropower fish assessment data for American Shad and other species, to document population impacts largely attributed to this hydropower facility. The researchers provide data demonstrating declines in American Shad adult lengths, mass, age, and percent repeat spawner with a corresponding increase in total annual adult mortality. The authors state that *“these significant changes were largely due to turbine mortality of adult A. Sapidissima during post-spawning outmigration. The tidal turbine is apparently removing larger older adults from the population because they have a higher probability of strike and have passed through the turbine repeatedly during successive, annual spawning runs.”* On the Connecticut River this situation is analogous with repeated successive dam/power stations. The researchers note acoustically tagged adult shad passed via the Annapolis Station turbine had a reported mortality rate of 46.3 (±34.7)% in 1985 and 21.3 (±15.2)% in 1986. Based on adult shad size (400-600mm) the authors note a

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probable blade strike of between 12.5 and 18.7% [rates similar to many estimates for Connecticut River basin turbines].

Adult shad that successfully pass Vernon Dam have access to the most upstream historic extent of their habitat but must later negotiate three main stem barriers on their post-spawn outmigration. For these fish an 85% downstream passage efficiency/survival rate at each project, results in only 61% of the starting number. However, with the exclusion of adult shad from turbine passage and/or other routes of additive project mortality, to achieve a through project target efficiency/survival rate of 95% at each project, the resultant outcome is 86% of the starting number. Thus, a 10% improvement in passage efficiency/survival translates to a 25% increase in bypassed fish to the lower river from this habitat.

Hydroelectric plants dramatically influence the flow fields in a river upstream and downstream of the project. Turbine discharge typically serves as the significant and persistent source of far-field attraction to migrating fish above and below dams. In the context of downstream passage of American shad, turbine passage is hazardous to both juveniles and post-spawn adults; entrainment should generally be avoided. Adult shad are relatively large fish, with females being larger than males (at age and in the annual run composition) and therefore more susceptible to blade strike (Figure 1). The conventional mitigation strategy is to install a dedicated downstream fishway that allows out-migrating juveniles and post-spawn adults to safely bypass the turbines. The efficacy of the bypass depends, in turn, on the same flow fields created by the turbines and any fish guidance structure including how fish are conveyed to a receiving waters and the associated concerns with that process and the receiving pool (USFWS 2019).

Where the efficacy of a downstream bypass is low (or the bypass is non-existent), careful analysis of the mortality of fish entrained through turbines should be made. Field studies (e.g., mark-recapture, balloon-tags) that empirically measure survival of entrained fish are preferred. Moreover, site-specific studies are recommended; extrapolating total entrainment rates from samples of other species or from other sites may be less precise (FERC 1995). Where field studies are impractical, infeasible, or cost prohibitive, desktop analyses may prove useful predictive tools.

Numerous desktop techniques have been documented and generally fall into one of two categories: empirically derived regression equations and fundamental methods that relate fish physiology and turbine physics. The so-called Von Raben method and Franke method are examples of the latter type. Both methods yield equations that predict the probability of blade strike depending largely on turbine geometry and fish length (Franke et al. 1997). The Franke method, an extrapolation and improvement upon Von Raben approach, is the preferred fundamental desktop analyses method. The CRASC recommends the following best practices:

- the Franke method should only be used for Francis, Kaplan, and fixed propeller turbines;
- where possible, use engineering drawings (rather than reports) to determine the inlet and outlet diameters on a Francis turbine;
- in the absence of better information, assume mid-blade paths for fish moving through Kaplan and fixed propeller turbines;
- where accurate turbine efficiency curves for a site are not available, typical turbine efficiency curves can be used and, perhaps, discounted depending on the condition of the runner;

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- care should be taken in selecting a value of the mortality correction factor or correlation coefficient, Lambda; unless Lambda has been calibrated, a conservative value of 0.2 is recommended.

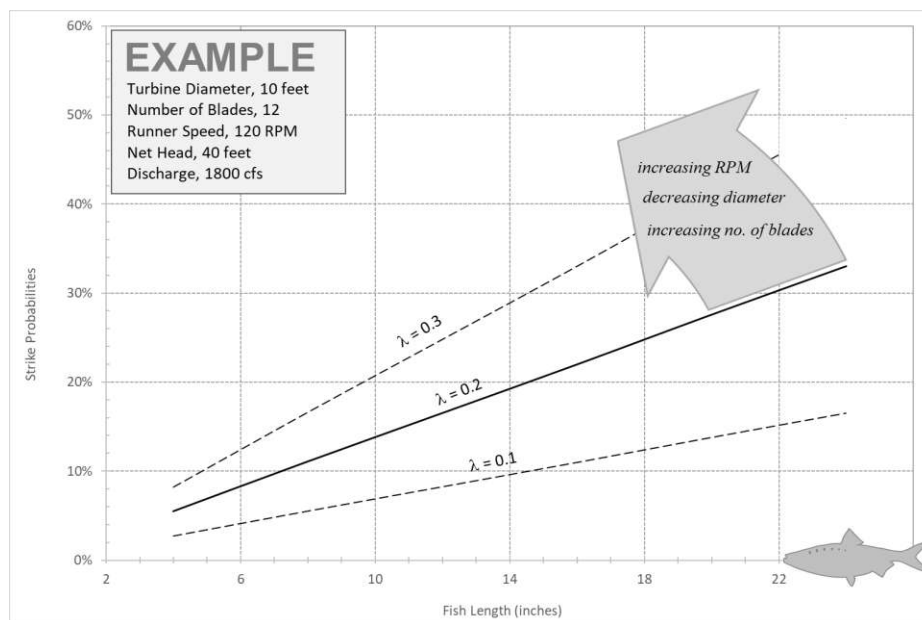


Figure 1. Blade strike probabilities for an example turbine in relation to selected Lambda and responses to increases in turbine RPM, fish length, decreases in turbine diameter, and increases in number of turbine blades.

While the appeal of desktop methods is clear, their application can be computationally complex and is best suited for a spreadsheet solution. To facilitate this, in 2018 the USFWS developed a computer implementation of the Franke method for Microsoft Excel™. This model is a probabilistic Excel-based, VBA application of the methods outlined in INEL's "Development of Environmentally Advanced Hydropower Turbine System Design Concepts" by G. Franke et al. (1997) for evaluating fish mortalities due to turbine entrainment. This model, provided "as is" and without warranty of any kind, is available for download from:

www.fws.gov/northeast/fisheries/fishpassageengineering.html

Juvenile shad mortality based on blade strike model probabilities have shown consistency for short-term (24 hr) mortality with field studies at several hydroelectric projects using balloon tagged juveniles passed through turbines, in a peer-reviewed study design (Heisey et al. 1992). However, juvenile fish field studies have been unable to quantify long-term delayed mortality that may occur from injuries (injury rates are often quantified in study recovered juveniles). The difficulty in retaining control fish for >48 hours is the cause of the issue, resulting in only immediate mortality estimates in recent study results.

Adult shad mortality, based on turbine blade strike model probabilities are increased greatly based on the size of the fish, as noted earlier (Figure 1). Unlike juvenile shad, the ability to use balloon tag methods and pass post spawn shad through turbines has not been successful, attributed to the reduced condition of fish having spent 4-6 weeks in-river without feeding and elevated water temperatures. In recent years, radio tags that can be programed to switch burst signal frequency, based on an internal

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ball bearing movement or lack of movement, has been used to assess mortality. However, several important limiting considerations with this tag type for analyses of “turbine” passed adult shad must be recognized. First, these tags must be programmed for a period of “inactivity” before the tag signal switches from (as an example) an interval of 3 seconds to an interval of 10 seconds. This trigger period has often been set to 24 hours that leads to a complete lack of credibility for a “live signal” following turbine passage, for at least the first 24 hours in the case of immediate mortality. Second, dead fish drift has been studied and documented, including on the Connecticut River with dead radio-tagged adult American Shad, directly inserted into the Holyoke Dam Hadley Falls Station turbine intakes. Bell and Kynard (1985) demonstrated dead turbine-passed adult shad, passed through Hadley Falls Station, drifted between 0.6 and 1.3 km downstream of the project in less than 24 hours of mobile radio tracking. Havin et al. (2017) also provides study results on the drift of dead salmon smolts (2.4 km) and eels (up to 30.1 km). Third, recognizing that dead fish drift, there is the potential that dead tagged individuals will not trigger the mortality switch and/or may alternate between a live signal and mortality signals in areas where drift/movement occurs (e.g., the tailrace of generating turbines).

Castro-Santos et al (2016) determined upstream passage efficiency rates for adult shad using radiotagged fish in 2011 and 2012 from the river mouth to the Holyoke Dam and its two fish lift fishway system (Castro-Santos et al. 2016). These researchers capture and dual tagged American Shad with a radio tag and a PIT tag alone, allowing adjustments for radio tag shedding. Study methods also included deploying a number of stationary radio receivers along the main stem river and also in and around the Holyoke Dam. A PIT reader and antennas were deployed at the Holyoke Fish Lift to document a passed shad. Study results using a Cormack Jolly Seber analyses determined arrival rates ($\pm$ standard error) of tagged shad to Holyoke Dam as $80.5 \pm 6.5\%$ (2011) and $77.1 \pm 7.6\%$ (2012). Passage rates of tagged fish that arrived were $73.8 \pm 7.0\%$ (2011) and $75.8 \pm 6.6\%$ (2012).

The Vernon Dam fish ladder’s passage efficiency also provides a basis for upstream passage efficiency criteria based on the number of shad counted passing at the Turners Falls gatehouse ladder. Since 2012, when USFWS fish passage engineers identified and fixed within ladder passage issues, annual shad passage counts have provided useful, consistent data on passage with a functioning fishway (Table 1). A 2011 radio telemetry study using American Shad tagged and released into the Turners Falls Power Canal, from the exit of the Cabot Station Fish Ladder, provided a least biased estimate (reduced handling/tagging effects with only viable fish passing through Gatehouse) to more accurately determine the proportion of the shad passing Gatehouse that reach the Vernon Dam tailrace (Castro-Santos 2011). Study results demonstrated 90% of the radio tagged shad (36/40) passing the Gatehouse were detected at a stationary receiver located 1 km downstream of Vernon Dam. Tagged fish moved rapidly to the Vernon Dam project area (median of < 2 days). Subsequent year radio tagging studies (FirstLight Power and TransCanada) had results affected by handling/tagging/tag effects (releases within the Turners Falls impoundment) and/or very limited sample sizes of tagged fish passing upstream of the Turners Falls power canal. Applying the 90% arrival rate for viable radio tagged shad to the observed passage counts differentials for the two facilities, results in Vernon’s upstream passage efficiency averaging 67.7% (Table 1). The removal of the first year (2012) following initial fixes at the facility (time series low) increases the mean passage efficiency rate to 72%.

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Table 1. Annual American Shad passage counts for Turners Falls Gatehouse Fish Ladder and the Vernon Dam Fish Ladder for the period 2012 – 2018.

Year	American Shad Passage			At 90% arrival to Vernon, required % passage efficiency for observed counts at Vernon
	TF Gatehouse	Vernon	% Passed from Gatehouse	
2012	26,727	10,386	38.9	43.2
2013	35,293	18,220	51.6	57.4
2014	39,914	27,706	69.4	77.1
2015	58,079	39,771	68.5	76.1
2016	54,069	35,513	65.7	73.0
2017	48,427	28,682	59.2	65.8
2018	43,146	31,724	73.5	81.7
Mean			61.0	67.7
S.D.			12.1	13.5

The CRASC Shad Management Subcommittee anticipates that FERC will issue license articles for Turners Falls, Northfield Mountain Pumped Storage, and Vernon in 2020 and that there will be license articles that address safe, timely and effective passage. Consequently, the improvements to fish passage at each of these facilities will need to be evaluated against the above stated fish passage performance criteria. Licensees of these projects must develop evaluation study plans in coordination with state and federal resource agencies. The results of these studies will allow licensees and resource agencies to consider structural, technical or operational changes if passage performance falls short of the criteria. Considerations for proper study design includes appropriate analytical approaches and adequate sample sizes of test fish to address statistical variability and capture representative variation in project operational and environmental conditions as well as fish movement timing (early, middle, late run) and characteristics of the species life stage (size, physiology). Several peer reviewed studies as well as unpublished evaluations in the Connecticut River have documented the capture, handling, tagging and tag related effects for study fishes using radio or acoustic tags (Frank et al. 2009; Olney et al. 2006; Bailey et. al 2004). Such effects must be taken into consideration when designing, conducting, analyzing and interpreting study results. Tag manufacturers and researchers have made advances in smaller radio tag sizes, tagging methods, analyses, and approaches to describe the type and extent of effects (e.g., PIT only tagged fish vs. radio & PIT tagged fish). Radio and acoustic tags in addition to PIT tags remain a primary evaluation method to understanding underlying behavior and movement, but other approaches may also be applied such as video/acoustic monitoring with caveats based on field of coverage and resolution. The state and federal agencies will provide further guidance during the consultation process.

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Acknowledgements

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Memorandum

Date: February 21, 2020

To: CRASC Commissioners and Alternates, Technical Committee and CRASC email distribution list (individuals submitting review comments)

From: CRASC Technical Committee and American Shad Plan Team

Subject: Review of submitted comments on Draft Addendum to the American Shad Management Plan (approved 2017)

This memorandum captures comments received during the two public comment periods that will be further described in the following text. The Addendum Plan Team worked collaboratively to examine and address submitted comments by the public. Our response is summarized in this memorandum and the attached table which identifies individual comments and responses.

The Connecticut River Atlantic Salmon Commission (CRASC) approved an updated Connecticut River American Shad Management Plan (2017 Plan) at its June 2017 meeting, replacing the 1992 Plan. The 2017 Plan comprises a set of management goals and objectives with supporting narrative. Within the Population Objectives, the Plan identifies the following fish passage objectives:

- 1.5 Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post spawn adults, and juveniles; and
- 1.6 Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency and delay at these three stages, as suitable information is available, to support other objectives of this Plan; and
- 1.7 Establish downstream performance measures, for adult and juvenile life stages that maximizes survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan.

The establishment of performance measures is supported, in part, by the Federal Energy Regulatory Commission's (FERC) draft environmental assessment for the American Tissue Project (FERC No. 2809), which states: *"Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities...Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and*

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determining whether effectiveness testing would or would not provide benefits to alosines...” (FERC 2018^A).

A team of 12 state and federal research and management agency biologists, as well as a senior U. S. Fish and Wildlife Service Fish Passage Engineer, developed the CRASC Shad Plan Addendum – Fish Passage Performance. The Plan Team has extensive expertise working with the monitoring, management, restoration, fish passage design and operation, and research of this species in the Connecticut River and in other systems.

The Plan Team used the following information sources to formulate appropriate and achievable criteria that address the Plan goals and objectives:

- peer reviewed and other publications;
- the 2017 CRASC American Shad Management Plan;
- U.S. Fish and Wildlife Service Fish Passage Criteria (2019);
- American Shad Passage Model (Stich et al. 2018);
- USFWS Turbine Blade Strike Model (2019);
- Atlantic States Marine Fisheries Commission’s Fishery Management Plan for American Shad (Amendment #3);
- ASMFC 2007 American Shad Benchmark Stock Assessment;
- the 1992 CRASC American Shad Management Plan; and
- other sources found in the Literature Cited section of the Addendum; as well as additional references cited in this memorandum and within the attached comments and responses table.

CRASC received written comments on the Draft Addendum from three power companies (Great River Hydro, FirstLight Power and Holyoke Gas and Electric) as well as two individuals (Mr. Karl Meyer and Mr. Robert Stira) during the first 30-day review period (August 9, 2019 through September 9, 2019). The companies and Mr. Stira requested more information on the Shad Passage Model (Stich et al. 2018) along with several other requests. The CRASC granted an additional 45-day comment period (September 12, 2019 through October 28, 2019) and provided, at the request of the power companies, the “R” code and related model details from Dr. Stich as well as model outputs from the Connecticut River model runs described in the Addendum. On October 28, 2019, a second set of review comments were received from FirstLight Power and Great River Hydro (jointly submitted and containing previously submitted review letters), and from Holyoke Gas and Electric. The Plan Team reviewed the submitted comments and organized our responses into a table format. The Plan Team met in mid-November 2019 to review the comments and develop a plan to provide responses.

A dominant topic of the power companies was the Shad Passage Model developed by Dr. Stich and utilized by the Plan Team along with other information (Stich et al. 2018). The companies’ comments suggest that they believe the Shad Passage Model was the primary basis for the development of passage performance criteria. This is not the case. As stated specifically in the Addendum, the model was “*one tool for managers*,” and was used, along with other diverse sources of information, to develop and support the criteria specified in the Addendum.

The companies’ comments also focused on the American Shad Passage Model outputs and the high variability associated with reported mean values. We understand there is high variability in model outputs; that variability is the basis for taking a precautionary approach in interpretation of outputs relative to current “minimum” escapement (number of fish passed at a dam) or population targets. The

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model provides clear and consistent patterns, most notably that high adult downstream survival at hydroelectric projects is critical to achieving management objectives, including long-term population growth, increased repeat spawning fish (i.e., spawners), and upper basin population targets.

Comments received by the companies also suggest they believe the minimum population targets defined in the 2017 Plan and used to help interpret model outcomes are long-term static figures. This is not the case. The 2017 Plan (page 6) states: *"This [return/production] estimate likely underestimates the full return/production potential due to problems of reduced passage issues (up and downstream) that were known to exist at each dam. CRASC may increase the minimum adult production target values as improvements to habitat quantity and quality and fish passage occur in the future with pending hydropower relicensing opportunities and other advances in technologies and regulatory or partnering opportunities."* CRASC's strategy is to address the constraints on the population that these minimum targets were derived under and, over time, update the management goals and objectives, as necessary, based on new information and improvements to passage. The CRASC intends to update the 2017 Plan at a 5-7 year interval, similar to the approach used by the Atlantic States Marine Fisheries Commission.

In the near future, there will be key fish passage and restoration opportunities, particularly in the upper Connecticut River basin, that will facilitate progress on achieving the 2017 Plan goals and objectives. The FERC relicensing process allows a rare opportunity to work with the utilities to mitigate the impacts of hydroelectric generation by improving upstream and downstream passage. These efforts will significantly and positively influence the status of shad populations over the long-term. Cumulative impacts of impediments to shad passage are particularly acute for the upper basin states, that have had to implement shad harvest restrictions, including closing the fishery to harvest (VT and NH) and reducing bag limits (MA). The restoration and development of sustainable fisheries, currently closed to the public in the upper basin, is a high priority for CRASC members that necessitates the upstream passage efficiency criteria described in the Addendum.

A concern expressed by the companies is how the Addendum passage performance criteria may be utilized in a regulatory context. We note that CRASC does not have any statutory authority within the Federal Power Act (i.e., FERC) or Clean Water Act (i.e., 401 water quality certification). However, the agencies charged with developing fish passage prescriptions and conditions through FERC relicense proceedings and/or 401 Water Quality Certification need management information to guide their recommendations. The extent to which the passage performance criteria are used in the regulatory processes will be up to the agencies, as will the design of evaluations to determine if those criteria are being met.

It is an increasing practice to incorporate fish passage performance criteria into fisheries management plans. The first CRASC American Shad Management Plan (1992) provided clear objectives for upstream fish passage. The 1992 Plan states, *"Achieve annual passage of 40-60% of the spawning run (based on a five-year running average) at each successive upstream barrier on the Connecticut River mainstem."* That criterion is similar to the proposed revised upstream passage efficiency criterion, which focuses on passing 75% of the shad that arrive at a project (as opposed to what has passed at the preceding dam). Based on a theoretical arrival of 80% of the shad from the previous dam,¹ with 75% passage efficiency of

¹ Previous upstream passage studies conducted on the Connecticut River have documented arrival rates in-line with this 80% target at the Holyoke (FERC No. 2004) and Vernon (FERC No. 1904) projects; refer to Addendum.

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those arrivals, an outcome of 60% passage is achieved. This aligns with the high end of the original 1992 criterion. As noted in the 2017 Plan and the Addendum, both Holyoke and Vernon projects have at times demonstrated achievement of 75% passage efficiency for fish arriving at a project.

The Addendum criteria also includes a 48-hour time period for shad to pass upstream (upon arriving within 1km of a project), to address negative impacts of delayed passage. Although a 24-hour time period for shad to pass in the Passage Model runs was shown to provide the best outcomes (for that setting, highlighting model sensitivity), we do not expect that the 24-hour time to pass criterion is achievable based on past field studies. Results from field studies indicate that a 48-hour time to pass criterion can be achieved; therefore, a higher upstream passage efficiency rate (75% as noted), as well as downstream passage survival (95% through project), are necessary in order to achieve minimum target population Management Plan goals and objectives among all basin areas, particularly for the upper basin (upstream of Vernon).

The companies provided their own Passage Model runs noting that “many” of the 81 scenarios they ran could achieve stated goals and objectives. However, the Plan Team’s review of the model output provided suggest that often only a subset of all management objectives are met. In some runs that met objectives, unrealistic parameter settings were used such as the 24-hour time to pass criterion discussed above. The companies contend that model outputs that fall within a very wide range (upper portion) of 95% confidence intervals may indicate achievement. We recognize there is a great deal of variability and thus uncertainty with the model outputs. We are cautious in the interpretation of the model results, using the mean as one guide for relative comparative responses and sensitivities (e.g., upstream passage delay and downstream passage survival at projects).

We contend that the companies’ (e.g., Figure 1) do not demonstrate achievement of the minimum population target and Plan goals and objectives using low upstream and downstream passage efficiency settings. The model output (e.g., Figure 1) is limited to the river mouth minimum target and does not meet the full scope of the management goals and objectives. Figures 23 to 32 suggest that minimum targets can be achieved with less than 75% upstream efficiency, but only with fish arriving and passing in 24 hours. We maintain the 24-hour ‘time to pass’ is not achievable and our 48-hour ‘time to pass’ is both reasonable and achievable. ‘Time to pass’ is likely linked to passage efficiency for fish arriving at a project. It is not reasonable to suggest a ‘time to pass’ expectation for arrivals at the “highest” level of effectiveness (24 hours) and then suggest concurrent passage efficiency in the “very poor” 25% to “low” 55% range as provided. The achievable 48-hour ‘time to pass’ requires 75% passage efficiency (achievable) as well as 95% downstream passage survival (achievable) to provide the best likelihood of achieving minimum targets and other Plan goals and objectives upstream of Vernon. Our conclusion that the efficiency targets are achievable is based on other supporting information and that when those targets are met the model results show minimum population targets can be met. In fact, the companies own model runs, shown in their Figure 28, in the top right panel, support the proposed criteria of the Addendum.

Support for the performance criteria in the Addendum is provided by a number of additional management plans, publications and other supporting information, as well as additional references listed below (Haro and Castro-Santos 2012; Noonan et al. 2012; Groux et al. 2015). Specific examples include:

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- The Migratory Fish Management and Restoration Plan for the Susquehanna River Basin establishes an 85% upstream shad passage criterion for fish reaching a project (SRAFRFC 2010).
- The U. S. Fish and Wildlife Service's Modified Prescription for Fishways (June 7, 2016) for the Conowingo Hydroelectric Project (FERC No. 405) states the licensee "shall" operate the project to achieve the SRAFRFC (2010) criteria and provides evaluation measures for those criteria (USFWS 2016).
- Parties to the Offer of Settlement for the York Haven Project (FERC No. 1888) agreed to the SRAFRFC Plan (2010) 85% upstream passage criterion for project arrivals and to the criterion of 95% through-project survival of juvenile shad and provides evaluation measures for those criteria (Patrizia 2014).
- The State of Maine's American Shad passage criteria specifies that, *"...the number of adult fish that need to be passed upstream at each fishway is estimated by dividing spawning escapement needed in all waters above the facility by an assumed passage efficiency (a goal of 90% is typically used)"* (MEDMR and MEDIFW 2008).
- Noonan et al. (2012) concluded *"To mitigate habitat fragmentation caused by anthropogenic barriers, upstream, passage facilities should allow 90-100% of migrating adult fish to pass in a safe and rapid manner (with citations)."* The researchers continued, *"...it was clear that current fishways are not achieving their primary conservation goal of restoring the connectivity of freshwater ecosystems."*
- In Silva et al. (2017), passage needs are discussed at length and include the following quote, *"Lucas and Baras (2001), similarly recommend attraction and passage efficiency targets of 90-100% for diadromous fishes, recognizing the cumulative impact, through reduced net passage across multiple sites, for effective restorative or population maintenance."*

We disagree with the companies' comments critical of passing more shad upstream of Holyoke in light of declines in repeat spawners citing information from Leggett et al. (2004). That paper's hypotheses have since been rejected in favor of more recent research that included a comprehensive analysis of published data on energetics and related data to model the shad population with respect to migration range, spawning success, and post spawn survival (Castro-Santos and Letcher 2010). Castro-Santos and Letcher concluded that delay, rather than energetics, was responsible for the loss of repeat spawners,

"...with migratory delay, rather than distance, being a dominate feature... delays incurred at dams are artificial consequences of human activities and can be mitigated for through improvements to design and operation of those dams and their associated fish passage structures (Kynard and Buerkett 1997; Haro et al. 1998; Kemp et al. 2006). Such mitigation would not be possible if the energetic costs of migration were driven primarily by migratory range, as proposed by Leggett et al. (2004)."

We also note in our table of responses that a number of iteroparous American Shad populations have native ranges penetrating much farther upstream than the Connecticut River shad population (280 km);

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the Susquehanna River (1,000 km to Otsego Lake) and James River (570 km) being just two examples (Limburg et al. 2003). However, shad in those systems have been severely depleted to a small fraction of their historical population sizes and have been restricted from significant reaches of historical habitat by dam construction and/or ineffective fish passage. This is similar to the situation on other rivers with dams and inadequate fish passage measures (Limburg et al. 2003; Limburg and Waldman 2009; Brown et al. 2013). Lastly, recent monitoring of juvenile American Shad production in the dammed habitat segments of the Connecticut River main stem has revealed density dependent effects on juvenile growth between Holyoke and Turners Falls dams that is not occurring with juveniles in habitats farther upstream (Mattocks et al. 2019). These examples are some of the justifications for, and benefits of, restoring access throughout the species' historical range that can be achieved most rapidly with the proposed criteria. This conclusion is based on the comprehensive, diverse sources of information and the Plan Team member's extensive knowledge, expertise and experience.

While the companies did not specifically comment on the topic of adult downstream passage performance, it is an issue directly linked to several management goals and objectives, such as increasing repeat spawner abundance. USFWS (2019) developed the Turbine Blade Strike Model that now provides a valuable tool to understand the potential impacts of passage at hydroelectric projects in the context of cumulative impacts and demonstrates the increased impact to larger/older female shad that have exponentially greater fecundity than virgin fish (covered in Addendum).

The previous CRASC American Shad Management Plan (1992) did not set specific criteria for downstream passage but did contain an objective to *"Maximize outmigrant survival for juvenile and spent adult shad."* The Addendum states that shad can be excluded from turbine passage and bypass facilities can be developed where absent or improved where needed to achieve 95% through project survival, helping to address the impact of cumulative project effects in this basin.

The USFWS Fish Passage Engineering Design Criteria (2019) documents a number of significant improvements to fishway designs, facility operational conditions, understanding of fish behavior, options for fish exclusion from turbines, and bypass designs that can address the challenges of designing effective passage facilities. The science of fish passage has experienced a rapid development in recent years, and there is widespread acknowledgement that fisheries managers must now incorporate new technologies to counter changing environmental conditions. The assertion by Silva et al. (2017) that *"Designing efficient fishways, with minimal passage delay and post-passage impacts, requires adaptive management and continued innovation"* is particularly relevant to the challenges faced by American Shad populations on the Connecticut River.

Without effective fish passage to provide access to historical spawning and nursery habitat, the species will not be able to achieve the abundance, size and age structure, and within-system range distribution that define population restoration goals in agency management plans. Mitigating the impacts of hydroelectric facilities and restoring runs of diadromous fish is achievable through the consistent application of science-based criteria. Developing performance criteria as a means of verifying the success of fish passage facilities is appropriate and has been explicitly requested by FERC. The CRASC, its constituent organizations, and the Plan Team relied on peer-reviewed population models (Stitch et al. 2018; Castro-Santos & Letcher 2010), recent research, assessments, plans, and fishway design guidelines

(summarized in USFWS 2019) in developing the fish passage performance criteria contained in the CRASC Shad Plan Addendum.

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Letter reference	Comment #	Comment	Response
FLP/GRH, 10/28/19, page 1	1	According to its developer (D. Stich personal communication), the model is neither final or stable at the present time nor was it when used to output population projections in the Draft Addendum.	The developer version on the master branch is used for ongoing research. Dr. Stich provided access to the legacy version of the model (used for these runs) that is frozen (final and stable). Dr. Stich states “I did not say this specifically I simply said that we are continually developing it (as is clearly stated on the software development page.” It is well-known that these models are based on incomplete and imperfect data. However they do represent the best available knowledge at the time they were developed. The intent of these models is to be a living document, such that they can be updated and refined as new information comes available. As such these models should never be considered 'final'. They are, however, stable in that they perform consistently and without error.
FLP/GRH, 10/28/19, page 1	2	...it was intended to be used as a tool in an iterative and collaborative approach to examine population trends as a result of various combinations of passage performance measures. Therefore, its application in developing very specific passage performance criteria is premature and inappropriate until such time as all parties agree that it is stable and how it should be applied	Dr. Stich has developed the SHADIA model to a state whereby the output it generates has served as a decision making support for the CRASC technical committee (TC). With input from the TC, Dr. Stich did indeed iteratively develop the model on the back end (e.g. temperature, flow, fecundity) and on the front end (various passage and mortality rates at each project). The passage model is <u>one tool</u> , one piece of information, that was used to inform criteria decisions (refer to page 5 of the Addendum). See comment response #6 regarding model stability. Further, all parties need not agree on how the model should be applied. This is a resource management tool. How the state and federal agencies use this tool, if at all, is within their regulatory and management discretion.
FLP/GRH, 10/28/19, page 1	3	The Draft Addendum focus on mean population values projected by the model was inappropriate. It should focus on use of the model as a tool to examine options for increasing the Connecticut River shad population by looking for positive trends through a variety of mitigation schemes and approaches	The model does produce a full range of user-specified confidence intervals. The mean was used for simplicity and illustration, but the consequences of management actions are true across the range of likely responses. Lower confidence limits show the same trends as the means, just at different magnitudes. We agree that managers should be concerned with lower confidence intervals, because these represent the risk of spawning failure. This is adequately captured by the model and should be included in the report. We agree that managers should be concerned with lower confidence intervals, because these represent the risk of spawning failure. This is adequately captured by the model and should be included in the report.

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FLP/GRH, 10/28/19, page 1	4	Draft Addendum failed to represent and account for the projected variability in model output suggesting substantial uncertainty in population projections. Therefore, there is substantial uncertainty and imprecision in the effect of passage performance measures specified in the Draft Addendum.	Same as previous response. For fishery managers it is important to hedge against variability (precautionary approach is the term commonly applied) in projections to minimize risk of stock failure, other undesirable outcomes that would reduce the rate or ability to achieve management objectives (such as opening closed fisheries in VT and NH).
FLP/GRH, 10/28/19, page 1	5	The model should include separate functions for adult and juvenile downstream passage effectiveness/survival. Currently the model includes a single downstream passage effectiveness/survival input value for both adult and juvenile shad. This is problematic because passage induced (and natural) mortality differs substantially among those life stages and the effects on population should be examined separately. It is therefore illogical to conclude a common passage performance criterion	We agree. This issue is acknowledged directly in the software. As new data come available we intend to update this. Already Castro-Santos and Letcher (2010) have demonstrated the likely consequences of migratory delay to downstream migrant adults and its effects on spawning and survival. The model as presented is conservative. Adult survival is the greater challenge, but is also the more important driver of patterns. Future refinements are unlikely to change these impacts except to emphasize the importance of adult survival. See Boreman and Friedland (2003).
FLP/GRH, 10/28/19, page 2	6	The model continues to be improved and it is imperative that the Companies and CRASC work together to 1.) Agree on a final version of the model; 2.) Apply the model as a tool in guiding mitigation options; 3.) Agree on inputs (fixed or variable) and their relative effects on the modeled population.	The CRASC approach was to work with the partners identified as necessary to develop the population model tool, one of many pieces of information used to develop and support the performance criteria. There will be no fixed inputs, outside of management controls in the model. CRASC agency members decided who would be appropriate to include in that process of model development, as well as broader discussions on the available information used and cited in the Addendum, to achieve initially identified " <u>minimum</u> " restoration population targets as well as other priorities (increase repeat spawners and restore upper basin adult run size - for fisheries and ecological objectives) (CRASC 2017). The agency's approach is driven by our intent to develop information tools (such as the USFWS Turbine Blade Strike Model) and use many other sources of information to restore the American Shad population and achieve the 2017

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			CRASC Shad Plan goals and objectives. The "stable" version of the model has been provided to the companies.
FLP/GRH, 10/28/19, page 2	7	Mitigation options based on modeled populations should focus on the most cost-effective measures that result in enhancing the Connecticut River shad population.	Mitigation options can be judged on many criteria and all the criteria have importance and must be considered using a wide range of available information not only the model. We again state the model was one tool used by the Team. The focus for CRASC is to identify mitigation options that support management goals and objectives. The primary focus for CRASC is to identify options that provide the most restoration benefit.
FLP/GRH, 10/28/19, page 2	8	The development of passage performance criteria should be a transparent and collaborative process including the Companies.	The resource agencies have management authority for the protection and conservation of public trust resources. We have addressed this comment in several ways. We maintained an open process throughout the development of this plan addendum. We extended the comment period and provided requested information, and having company representatives speak before the CRASC Commission. Company representatives are free to attend our public meetings. The model design, parameter values and opportunities for use are all covered in other responses (#11, 12, 15, 16 etc.).
FLP/GRH, 10/28/19, page 2	9	Although the model is publicly available, the Companies independent review of it revealed problems and limitations noted herein which were not addressed in the Draft Addendum. A more collaborative approach may have prevented this	Despite the claim of problems and limitations, the TC model consistently suggested that in order to restore the adult shad population to the Connecticut River, low rates of mortality had the best chance for the population to meet management goals and objectives for whole basin restoration.
FLP/GRH, 10/28/19, page 3	10	Given the implications of the Draft Addendum on the Companies' FERC licenses, the Companies have a significant interest in ensuring that the Draft Addendum is supported by sound scientific principles and existing scientific information regarding Connecticut River American Shad. The Companies do not believe the Draft Addendum, as prepared, meets that standard.	The Draft Addendum integrates all the information available at the time and is based on sound scientific principles. The Shad plan and all the components will use adaptive management as more information becomes available. We include responses to specific comments below and reject the assertion that the Draft Addendum does not meet the standard described by the companies. In addition to the Stich model, we have incorporated the best available science to restore the American shad population.

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FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	11	CRASC should facilitate a presentation and workshop for interested parties, ideally led by Dr. Stich or a surrogate who is highly familiar with the model development and implementation to address, at a minimum, questions regarding model design, variable inputs and distributions, and output variability	The CRASC has used a publically available, peer reviewed model developed by Dr. Stich. The model design and parameters are all fully transparent, there are no black boxes or hidden parameters. The model design is explained in Stich et al. (2018) where it is noted that the model has the design flexibility for other river applications. The "Legacy" code posted on the Shadia web site provides those model details used for Connecticut River model runs. Dr. Stich has provided input to the companies on the R code and made the CT River Model run setting available on the publically accessible Shadia web site.
FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	12	CRASC should share specific input and output datasets it used to adapt the model for the Connecticut River. This information must be made available to interested parties in order to assess the relative predicted effects of modeled input variables	These are available in the software package. This was one of the big reasons for its development. The only system-specific considerations are information about growth and mortality, spawning dynamics, max age, starting population size, temperature data, and the actual configuration of the hydrosystem (including carrying capacity). Vignettes are also provided with the software that document the data.
FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	13	CRASC should institute a minimum 90-day review and comment period beginning after the presentation/workshop and after CRASC has disseminated requested data	The CRASC has provided what it has determined is a sufficient period of review time. The initial 30-day period, August 9 to September 9, was noted as insufficient by some reviewers based on the comments received to have the model code provided along with many other requests (note in this response document) The CRASC agreed to an additional 45 days of review September 12 to October 28 and provided the R model code and related files from Dr. Stich on the Connecticut River.
FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	14	CRASC should clarify its review and revision process and timing, commit to addressing any comments received, and ensure that a summary of responsiveness to those comments received is published and distributed to interested parties prior to presenting a final version to the CRASC for approval and adoption	CRASC has provided responses to reviewers comments, beginning with the extension of the review and comment period (following the first 30 day period), initiated on September 12. CRASC reviewed its plan to respond to submitted comments at the December 11, 2019 CRASC. It was noted at that meeting that CRASC Plan Team members were responding to comments in an internal process and that the next CRASC meeting in February 2020 would be when response would be publically provided.

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FLP/GRH, 10/28/19 Attachment B 9/9/19 letter page 4	15	the Companies were informed by CRASC that the “R” program code used to generate the model outputs described in the Draft Addendum and a PowerPoint presentation (Presentation) on the referenced model runs and a 45-day comment period with an October 28, 2019 deadline would be provided. CRASC’s response did not address the Companies requests to facilitate a workshop wherein interested parties could work collaboratively to understand the model and investigate its utility to develop passage performance criteria, or to clarify the review process and timing	The model is open and available for use by anyone as noted in the response comments. The resource agency group comprised of state, federal, research, academic biologists contained all the necessary expertise to develop the model, using the best available science. The power companies have the ability to run the model with different values. The model was just one tool used to inform the development of passage.
FLP/GRH, 10/28/19, page 4	16	<u>The intent of the extended review period could not be fulfilled.</u> The Companies’ incorporated model input code provided by CRASC and the publicly available Shadia model for the Connecticut River, downloaded from the GitHub site as directed by CRASC. However, model output differed significantly from that provided by CRASC. On October 9, 2019 the Companies conferred with Shadia’s originator, Dr. Dan Stich (SUNY Oneonta), who confirmed that the publicly available model version had been revised from the version used to produce the output used by CRASC to inform the Draft Addendum.	The CRASC believes a significant amount of time and information has been provided to any persons/entities that had an interest in providing review comments on the Addendum. The companies did reach out to Dr. Stich who provided what has been identified as the "Legacy Code" used for the Connecticut River model runs on October 9, 2019. The companies did complete a large number of model runs of their own and submitted those in the letter dated October 28, 2019. The dam passage performance standards models are updated as new data become available. The version the companies attempted to use during fall 2019 to reproduce previous results was the most recent and included climate predictions that were still under review at the time. For this reason, the legacy version (referenced in comment 17) that was used for the CRASC request was provided publicly through the software website to promote transparency and reproducibility.

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FLP/GRH, 10/28/19, page 4	17	Dr. Stich was able to make available a 'legacy' version of the model code which was expected to replicate that used to inform the Draft Addendum. At that point, 26 days of the 45-day review period had elapsed and there was insufficient time remaining to complete our intended sensitivity analyses	The TC has reviewed a sufficient number of modeled output and it has coordinated with Dr. Stich extensively. We have a good understanding of the inputs to which the model is most sensitive. We reiterate that the model was not the sole source of information for which we based our performance standard.
FLP/GRH, 10/28/19, page 4	18	the intended use of the model was to provide a tool for all parties to use to collaboratively assess the relative effects of various passage performance scenarios. The model was in development when used to inform the Draft Addendum, is still in development and the most current version is not considered stable, and new scientific information that may improve the model's predictive accuracy has become available	The companies understanding of the term "stable", in the context of modeling, is not accurate. By stable, Dr. Stich did not mean that the model was not performing well or had an inherent flaw, but rather that it was no longer being modified in any way. The model does not need to be stable and the broad thrust of the Companies' comments capture this very idea, the model should be constantly revised as new information becomes available. To that end, Dr. Stich and the CRASC team are constantly looking for and receptive to new data sources to incorporate into the model. The current ASMFC Benchmark Stock Assessment is still more than 6 months from completion and is focused on coast wide stocks, incorporating information from individual systems (e.g., the Connecticut River) as well as coast wide surveys of various life stages. Additionally, the companies' expectations for the results of the Stock Assessment are the inverse of how the management system functions in this case. Rather than producing new information that could be used in the model or other important aspects of the Draft Addendum, the Stock Assessment will incorporate much of the data that has already been considered on the Connecticut River for coast wide management. It is possible that some aspect of the Assessment process will provide new information or tools that can be brought into this or future Addendums and CRASC looks forward to any opportunity to benefit shad restoration on the Connecticut River. We are unsure where the companies reference to the model being a tool "for all parties to use collaboratively" comes from, but the resource agencies have found it a useful piece of additional information in developing passage performance criteria working towards achieving goals and objectives of the CRASC Plan.

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FLP/GRH, 10/28/19, page 4	19	...the Companies recommend that CRASC support the development and validation of the model to a more stable state and then work collaboratively with the Companies and stakeholders in its use as a tool to help evaluate projected effects of passage performance criteria.	The TC states again that the model was one piece of information for the criteria development. As new peer-reviewed information becomes available, determination can be made on next steps. Other sources of information (research) and data (fishery dependent and independent) have been and will continue to be used to assess stock status and trends (CRASC 2017; ASMFC 2012). It will be adjusted over time as we gain more information and test the assumptions on which it is based. It represents our current understanding of the Connecticut River shad population.
FLP/GRH, 10/28/19, page 4 & 5	20	<u>Development of Passage Performance Criteria as Described in the Draft Addendum was Premature,</u> revisions to the model have been made to include the best available scientific information, including updated age and growth and mortality data derived from an ongoing stock assessment ⁴ , and climate information The model currently includes a common downstream passage effectiveness/survival input value for adult and juvenile shad. This is problematic because passage induced (and natural) mortality differs substantially among those life stages. It is therefore illogical to conclude a common passage performance criterion. The model should include separate functions for adult and juvenile downstream passage effectiveness/survival, and the sensitivity of the model to those functions and the projected effects on the population should be examined separately. The model was very	See earlier responses. The model will continue to be developed to help serve the management community, however the version provided is appropriate for management purposes. We agree that adult and juvenile mortality estimates should be considered separately and this will be included in future versions of the model. Available data indicate that shad populations are most sensitive to adult survival. Therefore we do not expect the outcome of future models to differ greatly, even when adult and juvenile mortality are separated.

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		sensitive to downstream passage and this change may substantially change output.	
FLP/GRH, 10/28/19, page 5	21	The Draft Addendum Incorrectly Focused on Mean Population Values Projected by The Model Rather Than Focusing on Population Trends, and Did Not Consider Confidence Around Model Projections	The Draft Addendum focused on using a wide variety of information sources to inform the performance criteria and target population goals, not just the model outputs. The Plan Team used the population model and described model outputs to help inform criteria with an understanding the mean outputs exhibit wide confidence intervals. The mean was used for simplicity and illustration, but the consequences of management actions are true across the range of likely responses. The Team also contends the mean output values do provide context for projected outcomes among differing scenarios for passage efficiency and survival. As such, the Team applied a precautionary approach (commonly applied in fishery conservation dealing with uncertainty) as part of the discussion on the model outputs and other information sources. The mean is just the average likely outcome. Some are better, but some are worse. In principle, managers want to minimize risk (this is the precautionary principle). By focusing in means we are providing the least biased predictor of success, however this means that greater protections would improve likelihood of success. Note that the models run by the companies also confirm this--to get better than 50% likelihood of success requires that both upstream and downstream passage rates be maximized, with a minimum of delay. This is the basis of the requirements we have called for.
FLP/GRH, 10/28/19, page 5	22	That approach is misapplied because it undermines the inherent stochasticity of the model and considers the result as deterministic. The model incorporates environmental stochasticity and inter-annual variability by drawing from parameterized distributions for many input variables (see Stich et al. 2018).	We disagree. Although means are discussed the model is in fact stochastic, not deterministic. Managers must consider likely outcomes of decisions and that is what the model is intended to support

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FLP/GRH, 10/28/19, page 5	23	The Draft Addendum failed to present, discuss and seemingly consider the confidence intervals around modeled population projections. In the Presentation of model output provided in support of the Draft Addendum, figures depict the annual population as an average of approximately 123 iterations per scenario, but no information regarding the variability around those projections. It is therefore important to demonstrate and evaluate model results in the context of that variability. For example, Figure 1 depicts ~120 iterations of a single model run. The mean projected annual population falls roughly in the middle of a large amount of variability.	The model confidence intervals are wide for outputs, there is uncertainty around the parameter settings bounded by the best science available in an approach peer reviewed by the Canadian Journal of Fisheries and Aquatic Science. As such, the CRASC position is to take a precautionary approach in model output interpretations. Our Team's interpretation of model outputs is based upon the design and parameterization of the model through discussions with Dr. Stich and each member's background working with American Shad management, restoration and passage (include Dr. Ted Castro-Santos and his published modeling work with shad). This is the rationale for the agencies being conservative in their interpretation of the model outputs that are viewed as informative for trends and relative shifts in parameter settings reflected in the mean value. However, the model outputs are not the sole driver for the development of the passage criteria, a fact that is clearly stated in the Addendum. It was not the intent of the CRASC to suggest the model is the primary informational factor in our criteria development, we contend that is clearly expressed in the plan (page 5) and also covered in the memorandum.
FLP/GRH, 10/28/19, page 6	24	Figures 3-11 represent the same output but with 95% confidence intervals for each modeled scenario. The wide confidence intervals demonstrate a high level of variability and call into question the validity of specific passage performance criteria with regards to the Plan objective. While the mean of few scenarios approached the Plan objective, the confidence limits of many scenarios exceeded it⁵.	Variability within complex models is inherent, especially those which examine and incorporate any level of environmental stochasticity, as Shadia does. The model is a tool used to help support criteria development that included consideration of numerous other supporting sources of information. It is important to consider that all plan thresholds are clearly defined as minimum targets and expectations these levels would be exceeded, partly attributed to needed improvements in passage (greater upstream passage efficiencies) and survival. Means allow us to 1) graphically explore the potential consequences of different management actions; and 2) precautionary approach requires that we consider minimum likely returns, not maximum likely returns, and to ensure that those minimum likely returns meet management goals. Note that we do not consider 24 h maximum delay to be a realistic or achievable goal. Within realistic parameters everything in these models points to minimizing delay and maximizing safe passage in both directions as the management strategy that is most likely to achieve targets. We had noted mean values in outputs in our consideration of model outputs we ran but that does not mean variability was not examined or considered by the CRASC. It would be irresponsible for the agencies to consider managing a population solely on wide ranging confidence interval of a

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			model - at the estimated upper 95% level, for a population considered under restoration. Additionally, the plan is not static nor concerned solely with minimum thresholds or model outputs, especially when considered over the full lifespan of a 40 year operating license. Figures 3-11 only consider the minimum target to the river mouth, it does not provide any information relative to potential outcomes for the upper basin, and has <u>zero</u> examples for achievement of the minimum target with the mean output.
FLP/GRH, 10/28/19, page 6	25	The trend in population growth was generally similar among scenarios with the most rapid population growth occurring over approximately the first two generations (~10 years). Similarly, output for modeled populations above Turners Falls (Figures 12-21) and Vernon (Figures 22-31) Dams demonstrated high variability with upper confidence limits well above the targets and lower confidence limits below the targets in all scenarios	We fully acknowledge variability in the model's output. Having acknowledged that, as managers, we have taken a conservative approach to reaching our management goals and objectives with other information for criteria utilized. Model runs for Vernon (<u>minimum adult population target</u>), the referenced figures 22-31) supports our position that high upstream passage efficiency is necessary when using the achievable criteria of 48-hour time to pass and that high downstream passage survival is also required to help achieve the goals and objectives to the upper basin. Further, among our many specified management goals and objectives, we seek to open closed fisheries in NH and VT and reestablish ecological roles among all life stages that have been severely depleted in the upper basin and that can be addressed by attainable upstream fish passage efficiencies and time-to pass (refer to memorandum). Also refer to response in #25.
FLP/GRH, 10/28/19, page 6	26	Both the summary of results in the Presentation provided by CRASC and in the Companies' independent assessment of passage performance using the model indicated that there are multiple scenarios that can result in projected population growth toward meeting Plan objectives and there are trade-offs in terms of management objectives relative to passage performance	The Plan is clear in using the most upstream river segment as the central component of the standard. Having the necessary upstream passage and downstream measures become a necessity as a result of achieving the many objectives of opening fisheries, restoring ecological functions, and ensuring long-term population resilience and health (% repeats). We have made the decision to take a precautionary approach to restoring the shad population relative to criteria. Given the uncertainty in ocean conditions, bycatch, water quality, timing of flows, and other factors, the decision to implement high performance standards provides the highest likelihood for achieving management goals. We reiterate that the model is not the only tool upon which we made our performance standard decision.

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FLP/GRH, 10/28/19, page 6	27	To demonstrate that many scenarios could achieve the objectives, the Companies performed model runs using the same suite of passage performance criteria as above, but with an upstream passage rate of 25% (Figures 32-41). Based on the results of this analysis, there is a suite of scenarios that could be used to meet population and upriver distribution goals, even with such a low upstream passage rate.⁶ These include scenarios with lower proportions of downstream passage times, greater times to passage, and/or a combination of both.	The companies' letter states 25% upstream passage efficiencies applied to the model can achieve agency goals. The provided company model runs show that the mean population model does not achieve the "minimum" population target currently set for shad passage upstream of Vernon Dam for Figures 32, 39, 40, and 41. It seems that the companies have misunderstood the meaning of the confidence intervals. Just because there is a slight possibility of achieving a management goal is no justification for pursuing a given strategy. Our responsibility is to ensure that restoration has a good chance of success, and none of the models shown here support that goal. On the contrary, this very argument supports what we have proposed as the most appropriate and reasonable suite of criteria. The agency identified Vernon minimum target is critical to achievement of the 2017 CRASC Plan goals, and is the most sensitive to poor passage efficiency settings, higher delays, and increased impacts from poor downstream survival. The companies appear to be pointing to the fact the upper 95% confidence interval is located above that "minimum" target for Vernon. The TC refutes the suitability of using an "upper 95% CI" as a determination of achieving the noted minimum passage value. The precautionary approach, reasonably applied to a this population, is the logical choice for a species that remains in restoration status as other East Coast populations are all considered at "all-time" low levels of abundance (ASMFC 2007). The 24 hour time to pass used by the company is unrealistic based on field data, we chose an achievable 48 hour time to pass. We used other numerous other sources of information, not just model based, to inform our decisions. The criteria identified in the draft addendum are based on a holistic administrative record, are feasible, and are realistic. The precautionary approach requires that we at minimum provide strategies that have a greater than 50% chance of success (this is indicated by the mean predicted outcome meeting or exceeding population targets...e.g. the mean predicted outcome must be above the target threshold indicated by the dotted lines on the plots). To that end we have identified strategies that meet this requirement. These criteria will provide the best likelihood, given the breadth of information considered and discussed, to achieving <u>initial minimum</u> management goals and objectives.
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FLP/GRH, 10/28/19, page 6	28	studies produced results that should be considered in future model runs and management strategies. For example, recently conducted shad telemetry studies conducted for the relicensing of the Turners Falls Project indicate that 80% of the early tagged shad released at Holyoke arrive at Cabot Station while less than half (35%) of those tagged later in the season arrive at the Project.	If fish arrive at the project (80% or 35% can be time varying,) they should be passed, it is addressed by the definition of the criteria.
FLP/GRH, 10/28/19, page 7	29	The upstream relocation of the shad population has resulted in higher total energy expenditure and increased adult mortality leading to a dramatic reduction in the repeat spawning component of the population and in the mean size and age of adult fish.... The loss of larger repeat spawning females is estimated to have resulted in a 20% reduction in mean population fecundity and could account for a 14% reduction in annual recruitment to the population (Leggett et al. 2004 ⁷). This most likely has contributed to the failure of the population to respond numerically to the increased access to upriver spawning habitat. A prudent management strategy would be to adjust the passage of shad during the latter part of the annual run to ensure the restoration and the maintenance of an age and repeat spawning structure more consistent with historic	This decrease can also be explained by increased exposure to downstream turbine or other ineffective downstream passage which is known to have occurred and is occurring as well as delays in both upstream and downstream passage. If one assigns a conservative through project survival rates of 0.85 for outmigrating adults, applied to the third power (for passage of fish by three main stem projects– VT/NH fish), that leaves 61% of starting number (no modeling required). That degree of loss, is not acceptable for this population (under restoration - most notably in upper river basin habitats) given solutions exist to prevent such a loss from power company facilities. The USFWS turbine blade strike model is a useful tool to demonstrated the magnitude of the loss by turbine type and operations with routing data (refer to addendum). It is also important to note that turbine mortality is related to fish size, that larger females are selectively more impacted by turbine passage - exacerbating management concerns for the component of repeat spawners and the contributions larger females with their increased fecundity and potential contribution to production potential. We disagree with the companies' comments critical of passing more shad upstream of Holyoke in light of declines in repeat spawners citing information from Leggett et al. (2004). That paper's hypotheses were carefully considered and refuted by more recent research that included a comprehensive analysis of published data on energetics and related data to model the shad population with respect to migration range, spawning success, and post spawn survival (Castro-Santos and Letcher 2010). Castro-Santos and Letcher concluded that delay, rather than energetics, was responsible for the loss of repeat spawners. CRASC is seeking to effectively address poor upstream passage efficiencies, associated delays tied to inefficiencies, and also turbine/project route mortality of the commercial hydro power operators. On the matter of distance as a concern, Limberg et al. (2003) provides examples of numerous iteroparous (repeat spawner) shad population that were

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		levels. Failure to do so could further erode the proportion of repeat spawners and the number of individuals of older age classes, thereby placing the population at risk of recruitment failure in the event of a period of several years of successive poor recruitment.	documented to penetrate much greater distances up rivers than the Connecticut River. Examples of "long distance" migrating populations (greater than the Connecticut 280 km) historically used by these "repeat" spawner populations include; St John River, New Brunswick (300 km), Hudson River (320 km), Delaware River, NJ/NY (380 km), Susquehanna River, MD/PA/NY (>800 km), Potomac River MD/WV (310 km), Roanoke River NC/VA (375 km), and James River, VA (575 km). Castro-Santos and Letcher (2010) note "<i>delays incurred at dams are artificial consequences of human activities and can be mitigated for through improvements to design and operation of those dams and their associated fish passage structures (Kynard and Buerkett 1997; Haro et al. 1998; Kemp et al. 2006)...</i>"such mitigation would not be possible if the energetic costs of migration were driven primarily by migratory range, as proposed by Leggett et al. (2004)." Finally, the intent to allow the population to access a diversity of habitat over its full range for spawning and nursery habitat will 1) help reduce the occurrence of density dependent effects on juveniles (if constrained to select habitats - as detected currently); 2) help reduce potential negative impacts from more localized events (high rain events in one portion of the basin, other localized impacts); and 3) achieve the ecological benefits derived from the timing and magnitude of juvenile production that should be occurring among all the habitats - it not simply about adult fish only (refer to CRASC 2017).
FLP/GRH, 10/28/19, page 7	30	The Companies reiterate that use of modeled population projections should consider variability in output and focus on trends, rather than a deterministic interpretation of results.	This has been addressed in previous comment responses.
FLP/GRH, 10/28/19, page 7	31	Model revision is necessary to incorporate the best available data and include separation of juvenile and adult downstream passage, and the model should be verified as stable and agreed upon as final for the purpose of assessing passage performance.	The separation of juvenile and adult downstream passage survival is not necessary to evaluate the management questions of interest. Having both adults and juvenile downstream passage survival track for outcomes at 75%, 85%, and 95% are both logical and supported by available evidence to be representative to commonly expected ranges for some larger and mid-size project turbines on the main stem river. Please also refer to the response to comment #5, essentially the same question. The stability of the model was addressed in previous comment responses (#1, etc.).

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FLP/GRH, 10/28/19, page 7	32	we recommend that a working group, including the Companies and HG&E be convened to collaboratively apply the model as a tool to assess the sensitivity of passage performance criteria broadly, then more specifically investigate those criteria that have the greatest affects with consideration for cost-effective measures	The TC has provided opportunity for public comment during the development of the model scenarios and inputs. It is the responsibility of the resource agencies to apply the model within the context of numerous other sources of information (cited and discussed), to inform management and restoration decisions.
FLP/GRH, 9/9/19		The following comments were not included in the 10/28/19 FLP/GRH letter that referenced the 9/9/19 letter and included that letter as Attachment A. There were some instances of 9/9/19 letter comments that were placed directly in the 10/28/19 letter by the companies and were addressed earlier in this summary.	

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FLP/GRH, 9/9/19, page 2	33	In page 1, paragraph 3, CRASC states that “Ideally, for a facility/project to have zero effect on migrating fish, 100% of fish that arrive at the station would pass with no delay, injury, or mortality...” This assumes that in an un-dammed system, 100% of fish arriving at a point would pass with no delay, injury, or mortality. Such a statement suggests natural impediments to fish migration should be ignored or either do not or would not exist otherwise. It does not account for natural physical barriers (e.g. velocity, falls), which may have induced delays or passage failure: many at the same locations as present day Connecticut River main stem dams. It also ignores natural variation in temperatures, flows, or behavioral (e.g., spawning activity, predation), factors that can induce natural delay or termination of upstream migration. Lastly, it artificially establishes hydroelectric project passage zones that range from a minimum of one kilometer to several kilometers rather than a point. These factors potentially contributing to migratory extent and duration should be acknowledged in the Draft Addendum.	The TC acknowledges that no hydroelectric project is capable of such an ideal but the TC contends with the numerous citations, discussion on the topics in the Addendum as well as in the memorandum that <u>these criteria are achievable</u>. The precedent for criteria has been established on the Susquehanna River for American Shad (USFWS section 18 prescription cited in memo) after decades of failed passage measures in that basin, without any passage criteria in place. Other examples of precedent on similar passage criteria are in place for the State of Maine with Atlantic Salmon and on the West Coast with Pacific salmon stocks, through NOAA section 18 prescriptions. We note again that the FERC has identified the lack of defined passage criteria as an issue (citation in Addendum). The model does not ignore variation in temperature or flows. It selects from a distribution of temperatures and flows. Refer to page 2 of the Addendum as it clearly describes that arrival is based on fish migrating to 1 km from project. The 24-hour time to pass downstream of a project is supported by results of a juvenile shad tagging study in 2015 at the Vernon Dam/project, that suggest this rate is achievable and can be evaluated as a criteria. Results from the juvenile radio tagged shad released upstream of the project, passed the project in 0.7 hours (median) and that “approximately 87% of the shad that passed Vernon did so in 12 hours or less” (TransCanada 2017).
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FLP/GRH, 9/9/19, page 3	34	A significant upriver relocation of the main spawning activity by American shad in the Connecticut River to date has failed to produce the anticipated increase in total population size from the increase in total spawning habitat available. This upriver displacement of spawning has resulted in an increase in the length of the spawning migration and a corresponding increase in the energy expended to reach the spawning grounds. Fish are bioenergetically adapted to the length of their spawning migration. As the distance covered by a migrating shad increases, energy requirements also increase. Shad do not feed during migration and added energy demands for an extended migration may cause shad to exceed their limit of endurance. Prior to upriver relocation of the spawning activity, Glebe and Leggett (1981)³ found that energy allocated to migration was close to the minimum required for adult survival. Improvements to the Holyoke Dam fish lift in 1976 increased lifting capacity from 5-10% to about 50% of the annual run (Moffitt et al 1982)⁴. Additional upstream fish passage improvements at Holyoke after relicensing resulted in an estimate of over 70% of the shad run being passed	The coast wide decline in American Shad stocks is describe in the 2007 ASMFC Benchmark Assessment with annual updates from ASMFC demonstrating a continuation of this status for many populations through 2018 (ASMFC 2018). As a result of this well described coast wide decline, it is CRASC's contention that the opening of habitat in the Connecticut River has in fact mitigated non-riverine causes of population decline while numerous other shad systems have observed significant declines (e.g., adjacent Hudson River Shad fishery closed in 2009, remains closed). CRASC is seeking to address poor upstream passage efficiencies, associated delays tied to passage inefficiencies and turbine/project route mortality. The company incorrectly states that over 70% of the shad run passed over Holyoke in 2011 and 2012 (citing the CRASC Plan Addendum). The Draft Plan states on page 9 that 73.8% (2011) and 75.8% (2012) <u>of the shad that arrive (that is 1 km from Holyoke)</u>, passed at Holyoke. On the matter of migration distance, Limberg et al. (2003) provides examples of numerous iteroparous (repeat spawners) shad population documented to reach much greater distances up river than the Connecticut River, which have succumbed to dams and absent or inadequate fish passage. CRASC does not consider the artificial restrictions to migration on the Connecticut population to represents limitations of their energetic ability or biological ability. Anthropogenic limitations from interactions at projects (delay, inefficiency and mortality) are artificial impositions. With the draft addendum, we seek to correct the negative impacts/effects of hydropower development on the population. See response to #29 regarding energetics and distance.
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		over Holyoke in 2011 and 2012 (see CRASC Shad Plan Addendum).	
FLP/GRH, 9/9/19, page 3	35	Mortality of post-spawn adult shad has increased along with the increase of migratory range (Crecco et al. 1982)⁵. The increased use of body reserves due to migratory range extension may be a major cause of increased mortality of emigrating shad. Although the weight loss that results in death is unknown, Chittenden (1976)⁶ suggests that death may occur when somatic weight loss exceeds 40% of initial weight. A result of increased post-spawn mortality was a dramatic reduction in the repeat spawning component of the population and in the mean size and age of adult fish. In addition, an increase in the variance in annual population abundance followed this reduction in population age structure. The loss of larger repeat spawning females is estimated to have resulted in a 20% reduction in mean population fecundity and could account for a 14% reduction in annual recruitment to the population Leggett et al. 2004)⁷. This may have contributed to the failure of the population to respond numerically to the increased access to upriver spawning habitat. Reduced iteroparity	Refer to the response of comment #29 and #34 as it covers the incorrect assumptions on "distance" migrated as a possible main hypothesis. Response in question 31 also covers the downstream passage protection of adult shad which has only been developed in very limited areas as of this date as a driving factors coupled with the "delay" of fish passage covered by Castro-Santos and Letcher 2010. The fact that a higher proportion of shad tagged earlier at Holyoke arrived at Cabot (80%) versus 35% later in the season is not surprising and has no bearing on the application of the upstream passage criteria. The proposed criteria are based only on fish arriving at a project (1 km), and does not affect fish remaining in lower portions of a river reach. Seasonality as interpreted in the context of the comment is accounted for in the criteria. The performance criteria is applied to fish that arrive at a dam. This number will naturally vary throughout the migration season. Please note that here and elsewhere the company refers to Leggett et al. (2004), which as we have already stated has been refuted with respect to these and other points.

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		can deter restoration efforts because of the reduction of the effective population size and reproductive rate and because iteroparity serves as a buffer against environmental stochasticity. To mitigate for this effect, Leggett et al. (2004) recommended that migratory range be restricted by limiting the number of shad passed above Holyoke Dam. In addition, recent shad telemetry studies conducted for the relicensing of the Turners Falls Project indicated that 80% of the early tagged shad released at Holyoke arrive at the next upstream Project (Cabot Station) while less than half (35%) of those tagged later in the season arrive at the Project. This suggests that seasonality should be considered as well.	
FLP/GRH, 9/9/19, page 3	36	A prudent management strategy would be to adjust the passage of shad during the latter part of the annual run to ensure the restoration and the maintenance of an age and repeat spawning structure more consistent with historic levels...historic levels until the anticipated positive effects of increased spawning area created by fishway construction is reflected in the size of the population entering the river to spawn. Failure to do so could further erode the proportion of repeat spawners and the number of	Fish that arrive at the project (within 1 km) should have the opportunity to pass in a safe, timely and effective manner. Downstream migrating adult and juvenile should likewise have safe, timely and effective downstream passage. CRASC goals include improving the age structure of the population and increasing repeat spawning without restricting access to historic spawning and nursery habitats. Mitigating the known impacts of hydropower facilities would address management goals and objectives that don't ignore the biological and instinctual behavior of migratory fish. Refer to comment #29 for benefits of increasing access to historic spawning and nursery habitats and recruitment along with other ecological benefits noted in goals and objectives of the Management Plan (CRASC 2017).

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		individuals of older age classes, thereby placing the population at risk of recruitment failure in the event of a period of several years of successive poor recruitment.. Therefore, the Companies recommend that CRASC run a model scenario with reduced shad passage at Holyoke Dam during the latter part of the season.	
FLP/GRH, 9/9/19, page 4	37	How does CRASC rectify the criteria for minimum upstream adult passage efficiency of 75% within 48 hours with the potential for natural physical features to impose delay or obstruction to migration and the potential for shad to spawn within a project area without passing upstream? Recent studies have demonstrated velocity and physical barriers to shad passage at Rawson's Island / Rock Dam in the Turners Falls bypass as well as spawning activity there and in various reaches of the Connecticut River including below Vernon Dam.	Passage at Rawson Island and adjacent areas relative to shad movement has not been fully examined relative to a full range of potential discharge (Dam and Cabot) options that should be considered to achieve shad passage in that project area. The agencies are not limited to flows provided for earlier studies relative to their timing, duration, frequency, and magnitude. Higher discharges than those studied with less competing attraction by the Cabot Power Station, for sustained periods (rather than shifting study treatments), are expected to provide more suitable passage conditions and routes in the bypassed river reach. The power canal diverts up to 15,000 CFS of river flow - from the river in the bypassed reach during the upstream passage season, denying that section of the river (bypassed reach) those flow characteristics present since the last ice age. Fish that are not allowed to pass project areas (in this case to zone of passage flows and fishway efficiency issues) would be expected to start to spawn at some point.

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FLP/GRH, 9/9/19, page 4	38	What is the model sensitivity to specific input values, including upstream passage efficiency, upstream passage duration, downstream adult passage efficiency and duration and downstream juvenile passage efficiency and duration? It is not evident in the Draft Addendum how sensitive the outputs were to inputs and therefore it is impossible to draw conclusions about the relative benefits of defined passage performance criteria compared to other user input options.	Sensitivities are addressed in Stich et al (2018). Similar analyses were performed by Castro-Santos and Letcher (2010) indicating that models are indeed sensitive to some inputs. Downstream passage, marine survival, and movement parameters continue to dominate models, regardless of errors in other inputs.
FLP/GRH, 9/9/19, page 4	39	What is the effect of modeling the same input values for adult and juvenile downstream passage survival (75%, 85%, and 95%)? As described above, natural mortality of post spawned adults increases with migration distance. Additionally, juvenile turbine passage survival is generally high. The Companies recommend separate inputs for juvenile and adult passage survival.	Since receiving these comments we have provided the company with up-to-date versions of the model which allow them to address these questions. The companies were able to conduct there own model runs and comments on those outputs were addressed earlier in the table. Also refer to comment # 20 response to the matter of juvenile survival.

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FLP/GRH, 9/9/19, page 5	40	What is the expected natural mortality of outmigrating post-spawn adults and juveniles and how is that rectified with performance criteria? Stich et al. (2018) incorporated an input distribution for post-spawning survival “with a mean of about 0.80 (95% CI: 0.79– 0.87)”, referencing Raabe and Hightower (2014)8. It is unclear how this is manifested in the Draft Addendum criteria for downstream passage of adult American Shad. If natural post-spawn mortality within a production unit were approximately 20%, downstream passage survival of 95% could be numerically unattainable.	Natural and anthropogenic mortality sources are already included in the model. The point is to separate those processes to provide managers with tools they can use to make decisions.
FLP/GRH, 9/9/19, page 6	41	What was the variability in the various model run outputs? What is the overlap of probabilistic model output among the various input values for upstream and downstream passage survival and duration? Stich et al. (2018) noted that “the modeling approach was stochastic and thus incorporated uncertainty in input parameters, either through estimated precision of empirically derived parameters or by imposing a wide range of potential values over point-estimates where no estimate of precision was available.” As a result, model outputs would be expected to vary both intra- and inter-annually,	Models are available for anyone to run. When the models are run you get variability in the output. This was addressed in the more recent company comment letters following their use of the model and the comments that were responded to earlier (please refer to comments and responses #23 and #24).

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		depending on the range of those input values and the amount of replication in simulations.	
FLP/GRH, 9/9/19, page 6	42	What is the model sensitivity to production potential? Stich et al. (2018) used calculated production potential and presumably the Connecticut River adaptation of the model used production potential as described in Table A1 of CRASC (2017). What is the effect of altering those values?	Ongoing efforts are looking into this. We can assert that the model is sensitive to carrying capacity, because that creates a 'ceiling' above which the population cannot penetrate. As developed we have adopted a conservative value for carrying capacity based on current population sizes. If this were increased to approach theoretical potentials we would expect the model to continue to be sensitive to downstream adult passage, but the importance of expedited upstream passage would likely increase. Mattocks et al (2019) has shown density dependent effects of juvenile shad growth when comparing juveniles from the Holyoke Impoundment to juveniles in either the Turners Falls or Vernon Dam Impoundments.
FLP/GRH, 9/9/19, page 6	43	The Companies' August 30, 2019 comment letter and request for additional information remains our primary response to your solicitation for comments on the Draft Addendum to the CRASMP and it should not be perceived as being replaced by this letter and comments herein. We appreciate the opportunity to comment on the Draft Addendum and urge you and the CRASC to grant our August 30, 2019 request for extension and additional information.	An extension was granted via an email to all parties on September 12, 2019 from Ken Sprankle, providing the very R Code used in the modelling and the power point presentation output of the modeled runs, referenced in the Addendum. The new comment deadline was noted as October 28, 2019. The files were successfully electronically transferred to the companies by the end of the day, September 12, 2019. That would allow 45 days of additional review time.

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FLP/GRH, 8/30/19		The following comments were not included in the 10/28/19 FLP/GRH letter that referenced the 8/30/19 letter and included that letter as Attachment B. There were some instances of 8/30/19 letter comments that were placed directly in the 10/28/19 letter by the companies and were addressed earlier in this summary.	
FLP/GRH, 8/30/19, page 2	44	Request for Additional Time to Comment on Draft Addendum and Improved Transparency Regarding Review Process...it is imperative that the Connecticut River model be fully evaluated by Connecticut River stakeholders, including the Companies, with regard to the sensitivities of the various parameters, along with the values and sources of the parameters included in it.	This was addressed with time extensions and provided data, models, and other information

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FLP/GRH, 8/30/19, page 2	45	..based on the information provided in the Draft Addendum, it is not possible to assess the sensitivity of the model and the variability in output predictions derived from the Commission's application of the model. The supporting narrative section of the Draft Addendum concludes that the second model run showed "the highest upstream passage outputs were tied to the shortest time to pass (24 hours)." However, it is not evident in the Draft Addendum how sensitive the outputs were to changes in time to pass, and therefore it is impossible to make a conclusion about the relative benefit of the 24-hour criteria compared to other user input options. The question of sensitivity to this and other input values is critical to the application of this particular model because the precision of the model's output is a function of the distributions from which the input data are drawn.	This was addressed with time extensions and provided data, models, and other information. We considered other information that is cited and discussed in the Addendum and the memo relative to adult time to pass. The TC approach was to use all available information and determine criteria that would provide the best opportunities to achieve the suite of goals and objective in the Management Plan, given there is uncertainty in many aspects of information (model, environmental in future) that require a precautionary approach but were "achievable". We have numerous references supporting the fact our criteria are achievable and that precedent exists for such criteria, especially in light of preceding decades of shad passage issues in the Northeast (Brown et al. 2013). As mentioned in our response to comment #38, in response to this and similar questions we provided the company with the model and allowed them to explore these questions. The results of their access to this is evident from various other questions that they have posed. Thus we consider this question to be obsolete.
FLP/GRH, 8/30/19, page 2	46	...model outputs would be expected to vary both intra- and inter-annually, depending on the range of those input values and the amount of replication in Monte-Carlo simulations. It is not possible to assess the relative benefits of modeled passage criteria inputs without the context of the stochastic variability and uncertainty projected in the output data.	See comment responses #7, 21, 23, and 24, among others, to address this comment.

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FLP/GRH, 8/30/19, page 2 & 3	47	At the August 8, 2019 Commission meeting, it was noted that the proposed criteria set forth in the Draft Addendum are aspirational, and that CRASC cannot enforce the performance criteria. However, this characterization of the role of the Draft Addendum and the authority of the Commission obscures and minimizes the role of such performance criteria when applied in the various regulatory processes applicable to FERC licensees. The Draft Addendum (page 10) obliquely acknowledges this reality when it states that "...improvements to fish passage at each of these facilities will need to be evaluated against the above stated fish passage performance criteria. Licensees of these projects must develop evaluation study plans in coordination with state and federal resource agencies. The results of these studies will allow licensees and resource agencies to consider structural, technical or operational changes if passage performance falls short of the criteria." (emphasis added). This statement implies the Commission anticipates iterative physical and operational changes may be required throughout a license term if the criteria described in the Draft Addendum are not met. Given the consequential role of performance criteria and the need	We note that CRASC does not have any statutory authority within the Federal Power Act (i.e., FERC) or Clean Water Act (i.e., 401 water quality certification). However, the agencies charged with developing fish passage prescriptions and conditions (through FERC relicensing proceedings) and or 401 Water Quality Certification need management information to guide their recommendations and to be used in those regulatory processes. The extent to which the performance criteria are used will be up to the conditioning agencies, as will the design of evaluations to determine if those criteria are being met. While CRASC cannot enforce performance criteria, agencies within CRASC are free to indicate to FERC that a performance standard is needed. Indeed, FERC is on record stating the following in its Environmental Assessment for the American Tissue project that it issued on June 29, 2018 (Accession # 20180629-3008): "Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities...Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and determining whether effectiveness testing would or would not provide benefits to alosines..." (FERC 2018). The Addendum represents topics and measures managers have studied, documented, developed, and deliberated on as necessary to achieve Management Plan goals and objectives (as currently described, i.e., "minimum population targets").
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EXHIBIT E

		for measures in regulatory proceedings to be based on substantial evidence, it is imperative that any performance criteria adopted in the Draft Addendum are based on an accurate application of the model to the Connecticut River, accepted scientific principles associated with fish passage (including enhancing stock and not merely passage counts and timing), and existing scientific information about American Shad populations in the Connecticut River to ensure that such performance criteria are reasonably attainable and reasonably demonstrable.	
FLP/GRH, 8/30/19, page 3	48	First part of this comment is repeated in #43. If natural post-spawn mortality within a production unit is approximately 20%, downstream passage survival of 95% could be numerically unattainable. Thus, without further clarification from the Commission regarding its adaptations of the model for use on the Connecticut River, the assumption in the Draft Addendum that the performance criteria support safe, timely, and effective passage of American Shad is unsubstantiated	It appears there is confusion on the applied survival rate, that for the model runs was set as "project" passage specific. It does not reflect the applied distance based rate of natural mortality. The project passage survival rate is designed to reflect what is attributed to the "effect" of the project, which may include turbine passage, spill, bypass or other possible routes. Those sources of mortality from encountering a project on outmigration are considered additive. It is the additive sources of project encountered mortality, attributable to for example turbine passage, that can be addressed.

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HGE, 10/28/19, page 1	49	HGE submitted a request for CRASC to implement an extended review/comment period to ensure full consideration of all data and questions presented before the draft Plan is finalized. In addition, HG&E requested a presentation and workshop to address questions regarding the Stich model design, variable inputs and distributions and output variability.	Please refer to comment responses for #11, #12, #13, #14, #15.
HGE, 10/28/19, page 1	50	CRASC's response <i>[refers to providing R code, PowerPoint, and additional 45 days review]</i> did not fully address our questions, nor did it respond to our request to facilitate a workshop so that interested parties could work collaboratively to understand the model. HG&E reattaches its September 9, 2019 letter (Attachment A) to this submission and requests that CRASC address the comments and questions in that submittal as well as those below	Please refer to comment responses for #11, #12, #13, #14, #15.
HGE, 10/28/19, page 1	51	HG&E recommends that CRASC not approve the draft addendum to the Connecticut River American Shad Management Plan for the following specific reasons. 1) The model <i>Shadia</i> is not final or stable at the present time, nor was it final or stable when it was used to develop population projections in the Draft Addendum, according to the model's developer (D. Stich per. comm.). Thus, using it	Please refer to comment responses for #1, #2, and others. We again state the model was one of many pieces of information used by the TC to develop the criteria. It is not accurate to suggest the model was the primary driver for criteria. We have discussed and referenced many additional sources of information (in addition to what is provided in the addendum) that informed the development of the criteria.

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		that model to develop specific passage performance measures is premature and not appropriate, at least until it is final and stable.	
HGE, 10/28/19, page 2	52	The Draft Addendum inaccurately focused on mean population values projected by the model, rather than more appropriately using those projected values to identify population trends (D. Stich per comm.).	Refer to the response of comment #2, #3, and #23.
HGE, 10/28/19, page 2	53	The Draft Addendum failed to represent and account for variability in model output that suggests considerable uncertainty in population projections. Consequently, there is substantial uncertainty and imprecision in the effect of passage performance measures specified in the Draft Addendum.	Refer to the response of comment #3, #4.
HGE, 10/28/19, page 2	54	The model currently includes an unrealistic single, common downstream passage effectiveness/survival input value for both adult and juvenile shad. It should include separate effectiveness/survival input values for each life stage.	Refer to the response of comment #5.

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HGE, 10/28/19, page 2	55	The Draft Addendum failed to present, discuss and seemingly consider the confidence intervals around modeled population projections. Wide confidence intervals indicate both the variability in the model and uncertainty in population projections.	Refer to the response of comment #23 and #24.
HGE, 10/28/19, page 2	56	HG&E understands that FirstLight Power and Great River Hydro have spent considerable time and effort to run the <i>Shadia</i> model and they have concluded that there are multiple scenarios that could result in projected population growth toward meeting the Plan's objectives. For example , as HG&E understand that analysis, the Draft Addendum identified that upstream passage of 75% of adults arriving within 1 km downstream of a hydroelectric project and within 48 hours of arrival, and downstream passage and survival of 95% of adults and juveniles arriving within 1 km upstream of a project within 24 hours of arrival, were necessary to meet the Plan objectives. HG&E understand that FirstLight Power and Great River Hydro's model runs demonstrated that many scenarios could achieve the Plan's objectives. On that basis, HG&E agrees with FirstLight Power and Great River Hydro's conclusions that the <i>Shadia</i> model does not support	Refer to the response of comment #23, #24 and #27. HGE comments that along with the other companies the model does not support the criteria in the plan. We disagree as the model has shown that population is most sensitive to downstream passage survival when considering achieving upstream passage "minimum" passage targets to upstream of Vernon. In addition, the model was sensitive to "time to pass" for upstream passage. We have covered these topics in other previous responses - most notably that the model was one of many pieces of information used by the TC to develop the criteria. It is not accurate to suggest the model was the primary driver for criteria. We have discussed and referenced many additional sources of information (in addition to what is provided in the addendum) that informed the development of the criteria. Additionally the company outputs are based on "minimum" levels currently in the Plan (also discussed at length in earlier responses). Given wide confidence intervals we also as managers seeking to restore this population must take a precautionary approach in interpreting both data and model outputs (refer to comment response #24 and #27).

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		passage performance criteria in the Plan.	
HGE, 10/28/19, page 2	57	HG&E believes that going forward there is a need for transparency by the establishment of a working group to collaboratively assess relative value of modeled scenarios that includes HG&E, FirstLight Power and Great River Hydro.	Refer to the response of comment #8 and #19.
HGE, 10/28/19, page 2	58	Over the past 18 years, HG&E has spent tens of millions of dollars on American shad passage and has a significant interest in ensuring that the Draft Addendum is supported by sound scientific principles and existing scientific information regarding Connecticut River American Shad - before it is approved and finalized.	We agree that HGE has taken important and appropriate steps to improve up- and downstream fish passage and has done so in a collaborative approach. We also agree that all measures undertaken to improve passage should supported by sound scientific principles. See comment response #47.
HGE, 10/28/19, page 3	59	As indicated in the August 30, 2019 letters from all three Project owners (HG&E, FirstLight Power and Great River Hydro) directly impacted by this Plan, transparency is needed in regards to the Stich model design, variable inputs and distributions, and output variability. Therefore, HG&E renews its request for a model workshop and	Refer to the response of comment #6, # 8, #11, and #44.

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		further requests a full review and response to the questions in this letter.	
Stira, 9/5/19, page 1	60	Operators of fish passage facilities would be faced with demonstrating that the performance of their facilities meets the criteria presented in the Addendum. In some cases that would likely be impossible, given the limitations of current evaluation technologies. For example, the criteria for downstream passage of juvenile American shad stipulate that a minimum of 95% of emigrating juveniles that enter a hydro project area pass downstream through the project within 24 h and survive passage. To my knowledge there is no method available to verify that a project's facilities meet these criteria. Because of the small size and 'fragility' of juvenile shad, telemetric methods cannot be used with confidence since those methods would likely alter the behavior of tagged fish and bias the results of an evaluation. Another approach would be to estimate survival after turbine passage, which may exceed 95%, but researchers have had difficulty holding 'control' fish for	We disagree that the company could not design and conduct studies to demonstrate whether they are meeting passage criteria, it can be done and those studies can provide the necessary information as referenced in our memo with recent examples for Conowingo fish passage and York Haven fish passage (USFWS 2016; Patrizia 2014). The use of radio tagging technology includes micro tags (JSATS) and other smaller tag types in addition to PIT tags (balloon tags for turbine studies) may all be used (have been and are being used) to design suitable studies to obtain necessary data to assess project arrival, passage and survival (TransCanada 2017) . The FERC supports the use of such technologies and approaches to evaluate fish passage performance and fish survival as they should. Criteria on juvenile downstream passage may be also be assessed on the USFWS Turbine Blade Strike model, with discussion on the need for additional balloon tagging studies as a means to obtain additional information. Balloon tagging studies for juvenile shad have been routinely approved by FERC. However, as noted, the ability to determine delayed mortality (>24 hr) with balloon tag juvenile fish has not been successful due to the inability maintain controls beyond 24 hours. There are design and technology limitations in all aspects of fishery science management and research, an understanding of those limitations is important in the interpretation of the data and analyses that can be and has been part of the process of dealing with hydropower's impacts to our nation's diadromous fishery resources.

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		long periods. Without control survival, survival of fish after passage through the turbines cannot be calculated. In addition, a survival study would not yield data relative to the 24-h criterion. Why include criteria with which operators will not be able to demonstrate compliance?	
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Stira, 9/5/19, page 1	61	There are other issues raised by the criteria, such as the question of the declining condition of adult shad the farther they migrate upriver and the effect longer migration may have on post-spawning mortality and the likelihood of repeat spawning. The poorer the condition of the fish the less likely it may be to survive downstream passage through open river, much less through even a highly efficient passage facility. Operators should not be held accountable for 'natural' mortality.	CRASC's interest is reducing anthropogenic sourced mortality to the extent practicable to allow population restoration and achieve Management Plan goals and objectives. We do not suggest that companies should be accountable for natural mortality, only project related mortality impacts (immediate/short term and delayed from injury) that are know to occur. American Shad population exhibit varied life history characteristics. Population dynamics modeling and the use of parameter based on best information are better informing our understanding of the repeated exposure to delays on upstream passage as well as additive project specific mortality from downstream project passage. It is clear from those data that delay and whole river survival are serious management concerns for successful restoration (CRASC 2017, ASMFC 2007, ASMFC 2010). However, we have advanced significantly in our understanding of biological and engineering requirements for upstream and downstream fish passage of shad. We agree spent downrunning adults are on reduced energy reserves. This fact provides support for establishing the stringent downstream safety standards and preventing turbine passage
Stira, 9/5/19, page 2	62	The Addendum does not indicate how an operator would verify that it meets the criteria. Would one evaluation in one year showing the criteria have been met be sufficient, or would verification be required annually? The latter might impose an unreasonable burden on the operator.	That would be best left to the agencies in charge of conditioning and prescription authorities. An example of how this has been answered can be found in several examples, the first from York have Project on the Susquehanna River, within the Settlement Agreement that details responses to this for American Shad criteria (Patrizia 2014). A second includes the USFWS (2016) Fish Passage Prescriptions for the Conowingo Hydroelectric Project, also requiring achievement of shad passage criteria of the Susquehanna River Anadromous Fish Restoration Committee with details on evaluations. Other examples of criteria use and evaluations exist within the State of Maine FERC projects where anadromous Atlantic Salmon occur (NOAA) as well as the West Coast where Pacific Salmonids occur (NOAA).

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Stira, 9/5/19, page 2	63	Meeting the passage criteria would depend on the interplay of all factors, so failure to meet the criteria, especially for upstream passage, might have more to do with factors outside of a facility operator's control than with facility design and/or operation.	The TC understands that some factors are outside of project control and will need to be addressed by the regulatory agencies, FERC and owner operators in processes outside of the CRASC authority. We provided a number of examples and references in the memo for this table regarding the ability to achieve this passage rate and the fact criteria are in place for several species including shad (Susquehanna 85% upstream passage efficiency required) as well as noting the USFWS Section 18 for Conowingo (USFWS 2016) and the Settlement Agreement for York Haven (Patrizia 2014) that include evaluations of these. Also refer to response to comment #64.
Stira, 9/5/19, page 2	64	At the CRASC meeting of 8 August, one of the writers/reviewers said that the Addendum was "aspirational" in nature. If that's the case, an explicit statement to that effect should be included in the document. The Addendum will likely be used in regulatory proceedings, and all parties should be clear on the intent of the criteria.	We note that CRASC does not have any statutory authority within the Federal Power Act (i.e., FERC) or Clean Water Act (i.e., 401 water quality certification). However, the agencies charged with developing fish passage prescriptions and conditions (through FERC relicensing proceedings) and or 401 Water Quality Certification need management information to guide their recommendations and to be used in those regulatory processes. The extent to which the performance criteria are used will be up to the conditioning agencies, as will the design of evaluations to determine if those criteria are being met

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Stira, 9/5/19, page 3	65	Development of documents such as the Addendum would benefit from more representation from the private sector. The operators themselves may employ biologists to support fish passage at their facilities, and there are many biologists working for companies contracted to evaluate fish passage. These individuals have accumulated decades of experience in evaluating facilities relative to passage criteria and could have contributed to the development of the Addendum. Private sector involvement might also help avoid ‘groupthink’, a hazard for all organizations. At the very least, if Trout Unlimited is asked to contribute, shouldn’t the operators have been asked to do the same?	The CRASC Shad Plan Team was developed by the CRASC agency members and additional individuals that were considered to be helpful in advancing the CRASC Plan goals and objectives were asked to contribute in this effort.
Stira, 9/5/19, page 3	66	As an aside, hydro operator involvement in the workings of CRASC has declined steadily over time. In the past, operator representatives had a seat at the table at meetings of CRASC and its predecessor (though without ‘official’ recognition), and operators were asked to participate on CRASC Technical Committee subcommittees. At present, there is no similar interaction between the operators and CRASC, which seems odd given the major role the operators have in meeting CRASC’s goals for fish passage.	CRASC Commission and TC meetings are open to the public.

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Meyer, 9/9/19, page 1	67	Results from long-range studies and annual fish passage totals across more than four decades of fishway monitoring underscore the failures of restoration at key ecosystem sites—particularly in the Turners Falls Pool. Thus, Vermont, New Hampshire and northern Massachusetts have never benefited to any meaningful extent in the migratory fisheries restoration of shad on the Connecticut.	Fish passage had been established through earlier agency actions in the 1970s (primarily) and also in the 1980 and 1990s, and have since included FERC relicensing and Settlement Agreements (e.g., Holyoke). Initial fishway designs were approved using in some cases the approaches and information available at that time from West Coast designs (e.g., Ice Harbor design). We agree it is time to fully utilize all available information to better address those factors that are negatively impacting the resource and that includes using performance criteria for improved passage and protections that are achievable and can address project related impacts that impact the agencies ability to achieve management plan goals and objectives.
Meyer, 9/9/19, page 1	68	The time for facilities operators to comply with fish passage statutes has come due, given the federal relicensing of 5 main stem operations on the Connecticut currently underway	The FERC process is underway for the noted projects. Other projects are also soon to be up for relicensing.
Meyer, 9/9/19, page 2	69	The Anadromous Fish Conservation Act, Public Law 89-304, was adopted by Congress in 1965, two years before the states and federal fish agencies signed the “ <i>1967 Statement of Intent for a Cooperative Fishery Restoration Program for the Connecticut River Basin.</i> ” The first species mentioned in that document is <i>Alosa sapidissima</i> , American shad. Original restoration targets for the species were: “one million fish at Holyoke; 850,000 at Turners Falls; and 750,000 at Vernon.”	The agencies have adjusted projected adult run sizes from the initial Program years (1960s), but as we have noted in our responses, we believe our current targets to be minimum population targets and that as habitat access is provided and the population is allowed to respond, assessments and more current data may justify increases to current plan minimum targets (as discussed in the Plan and in previous responses).

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Meyer, 9/9/19, page 2	70	Shad populations on many East Coast Rivers have plummeted over the past half century. Fortunately, with the long-term success of the very basic fish lifts at Holyoke Dam, the Connecticut has shown some resilience and tenacity in retaining shad runs in the lower parts of the basin. But, ecosystem restoration for American shad and other migratory species has essentially failed across those same decades in all the upstream pools—commencing with the choke point at the Turners Falls dam, canal, and by pass reach of river.	The Addendum and its criteria are not project specific, it is to be applied to the basin in support of achieving Management Plan goals and objectives. The TC concurs that both upstream and downstream passage needs to be addressed and have provided a number of responses supporting these statements in addition to the memo.
Meyer, 9/9/19, page 2	71	...studies and ongoing investigations of the habitat and impoundments upstream of Turners Falls Dam point to the critical loss of millions of eggs and juveniles due to entrainment at the Northfield Mountain Pumped Storage Station. Couple this with upstream passage failures and downstream mortality estimates for adult shad—leading to the critical loss of repeat spawners that are necessary to bolster spawning success and grow the shad population as these robust recruits return to spawn in successive seasons, and you have a recipe for another failing shad population on another US River.	The Addendum does not address egg and larval fish entrainment. Study results at Northfield Mountain Pumped Storage does show entrainment of shad eggs, shad larvae, and juvenile shad. Fish passage designs and criteria have not been applied to eggs and larvae. The CRASC Plan does note the importance and ecological value of juvenile shad (not simply adult abundance alone). The TC does believe downstream passage protections for juveniles at NMPS are necessary and should be developed, to meet the 95% "through project" - passing survival. Pumped storage does not fall under "entrainment" regulations that are applied to other river users that pull water from the river (such as cooling water) that does require permits and possible considerations for losses at those early life stages.

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Meyer, 9/9/19, page 2	72	I am fully in support of the CRASC's science and results-based <i>American Shad Passage Performance Plan.</i>	
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RESEARCH ARTICLE SUMMARY

WILDLIFE DISEASE

Hunting the eagle killer: A cyanobacterial neurotoxin causes vacuolar myelinopathy

Steffen Breinlinger*, Tabitha J. Phillips*, Brigitte N. Haram, Jan Mareš, José A. Martínez Yerena, Pavel Hrouzek, Roman Sobotka, W. Matthew Henderson, Peter Schmieder, Susan M. Williams, James D. Lauderdale, H. Dayton Wilde, Wesley Gerrin, Andreja Kust, John W. Washington, Christoph Wagner, Benedikt Geier, Manuel Liebeke, Heike Enke, Timo H. J. Niedermeyer†‡, Susan B. Wilde†‡

INTRODUCTION: Vacuolar myelinopathy (VM) is a neurological disease characterized by widespread vacuolization in the white matter of the brain. First diagnosed in 1994 in bald eagles, it has since spread throughout the southeastern United States. In addition to avian species such as waterfowl and birds of prey, VM has also been found to affect amphibians, reptiles, and fish. Despite intense research efforts, the cause of this mysterious disease has been elusive. Neither contagious agents nor xenobiotics were detected in deceased animals, but field and laboratory studies demonstrated that VM can be transferred through the food chain from herbivorous fish and wildlife to birds of prey.

RATIONALE: Occurrence of VM has been linked to a cyanobacterium (*Aetokthonos hydrillicola*) growing on an invasive plant (*Hydrilla verticillata*) in man-made water bodies. Cyanobacteria are known to produce potent toxins, so we hypothesized that a neurotoxin produced by the epiphytic cyanobacterium causes VM.

RESULTS: Field studies in the southeastern United States confirmed that *H. verticillata* was colonized with *A. hydrillicola* in more than half of the watersheds. Wildlife VM deaths occurred only in reservoirs with dense *H. verticillata* and *A. hydrillicola* populations. Laboratory bioassays confirmed the neurotoxicity of crude extracts of *A. hydrillicola*–*H. verticillata*

biomass collected during VM outbreaks, but neurotoxicity was not detected in samples from VM-free sites. Laboratory cultures of the cyanobacterium, however, did not elicit VM. *A. hydrillicola* growing on *H. verticillata* collected at VM-positive reservoirs was then analyzed by mass spectrometry imaging, which revealed that cyanobacterial colonies were colocalized with a brominated metabolite. Sup-

plementation of an *A. hydrillicola* laboratory culture with potassium bromide resulted in pronounced biosynthesis of this metabolite. *H. verticillata* hyperaccumulates bromide from the environment, potentially supplying the cyanobacterium with this biosynthesis precursor. Isolation and structure elucidation of the metabolite revealed a structurally unusual pentabrominated biindole alkaloid, which we called aetokthonotoxin (AETX). Genome sequencing of *A. hydrillicola* allowed the identification of the AETX biosynthetic gene cluster. Biochemical characterization of a halogenase detected in the cluster demonstrated that it brominates tryptophan with the expected substitution pattern. AETX is highly toxic to the nematode *Caenorhabditis elegans* [median lethal concentration (LC₅₀) 40 nM] and zebrafish (*Danio rerio*; LC₅₀ 275 nM). Leghorn chickens (*Gallus gallus*) gavaged with AETX developed brain lesions characteristic of VM, whereas no lesions were observed in control chickens. VM diagnosis in treated chickens was verified using transmission electron microscopy of brain tissue.

CONCLUSION: We confirmed that AETX is the causative agent of VM. AETX biosynthesis relies on the availability of bromide. Seasonal environmental conditions promoting toxin production of *A. hydrillicola* are watershed specific. The consequences of elevated bromide from geologic and anthropogenic sources (e.g., water treatment and power plants) on VM should be further investigated. Notably, integrated chemical plant management plans to control *H. verticillata* should avoid the use of bromide-containing chemicals (e.g., diquat dibromide). AETX is lipophilic with the potential for bioaccumulation during transfer through food webs, so mammals may also be at risk. Increased monitoring and public awareness should be implemented for *A. hydrillicola* and AETX to protect both wildlife and human health. ■

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**From the cyanobacterium to the bald eagle—
 toxin transmission through the food chain.**

A. hydrillicola, growing in colonies on aquatic vegetation, produces the neurotoxin AETX. Waterbirds, tadpoles, aquatic turtles, snails, and fish consume this contaminated vegetation and develop VM. Predators develop VM when they consume animals that have been grazing on *A. hydrillicola*–covered plants.



RESEARCH ARTICLE

WILDLIFE DISEASE

Hunting the eagle killer: A cyanobacterial neurotoxin causes vacuolar myelinopathy

Steffen Breinlinger^{1*}, Tabitha J. Phillips^{2*}, Brigitte N. Haram², Jan Mareš^{3,4,5}, José A. Martínez Yereña^{3,5}, Pavel Hrouzek^{4,5}, Roman Sobotka^{4,5}, W. Matthew Henderson⁶, Peter Schmieder⁷, Susan M. Williams⁸, James D. Lauderdale⁹, H. Dayton Wilde¹⁰, Wesley Gerrin², Andreja Kust³, John W. Washington⁶, Christoph Wagner¹¹, Benedikt Geier¹², Manuel Liebecke¹², Heike Enke¹³, Timo H. J. Niedermeyer^{1††}, Susan B. Wilde^{2††}

Vacuolar myelinopathy is a fatal neurological disease that was initially discovered during a mysterious mass mortality of bald eagles in Arkansas in the United States. The cause of this wildlife disease has eluded scientists for decades while its occurrence has continued to spread throughout freshwater reservoirs in the southeastern United States. Recent studies have demonstrated that vacuolar myelinopathy is induced by consumption of the epiphytic cyanobacterial species *Aetokthonos hydrillicola* growing on aquatic vegetation, primarily the invasive *Hydrilla verticillata*. Here, we describe the identification, biosynthetic gene cluster, and biological activity of aetokthonotoxin, a pentabrominated biindole alkaloid that is produced by the cyanobacterium *A. hydrillicola*. We identify this cyanobacterial neurotoxin as the causal agent of vacuolar myelinopathy and discuss environmental factors—especially bromide availability—that promote toxin production.

Over the winter of 1994 to 1995, the largest undiagnosed mass mortality of bald eagles (*Haliaeetus leucocephalus*) in the United States occurred at DeGray Lake in Arkansas (1). More than 70 dead eagles were found in the next 2 years. The mysterious mortalities were characterized by a spongiform myelinopathy that had never been documented in wild avian populations (2, 3). Investigators of the Arkansas die-off began to notice eagles and waterbirds with similar neurological impairment throughout the southeastern states. By 1998, the emerging disease was termed avian vacuolar myelinopathy (AVM) and had been confirmed at 10 sites in six states (1). AVM

has since been documented in numerous avian species across the southeastern United States during the fall and winter, most notably in waterbirds such as American coots (*Fulica americana*), ringnecked ducks (*Aythya collaris*), mallards (*Anas platyrhynchos*), and Canada geese (*Branta canadensis*) and in various birds of prey (3–7). All documented AVM cases were recovered on or near man-made water bodies with abundant aquatic vegetation that senesces during the late fall and winter months (3–7). The abundance of fish and avian prey associated with these aquatic plants attracts overwintering and nesting bald eagles and other birds of prey (8–10). AVM-afflicted wildlife are prone to injury and become easy prey for predators, as clinical signs of the disease include the severe loss of motor functions (movie S1 shows affected American coots) (2, 10). Although neurological impairment is a visual indication of disease, AVM diagnosis relies on histological confirmation of widespread vacuolization of the myelinated axons (intramyelinic edema) in the white matter of the brain and spinal cord (1).

Early sentinel field trials documented neuropathy and vacuolar lesions in wild coots and mallards within 5 days of release into a lake with an ongoing AVM epizootic (4–6). Initial chemical analysis of sediment and dead birds recovered from reservoirs where AVM cases were documented revealed no xenobiotic compounds known to induce intramyelinic edema in mammals and birds—e.g., hexachlorophene, triethyltin, or bromethalin (1, 11, 12). Early laboratory feeding trials using plants, water, and sediment collected from disease sites

failed to induce the neuropathy and vacuolar lesions seen in wild birds (13, 14). Additionally, no contagious transfer, pathogens inducing myelinopathy, or neuroinflammation were documented in wild or experimental AVM-affected animals (12, 13). These early studies suggested that an unknown, seasonal, and environmental neurotoxin could be responsible (14, 15).

The search for the elusive source of this disease then focused on environmental conditions in AVM-positive water bodies, which revealed that all of them supported invasive submerged aquatic vegetation, primarily *Hydrilla verticillata*, with a previously unidentified epiphytic cyanobacterium—*Aetokthonos hydrillicola*—colonizing up to 95% of the plant leaves (16–18). Field and laboratory studies demonstrated that AVM could be transferred up the food chain. It is induced in herbivorous waterbirds after ingestion of *H. verticillata* colonized by *A. hydrillicola* and in birds of prey that consume the affected waterfowl (9, 16, 19, 20). Not only does AVM present an emerging threat to the Southeast's avian species (5, 6), but subsequent field and laboratory *H. verticillata*–*A. hydrillicola* feeding trials have confirmed neuropathy and mortality in a wide variety of taxa, including amphibians, reptiles, and fish, as well as secondary disease transfer through the food chain. Thus, the disease is now referred to as vacuolar myelinopathy (VM) (21–24).

Cyanobacteria have long been associated with the production of toxins and other specialized metabolites (25–29). We hypothesized that a neurotoxin produced by the epiphytic cyanobacterium *A. hydrillicola* is the causative agent of VM. Here, we present our evidence that VM is caused by a cyanobacterial neurotoxin with notable structural features. In addition to discovering the neurotoxin, we have identified its biosynthetic gene cluster and present toxicity data on model birds, fish, nematodes, and crustaceans. Finally, we discuss environmental factors that promote toxin production.

Results

A. hydrillicola distribution

Sampling of submerged aquatic vegetation in lakes, reservoirs, and other water bodies throughout the southeastern United States has revealed a complex and widespread pattern of *A. hydrillicola* distribution (16–18). As of fall 2019, we documented *H. verticillata* colonized with *A. hydrillicola* in 31 of 69 sampled watersheds (Fig. 1 and table S1). Water bodies include large (>10,000 ha) hydropower or water-supply reservoirs, county water-source reservoirs, suburban recreational lakes, and farm ponds. Given the difficulty of documenting animals dying from VM and the extensive spread of invasive *H. verticillata*, our current

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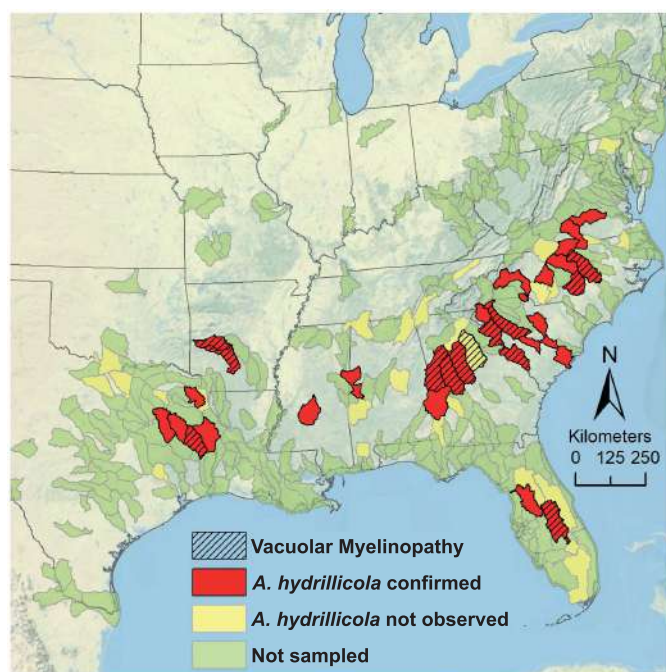


Fig. 1. VM occurs in watersheds where *A. hydrillicola* colonizes *H. verticillata*. Watersheds where VM has been diagnosed (indicated by black crosshatching). Watersheds where *H. verticillata* has been confirmed to be colonized with *A. hydrillicola* are shown in red, and watersheds where *A. hydrillicola* has not yet been observed on *H. verticillata* are shown in yellow. Watersheds not yet screened for *A. hydrillicola*, but where *H. verticillata* occurs, are shown in green. Base map: copyright 2013 from the National Geographic Society.

map of *A. hydrillicola* distribution is certainly underestimating the prevalence of the cyanobacterium and its threat to endemic wildlife, fish, and freshwater resources.

Discovery and production of the putative toxin

In 2011, we collected *H. verticillata* with epiphytic *A. hydrillicola* from the J. Strom Thurmond Reservoir (in Georgia and South Carolina) to isolate the cyanobacterial strain for mass cultivation and subsequent isolation of the putative cyanotoxin. As a result of challenges in establishing culture conditions for this epiphytic colonizer, it took 2 years to generate sufficient *A. hydrillicola* biomass for a first feeding trial. The identity of the strain was confirmed as *A. hydrillicola* by 16S ribosomal RNA sequencing. However, chickens gavaged with this *A. hydrillicola* biomass did not develop VM, which failed to support that *A. hydrillicola* was producing a VM-inducing toxin.

Hypothesizing that the cyanobacterium produces the hypothetical toxin only when growing on *H. verticillata*, but not in laboratory culture, we collected additional samples of *A. hydrillicola* growing on *H. verticillata* at confirmed VM sites. The cyanobacterial colonies on the *H. verticillata* leaves were analyzed by atmospheric-pressure matrix-assisted laser desorption/ionization mass spectrometry imaging (AP-MALDI-MSI) to detect cyanobacteria-specific metabolites in situ. Using AP-MALDI-MSI, we could colocalize the cyanobacterial colonies with a metabolite with the sum formula $C_{17}H_6Br_5N_3$ (Fig. 2, A to D), which was not detectable in laboratory cultures by high-performance liquid chromatography-

mass spectrometry (HPLC-MS). Neither commercial (Dictionary of Natural Products 28.2, SciFinder) nor in-house natural product databases revealed an entry for this elemental composition, which suggests that it is a novel natural product. The fact that the metabolite contains five bromine atoms is notable, as polyhalogenated synthetic compounds, such as bromethalin or hexachlorophene, are known to induce VM-like brain lesions in birds and mammals (1, 5, 11, 30).

The presence of bromine in the putative toxin presented a potential explanation for why our laboratory cultures of the cyanobacterium did not cause VM. Our standard cultivation medium, BG11, does not contain any bromide, which is critical for the biosynthesis of the toxin. Supplementation of the cultivation medium with potassium bromide resulted in the pronounced biosynthesis of this pentabrominated metabolite. We found a nonlinear relation between bromide concentration in the medium and the production of the pentabrominated metabolite by the cyanobacterium. We determined that the optimum bromide concentration for productivity is between 0.1 and 0.5 mM KBr (fig. S1).

Although a minor production can readily be detected by HPLC-MS once the medium is supplemented with bromide, we observed a substantial increase in production under stress conditions. A drop in temperature (from cultivation at 28°C down to 21°C) or enhanced culture movement (shear stress) trigger metabolite production to an extent (>100-fold) that it becomes easily detectable by HPLC-UV (ultraviolet, detection at 286 nm) (figs. S2 and S3).

Hypothesizing that this pentabrominated metabolite was the putative toxin, we screened *A. hydrillicola*-*H. verticillata* assemblages collected from lakes during VM outbreaks using HPLC-MS and compared them with biomass from VM-free sites (where *H. verticillata* was not colonized with *A. hydrillicola*). We could detect this metabolite only in biomass collected from VM-affected lakes, which strengthened our hypothesis (fig. S4). Furthermore, the compound could be detected in the tissues of two deceased wild American coots collected during an AVM outbreak at the J. Strom Thurmond Reservoir (Georgia) in November 2014 (fig. S5), which confirmed that the compound is absorbed from the gut and accumulates in wild waterfowl. Additionally, we observed a seasonal variation of the toxin concentration in *A. hydrillicola*-*H. verticillata* biomass collected from J. Strom Thurmond Reservoir, with the peak concentration detected in November (fig. S6). This observation agrees with the finding that VM occurrences have been documented in late autumn in reservoirs, coinciding with seasonal water temperature declines and lake turnover.

As the biosynthesis of the pentabrominated metabolite requires bromide, we investigated bromide availability in *A. hydrillicola* habitats. Total bromine content in *H. verticillata* and sediments as well as the bromide concentration in water from VM-positive (containing *H. verticillata* colonized by *A. hydrillicola*) and VM-negative (containing only uncolonized *H. verticillata*) reservoirs was monitored seasonally. Colonized and uncolonized *H. verticillata* leaves contain significantly ($P < 0.001$) higher concentrations of bromine than sediments (~20-fold) and water (500- to 1000-fold) (fig. S7). In late summer, southeastern U.S. reservoirs are stratified, with warm, sunlit, and oxygenated water above and cool, dark, and anoxic water trapped below. During late fall, surface water temperatures cool, water layers mix, and *H. verticillata* senesces. We propose that this seasonal shift provides a bromide-enriched local environment, which ultimately triggers *A. hydrillicola*'s production of the elusive toxin.

Isolation and structure elucidation of aetokthonotoxin (AETX)

Cultivation of *A. hydrillicola* with bromide supplementation as well as field collections of *A. hydrillicola*-*H. verticillata* assemblages allowed us to isolate the compound in sufficient amounts for structure elucidation and bioactivity characterization. Because of the proton deficiency of the compound, extensive nuclear magnetic resonance (NMR) and infrared spectroscopic as well as high-resolution mass spectrometric analyses were required to elucidate its structure, which was confirmed by x-ray crystallography (Fig. 3, supplementary

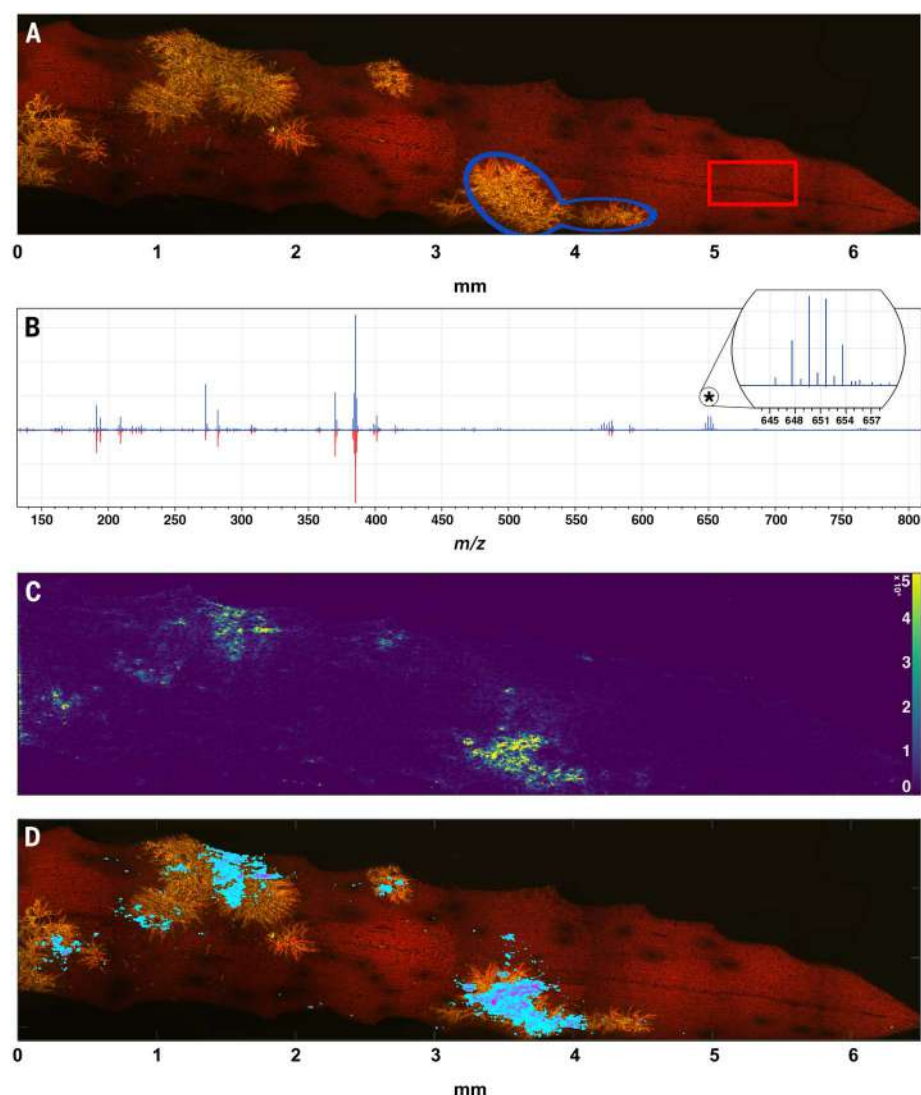


Fig. 2. AP-MALDI-MSI of *A. hydrillicola* colonies growing on *H. verticillata* reveals a cyanobacterium-specific metabolite. (A) Micrograph of *A. hydrillicola* colonies on *H. verticillata* leaf. Autofluorescence (excitation, 395 to 440 nm; emission, 470 nm) was used to acquire the image. Regions of interest for evaluation of the subsequent MSI experiments are shown bordered in red (leaf without cyanobacterium) and blue (cyanobacteria colony on the leaf). (B) Comparison of mean mass spectra of the two regions of interest. The enlarged region shows the characteristic isotope pattern of the pentabrominated metabolite at a mass/charge ratio (m/z) of 645 ($[M - H]^+$). This molecule is exclusively found to be associated with the cyanobacterial colony. (C) AP-MALDI image showing the spatial distribution of the distinct feature m/z 649.6382 $\pm$ 2 parts per million (ppm) ($[C_{17}H_6^{79}Br_3^{81}Br_2N_3 - H]^+$). Intensity is scaled from 0 (violet) to 5 $\times 10^4$ (yellow). (D) Overlay of micrograph and m/z feature 649.6382 $\pm$ 2 ppm.

text, fig. S13, and tables S4 to S9). The structure has notable chemical features. Most prominent—also evident from the isotope pattern observed in mass spectrometry analyses of the compound—are the five bromo substituents. Brominated organic compounds are often found to be produced by marine organisms but are also found in plants, fungi, lichen, bacteria, and even humans (31–33). Several bromoindoles have been isolated from natural sources (34). Tyrian purple, one of the first brominated indole alkaloids to have been

discovered, is not only the most famous example, it is also a 2,2'-biindole (35). Many brominated organic compounds exhibit strong bioactivity, ranging from antifungal to antimicrobial to antioxidant activity (36). Synthetic representatives have lately become infamous as environmental pollutants (37): Because of their lipophilicity, they tend to accumulate in sediment and biota, where they can pose a serious threat to ecosystems (38, 39). Another notable chemical feature of the compound is the connection of the two indole moieties via

N1 and C2'; to date, no natural 1,2'-bi-1H-indole has been described. The two indole substructures present in AETX are rare in natural products. The 2,3,5-tribromoindole substructure has only been described from red algae of the genera *Laurencia* and *Nitophyllum* (40), the mollusk *Aplysia dactylomela* (likely because of its red-algal diet) (41), and the cyanobacterium *Rivularia firma*, which produces numerous structurally related brominated 1,3'-, 3,3'-, and 3,4'-bi-1H-indoles (42). 5,7-Dibromoindole-3-carbonitrile has not yet been found as a natural product substructure. Indole-3-carbonitrile without additional substituents has only been described once as a natural product, isolated from a halophilic bacterium probably belonging to the genus *Bacillus* (43). On the basis of the systematic name of the cyanobacterium, *A. hydrillicola* (which is Greek for “eagle killer residing on *Hydrilla*”), we called this compound aetokthonotoxin (AETX), or “poison that kills the eagle” [from the Greek *ἀετός* (*āetós*), eagle; *κτείνω* (*kteínō*), to kill; and *τοξικόν* (*toxikón*), toxin].

AETX biosynthesis

Because of the specific structure of AETX, which illustrates several chemical features not previously observed in nature, we investigated its biosynthesis. Biosynthetic machineries of most cyanotoxins are organized in compact gene clusters, which can be linked to the resulting structures by functional annotation. Thus, we sequenced the whole genomes of two independent *A. hydrillicola* strains isolated from J. Strom Thurmond Reservoir in 2011 (confirmed to produce AETX, as described above) and 2014 and subsequently performed a bioinformatic analysis. Both sequenced genomes contain an identical gene cluster consisting of six deduced genes (*aetA* to *aetF*), whose annotated functions imply their involvement in AETX biosynthesis (Fig. 4A). BLAST searches against all available genomes in the National Center for Biotechnology Information (NCBI) database did not show the presence of a similar gene cluster sequenced to date (as of October 2020). The genomic regions adjacent to the candidate gene cluster contained other cyanobacterial genes, and the deduced proteins within the cluster had closest relatives in cyanobacteria (table S10), corroborating its cyanobacterial origin.

The gene *aetE* was predicted to encode a tryptophanase (fig. S37 and table S10)—a well-studied enzyme responsible for the conversion of tryptophan to indole (44). This provides a viable hypothesis to explain the origin of the two indole cores in AETX from tryptophan (or a tryptophan-derived intermediate of the pathway). Two genes, *aetA* and *aetF*, were predicted to encode NAD(P)/FAD-dependent halogenases related to known halogenases involved in the biosynthesis of cyanobacterial

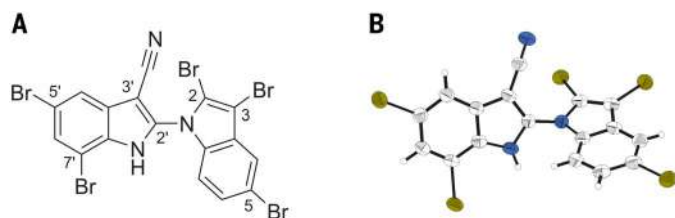


Fig. 3. AETX is a pentabrominated biindole alkaloid. (A and B) Structure (A) and x-ray crystallography structure (B) of AETX.

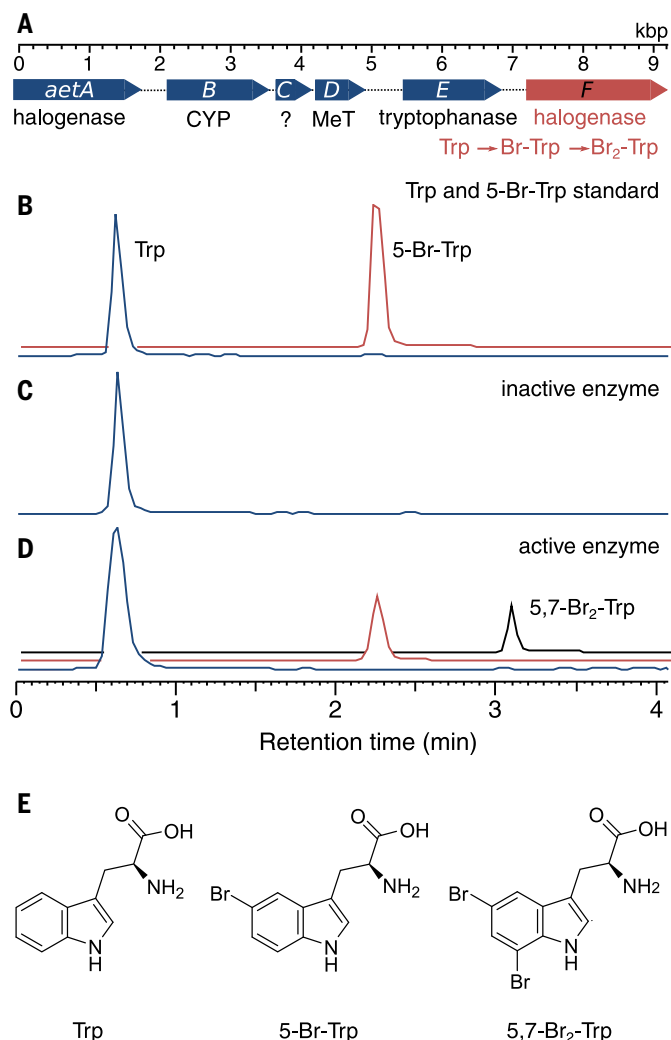


Fig. 4. The halogenase AetF encoded in the AETX gene cluster brominates tryptophan. (A) Map of the 9.23-kilobase pair (kbp) AETX biosynthetic gene cluster consisting of six predicted genes coding for two halogenases, a cytochrome P450 (CYP), a tentative methyl-transferase (MeT), a tryptophanase, and a single unknown protein. (B to E) HPLC-MS analysis (extracted ion chromatograms) of authentic standards compared with the reaction mixtures of assays with fresh and heat-inactivated purified His-AetF ($N = 3$). (B) L-tryptophan [Trp; retention time (t_r) 0.73 min] and 5-bromo-L-tryptophan (5-Br-Trp; t_r 2.26 min) standards. (C) Heat-inactivated His-AetF does not brominate L-tryptophan. (D) Functional His-tagged AetF brominates L-tryptophan to 5-bromotryptophan and 5,7-dibromotryptophan (5,7-Br₂-Trp; t_r 3.03 min), proving the tryptophan brominase activity of AetF in vitro. (E) Structures of the detected tryptophan variants (L-tryptophan, 5-bromotryptophan, and 5,7-dibromotryptophan).

metabolites (45, 46) (table S10). Besides *aetA* and *aetF* from the *aet* cluster, bioinformatic analysis of the *A. hydrophilica* genome did not reveal any other homologs to known bacterial tryptophan halogenases organized in a bio-

synthesis gene cluster, which further supports their involvement in AETX biosynthesis. The presence of two distinct halogenases could explain the different substitution patterns of the two indole cores of the AETX molecule,

which could be achieved by two or more subsequent (poly)halogenation reactions.

To test this hypothesis and provide initial mechanistic evidence for the role of the *aet* gene cluster in AETX biosynthesis, we assessed the activity of the putative halogenase AetF in *in vitro* experiments. Assays containing recombinant AetF and L-tryptophan as substrate showed the formation of two brominated products (Fig. 4, B to E). The high yield of recombinant AetF from *Escherichia coli* (fig. S36) allowed us to conduct a larger-scale *in vitro* assay with yields of both brominated products sufficient for isolation. Subsequent NMR analysis of the products unambiguously confirmed that AetF is capable of bromination of tryptophan at positions 5 and 7, which exactly matches the substitution pattern observed in one of the AETX indole substructures (figs. S39 to S47). Additional *in vitro* assays showed that indole is not a substrate of the enzyme, but 5,7-dibromoindole was obtained when 5-bromoindole was provided to AetF (fig. S38). On the basis of these data, we conclude that tryptophan is the primary substrate for AetF, as the enzyme is capable of introducing bromine into unsubstituted tryptophan. The additional AetF bromination activity on 5-bromoindole could result from its steric similarity to 5-bromotryptophan, which we found to be an intermediate of the stepwise bromination of tryptophan. Further *in vitro* assays with AetA and structural analyses of its products are needed to fully elucidate the chronology of the individual halogenation reactions. The functions of the remaining predicted genes have yet to be experimentally confirmed. Hypothetically, 5-bromotryptophan produced by AetF (or a later, more complex intermediate) could be used for subsequent additional bromination by AetA to generate the 2,3,5-tribrominated indole substructure. Concerning the possible function of AetB, it is noteworthy that cytochrome P450-like proteins have been previously found to play a crucial role in carbonitrile formation in natural products (47).

Bioactivity characterization of AETX

Initial HPLC microfractionation of an *A. hydrophilica*-*H. verticillata* assemblage extract revealed that the microfraction containing the pentabrominated compound is toxic to water fleas (*Ceriodaphnia dubia*), nematodes (*Caenorhabditis elegans*), and larval zebrafish (*Danio rerio*). This again strengthened our hypothesis that this compound might be the toxin responsible for causing VM. After preparative isolation of AETX, we determined the lethal dose for 50% of the population (LC₅₀) of the purified compound for *C. elegans* (40 nM) and larval *D. rerio* (275 nM) (fig. S48 and tables S12 to S14). At sublethal concentrations (>10 nM), an inhibitory effect of AETX on reproduction could be observed for *C. elegans*. Exposure to

purified AETX induced neurological seizure-like behavior in larval zebrafish (movie S2), consistent with behavior seen when larva were exposed to AETX containing *H. verticillata*-*A. hydrillicola* biomass extract that had been confirmed to cause VM lesions in the chicken bioassay. Neurological behaviors observed in zebrafish included twitching, gulping, full-body convulsions, loss of equilibrium, bunching toward the edge of the treatment dishes, rapid pectoral fin movements, and lack of escape response when stimulated with a probe.

AETX causes VM

To test whether AETX was the cause of VM, we used an avian bioassay (3, 9, 15, 19, 21). Specific pathogen-free leghorn chickens (*Gallus gallus*) were gavaged with either a suspension of purified AETX (15 mg per kilogram of body weight), AETX containing *H. verticillata*-*A. hydrillicola* extract as positive control (HTX; 4 mg of AETX per kilogram of body weight), or solvent control [10% dimethyl sulfoxide (DMSO) in deionized water]. All birds appeared normal on physical and neurological exams before the start of the study. During the short duration of the study, chickens did not exhibit pronounced clinical signs of VM in any treatment group (four doses over the course of 8 days). However, histological results revealed that chickens in the HTX ($N = 3$) and purified AETX ($N = 3$) treatment groups developed extensive vacuolization throughout the white matter of the brainstem, optic tectum, and cerebellum, whereas no lesions were documented in carrier solvent control chickens ($N = 2$) (Fig. 5A). Transmission electron microscopy of the optic tectum of birds from both the HTX and AETX groups revealed numerous vacuoles delimited by myelin laminae that had split at the intraperiod line, confirming the diagnosis of VM (Fig. 5B). Thus, we could confirm that AETX is the causative agent of VM.

Conclusions

The causative agent of VM has eluded scientists for >25 years. Our discovery that VM is induced by a pentabrominated biindole alkaloid produced by an epiphytic cyanobacterium expands the role of cyanobacteria as potentially dangerous toxin producers. Although harmful blooms of planktonic algae have been shown to extensively alter ecosystems, our findings warrant further research into the potential toxins produced by epiphytic and benthic species. Our in vitro cultivation experiments show that the biosynthesis of AETX depends on bromide availability and that physical stressors (e.g., temperature and agitation) enhance production. We need to understand the complex environmental factors that affect the distribution and toxicity of *A. hydrillicola*. Further investigation is also needed on bioavailability

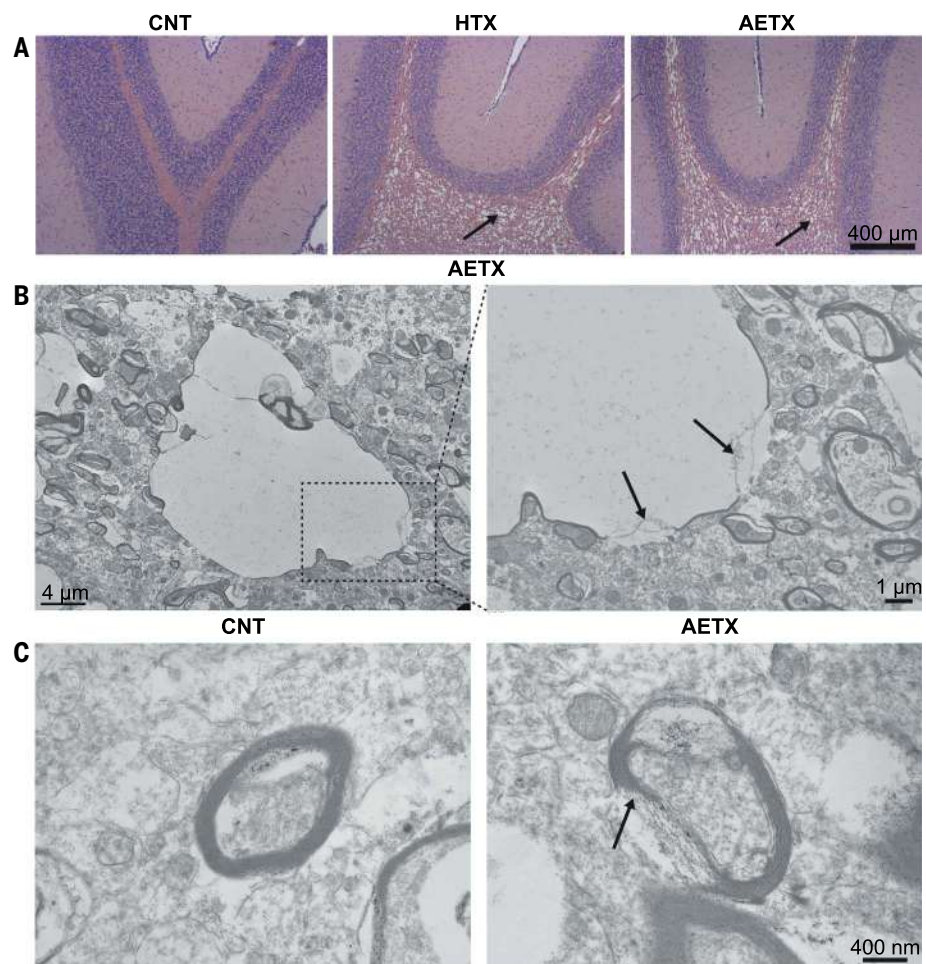


Fig. 5. Light and transmission electron microscopy of brain tissue from chickens exposed to AETX and controls confirm that AETX is causing VM. (A) Histologic sections of cerebellum with hematoxylin and eosin stain for solvent control (CNT), aetokthonotoxin containing *H. verticillata* extract (HTX), and pure aetokthonotoxin treatments (AETX). Chickens exposed to HTX and AETX treatments had widespread vacuolization of the white matter myelin tracts compared with controls (arrows). (B) Numerous vacuoles delimited by myelin laminae that had split at the intraperiod line (arrows) were observed, confirming the diagnosis of VM in both AETX (shown here) and HTX treatment groups. (C) Image of solvent control oligodendrocyte (left) and of oligodendrocyte bursting open (right) because of intramyelinic edema when treated with AETX (arrow). Transmission electron micrographs were taken of the optic tectum of test animals.

of bromide from natural (i.e., geologic origin) and anthropogenic sources (e.g., power plants, fungicides, and gasoline additives) and how they influence AETX production.

Dense infestations of submerged aquatic plants can be managed using chemical, biological, or physical controls. Notably, herbicides containing bromide as counterions (e.g., diquat dibromide) are currently used to combat the spread of invasive submerged aquatic plants, including *H. verticillata*. Benefits and risks of using any bromide-containing chemical control agents within VM reservoir watersheds need to be reassessed. Biological controls, especially triploid grass carp (*Ctenopharyngodon idella*), can remove excess plants, but fishery managers are reluctant to stock these fish for vegetation control because of concerns of

overstocking and escape. These triploid sterile grass carp have been effective in eliminating *H. verticillata* in VM reservoirs with a history of eagle deaths (e.g., DeGray Lake, Arkansas, and J. Strom Thurmond Reservoir, Georgia and South Carolina) (21, 48). Physical control of *H. verticillata* is often ineffective because of its ability to reproduce from fragments, tubers, and turions released during mechanical harvesting. Site-specific, integrated management solutions have emerged from more than 50 years of research into invasive-plant control by the Florida Fish and Wildlife Conservation Commission, the U.S. Army Corps of Engineers, and the University of Florida (49). Controlling *H. verticillata* in VM reservoirs with toxic *A. hydrillicola* is critical to protect aquatic species and their consumers, but doing so

presents additional complexity and risks. Future vegetation management should prioritize overall ecosystem health and affordable, long-term solutions to control and prevent the expansion of *H. verticillata* and *A. hydrillicola*.

Wildlife are exposed to AETX in their environment for a substantially longer time period compared with the animals in our short-term bioassays. Raptors breeding on VM reservoirs and juveniles returning to their natal territories extend the disease risk over generations. Considering the lipophilicity of AETX and the demonstration of trophic transfer, there is potential for bioaccumulation. The confirmation that additional herbivorous aquatic taxa in VM food webs are susceptible to AETX (i.e., birds, fish, amphibians, reptiles, and invertebrates) also increases the potential risk to their consumers. Because we do not yet fully understand how *A. hydrillicola* and its neurotoxin affect the complex aquatic ecosystems, increased monitoring and public awareness should be implemented for *A. hydrillicola* and AETX. A toxin produced by cyanobacteria that colonize a highly invasive plant, which has the capacity to affect diverse animal phyla, should not be underestimated in its potential impact on our environment. Analytical methods described should facilitate expanded monitoring of AETX in aquatic environments and animal tissues. Moreover, there remains a critical need for research on mammalian susceptibility to VM and on human health risks from the consumption of fish and waterbirds from VM reservoirs.

Materials and methods summary

H. verticillata samples collected from numerous watersheds from 2014 to 2020 were screened for the presence of *A. hydrillicola*. After isolation of *A. hydrillicola* from environmental samples and adaptation to laboratory conditions, the cyanobacterium was cultivated in BG11 medium with or without the addition of potassium bromide. *H. verticillata* leaves colonized with *A. hydrillicola* were analyzed using fluorescence microscopy as well as AP-MALDI-MSI (9-AA as matrix in negative-ionization mode; lateral resolution, 10 μ m). Environmental bromide and bromine concentrations in *H. verticillata*, sediment, and water samples were analyzed by x-ray fluorescence spectroscopy and ion chromatography. The structure of AETX was elucidated by NMR spectroscopy, high-resolution tandem mass spectrometry, infrared spectroscopy, and x-ray crystallography after isolation of the compound using flash chromatography, semi-preparative HPLC, and recrystallization. The genome of *A. hydrillicola* was amplified from single filaments using multiple displacement amplification and then sequenced using the Illumina MiSeq platform. The putative AETX biosynthetic gene cluster was identified by BLASTp searches for bacterial halogenases

against the *A. hydrillicola* genome. The halogenase AetF was heterologously expressed in *E. coli* and then purified. Biochemical assays to characterize its activity used tryptophans and indoles as substrates. Reaction products were structurally characterized by HPLC-MS and NMR spectroscopy. *A. hydrillicola*-*H. verticillata* extract fractions and pure AETX were tested for activity on *C. dubia*, *D. rerio*, *C. elegans*, and *G. gallus*. Bioassays on *D. rerio* and *G. gallus* were performed in accordance with the National Institutes of Health Guide for the Care and Use of Laboratory Animals and followed protocol A2017 11-007-Y1-AO, which was reviewed, approved, and overseen by the University of Georgia Institutional Animal Care and Use Committee. VM occurrence in treated birds was confirmed by analysis of the white matter of their optic lobe using light microscopy and transmission electron microscopy. Tissues of deceased wild birds were extracted and analyzed for AETX by HPLC-MS. A full description of the materials and methods used in this study is provided in the supplementary materials.

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laboratory culture, developed and validated an HPLC method to quantify the toxin, and did MS imaging experiments; B.G. and M.L. supported S.B. with his first MS imaging experiments; S.B. solved the structure of AETX with support from P.S. and T.H.J.N.; C.W. performed the x-ray crystallography study; B.N.H. and W.M.H. fractionated *A. hydrillicola*–*H. verticillata* assemblage extracts on HPLC for initial bioactivity assays; W.M.H. and J.W.W. supported B.N.H. and T.J.P. with HPLC-MS analyses; design and conduction of the bioactivity assays was as follows: G. gallus (T.J.P., B.N.H., and S.M.W.), *C. dubia* (B.N.H.), *D. rerio* (T.J.P. and J.D.L.), and *C. elegans* (S.B.); S.M.W. diagnosed VM in treatment animals using light and transmission electron microscopy; A.K. and J.M. sequenced the *A.h.* genome using whole-genome amplicons from single filaments; H.D.W. isolated DNA and sequenced the *A.h.* genome; P.H. and S.B. performed chemical analysis of biochemical assays; R.S. and J.A.M.Y. prepared the recombinant halogenase and designed the enzyme assays, which were then performed by J.A.M.Y.; J.A.M.Y., A.K., and P.H. performed the purification of in vitro-brominated biosynthetic intermediates; J.M. did bioinformatics analyses and identified the putative AETX biosynthetic gene cluster; S.B., T.J.P., B.N.H., J.M., J.A.M.Y., P.H., R.S., P.S., W.G., T.H.J.N., and S.B.W. conducted data analysis; and S.B., T.J.P., J.M., T.H.J.N., and S.B.W. wrote the manuscript with contributions from the other authors. **Competing interests:** T.H.J.N. serves as scientific adviser on the advisory board of Cyano Biotech GmbH, and H.E. is CSO of Cyano Biotech GmbH. The other authors declare no competing interests. **Data and materials availability:** NMR and MS raw data are available at Figshare (50). X-ray data and models are available at the Cambridge Crystallographic Data Centre under accession no. CCDC-2018827. The whole-genome assemblies (Whole Genome Shotgun projects) of two *A. hydrillicola* strains, CCA1A 1050 and Thurmond2011, have been deposited at DDBJ/ENA/GenBank under the accession nos. JAA1HA000000000 and JAAKGC000000000, respectively. The versions described in this paper are JAA1HA010000000 and JAAKGC010000000. The sequence of the putative AETX biosynthetic gene cluster can be found at DDBJ/ENA/GenBank under the accession no. MT225528. All other data are available in the main text or the supplementary materials.

SUPPLEMENTARY MATERIALS

science.sciencemag.org/content/371/6536/eaax9050/suppl/DC1
Materials and Methods
Supplementary Text
Figs. S1 to S50
Tables S1 to S14
References (51–94)
MDAR Reproducibility Checklist
Movies S1 and S2

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EXHIBIT G



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 1

5 POST OFFICE SQUARE, SUITE 100
BOSTON, MA 02109-3912

AUG - 4 2010

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

James A. Ginnetti, Vice President
FirstLight Hydro Generating Company
FirstLight Power Resources
One Corporate Center
20 Church Street
Hartford, CT 06103

Subject: EPA Clean Water Act Administrative Order Docket No. 10-016

Dear Mr. Ginnetti :

Enclosed is an Administrative Order ("Order") issued, pursuant to Sections 308(a) and 309(a)(3) of the Clean Water Act, 33 U.S.C. §§ 1318 and 1319(a)(3), to FirstLight Hydro Generating Company and FirstLight Power Resources ("FirstLight"), the owner and operator of the Northfield Mountain Pumped Storage Hydroelectric facility (the "Facility"). The Order cites FirstLight for violations of the Clean Water Act associated with the removal and discharge of sediments that accumulated in the Facility's pumped-storage reservoir inlet channel, the pressure shaft of the four unit penstocks, and the mile-long tailrace tunnel to the Connecticut River. The sediments accumulated in these areas as a result of the draw down of the water levels in the pumped-storage reservoir.

The Order requires FirstLight to immediately cease its cleaning activities and the discharge of sediments to the Connecticut River pending the implementation of a sediment reduction alternative that will reduce the impacts of the discharge on the Connecticut River. The Order also reiterates the requirement for the submission of a plan to address the sediments that have already been deposited into the Connecticut River that was contained in a Section 308 Information Request that EPA issued to FirstLight on July 20, 2010. Finally, the Order requires FirstLight to develop and implement measures designed to prevent the discharge of sediments associated with draining the pumped-storage reservoir in the future.

Enclosed with this Order is an information sheet intended to assist small businesses, as defined by the Small Business Administration ("SBA") at 13 CFR § 121.201, in understanding and complying with environmental regulations. EPA is routinely providing this information to businesses, whether or not they are small businesses as defined by the SBA, in the course of the EPA's enforcement

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activities. The Small Business Regulatory Enforcement and Fairness Act provides small businesses the opportunity to submit comments on regulatory enforcement at the time of EPA enforcement activity. The Small Business Ombudsman may be reached at 1-800-368-5888. Please be aware that availing yourself of this opportunity does not relieve FirstLight of its responsibility to comply with federal and state laws and this Order.

FirstLight may also assert a business confidentiality claim with respect to part or all of the information submitted to EPA in the manner described at 40 C.F.R. Part 2.203(b). Information covered by such a claim will be disclosed by EPA only to the extent, and by means of the procedures set forth in 40 C.F.R. Part 2, Subpart B. If no such claim accompanies the information when it is submitted to EPA, it may be made available to the public by EPA without further notice to FirstLight.

If you have any questions concerning the technical terms of this Order, please contact Michael Fedak (617) 918-1766 or George Harding (617) 918-1870 of the Water Technical Unit, or have your attorney contact Michael Wagner, EPA's legal counsel in this matter, at (617) 918-1735.

Sincerely,



Susan Studlien, Director
Office of Environmental Stewardship

Enclosures

cc: John Howard (FirstLight)
Susan Orr (FirstLight)

EXHIBIT G

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY REGION I

IN THE MATTER OF:	)	DOCKET NO. 10-016
	)	
FirstLight Hydro Generating Company;	)	FINDINGS OF VIOLATION
FirstLight Power Resources, Inc.	)	
NPDES Permit No. MA0035530	)	AND
	)	
Proceedings under Sections 308 and	)	ORDER FOR COMPLIANCE
309(a)(3) of the Clean Water Act,	)	
as amended, 33 U.S.C. §§ 1318 and	)	
1319(a)(3)	)	

I. STATUTORY AUTHORITY

The following Findings are made and ORDER issued pursuant to Sections 308(a) and 309(a)(3) of the Clean Water Act, as amended (the "Act"), 33 U.S.C. §§ 1318 and 1319(a)(3). Section 309(a)(3) of the Act grants to the Administrator of the U.S. Environmental Protection Agency ("EPA") the authority to issue orders requiring persons to comply with Sections 301, 302, 306, 307, 308, 318 and 405 of the Act and any permit condition or limitation implementing any of such sections in a National Pollutant Discharge Elimination System ("NPDES") permit issued under Section 402 of the Act, 33 U.S.C. § 1342. Section 308(a) of the Act, 33 U.S.C. § 1318(a), authorizes EPA to require the submission of any information required to carry out the objectives of the Act. These authorities have been delegated to EPA Region I's Administrator, and in turn to the Director of EPA, Region I's Office of Environmental Stewardship ("Director").

The Order herein is based on findings of violation of Section 301 of the Act, 33 U.S.C. § 1311. Pursuant to Section 309(a)(5)(A) of the Act, 33 U.S.C. § 1319(a)(5)(A), the Order provides a schedule for compliance which the Director has determined to be reasonable.

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II. DEFINITIONS

Unless otherwise defined herein, terms used in this Order shall have the meaning given to those terms in the Act, 33 U.S.C. § 1251 *et seq.*, the regulations promulgated thereunder, and any applicable NPDES permit. For the purposes of this Order, "NPDES Permit" means FirstLight Hydro Generating Company's NPDES Permit, No. MA0035530, and all amendments or modifications thereto and renewals thereof as are applicable and in effect at the time.

III. FINDINGS

The Director makes the following findings of fact:

1. FirstLight Power Resources, Inc. and FirstLight Hydro Generating Company (together, hereinafter "FirstLight"), are each a person under Section 502(5) of the Act, 33 U.S.C. § 1362(5).
2. FirstLight is the owner and operator of the Northfield Mountain Pumped Storage Hydroelectric Facility located in Northfield, Massachusetts (the "Facility").
3. The Federal Energy Regulatory Commission issued License No. 2485 authorizing the operation of the Facility in May, 1968.
4. On September 30, 1996, the Facility's previous owner, Northeast Utilities Service Company was issued NPDES Permit No. MA0035530 ("NPDES Permit") by the EPA under the authority of Section 402 of the Act, 33 U.S.C. § 1342. The NPDES Permit regulates the discharges from floor and associated drains. It expired on September 30, 2000, but remains in effect pursuant to 40 C.F.R. § 122.6 due to a timely reapplication.
5. The NPDES Permit authorizes FirstLight to discharge pollutants from outfall 001 to the Connecticut River provided the discharges do not cause or contribute to violations of federal or state water quality standards.
6. The Connecticut River flows to Long Island Sound. Both are navigable waters of the United States as defined in 40 CFR § 122.2 and, therefore, navigable waters under Section 502(7) of the Act, 33 U.S.C. § 1362(7).

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7. On May 1, 2010 FirstLight began to draw down the water levels in the pumped-storage reservoir.
8. On May 3, 2010 FirstLight notified EPA that accumulated silt and sediments from the pumped-storage reservoir were being drawn down and were being discharged to the Connecticut River.
9. On July 15, 2010, EPA inspected the Facility in response to a citizen complaint regarding the discharge of sediments to the Connecticut River.
10. On July 20, 2010, EPA issued an Information Request pursuant to Section 308 of the Act requesting information regarding alternative methods of stopping or mitigating the quantity and impacts of the discharges of accumulated silt and sediments.
11. FirstLight continues to remove accumulated silt and sediments from the Facility's tailrace tunnel through mechanical excavation, mixing the accumulated silt and sediments with river water, and then discharging it to the Connecticut River through an outfall pipe.
12. The accumulated silt and sediments that FirstLight is discharging to the Connecticut River are pollutants within the meaning of Section 502(6) of the Act, 33.U.S.C. § 1362(6).
13. The outfall through which FirstLight is discharging accumulated silt and sediments to the Connecticut River is a point source within the meaning of Section 502(14) of the Act, 33.U.S.C. § 1362(14).
14. The NPDES Permit does not authorize FirstLight to discharge silt and sediments that have accumulated in the Facility.
15. Section 301(a) of the Act, 33 U.S.C. § 1311(a), makes unlawful the discharge of pollutants to waters of the United States except, among other things, in compliance with the terms and conditions of an NPDES permit issued pursuant to Section 402 of the Act, 33 U.S.C. § 1342, or a permit issued pursuant to Section 404 of the Act, 33 U.S. § 1344.
16. FirstLight has not received authority under the Act to discharge accumulated silt and sediments to waters of the United States.

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17. FirstLight's discharge to the Connecticut River of accumulated silt and sediments without authorization to do so under the Act occurred, and continues to occur, in violation of Section 301(a) of the Act, 33 U.S.C. § 1311(a).

IV. ORDER

Accordingly, pursuant to Sections 308 and 309(a)(3) of the Act, it is hereby ordered that :

1. FirstLight shall immediately cease the discharge of silt, sediments, and other pollutants from the Facility to the Connecticut River and all other waters of the United States in concentrations greater than those contained in water passing through the Facility while power generation at the Facility is occurring.
2. Within 24 hours following the cessation of discharges in accordance with Paragraph IV.1 of this Order, FirstLight shall submit a written notification to EPA via e-mail and certified mail that it has ceased discharges in accordance with this Order.
3. Within 10 days of receipt of this Order, FirstLight shall submit a description and schedule for implementation of the technology(ies) that it has chosen to reduce the concentration of silt and sediments in all discharges from the Facility to the concentrations of silt and sediments contained in water passing through the Facility while power generation at the Facility is occurring.
4. By August 10, 2010, FirstLight shall provide EPA with an estimate of the volume of solids in cubic yards that have been discharged to the Connecticut River from the Facility since May 1, 2010 and the estimated volume of sediments that remain to be removed from the Facility. The estimates shall be accompanied by FirstLight's plan to address solids accumulations in the Connecticut River that occurred during the draining of the pumped-storage reservoir and subsequent cleaning operations. The plan shall include a description of each alternative that was

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considered, the costs associated with their implementation, a description of any federal, state, or local permits required for implementation, the ultimate fate of solids removed, and a schedule for the implementation of the recommended plan.

5. By November 1, 2010, FirstLight shall submit a report identifying the measures that it will adopt to prevent discharges of sediments associated with draining the pumped-storage reservoir in the future and a schedule for their implementation.
6. The implementation schedules submitted pursuant to Paragraph IV.3., IV.4., and IV.5. of this Order shall be incorporated and enforceable hereunder upon the implementation schedules' approval by, and as amended by, EPA.
7. Beginning August 17, 2010, and by the first and third Tuesday of every subsequent month, and continuing through the month when the Facility is fully operational, FirstLight shall submit status reports delineating its progress in implementing the provisions of this Order. At a minimum, these progress reports shall include a description of:
 - a. The activities undertaken during the two-week period prior to the submission of the report directed at achieving compliance with this Order;
 - b. The status of all plans, reports, and other deliverables required to be submitted by this Order during the two-week period prior to the submission of the report; and
 - c. The activities expected to be completed during the next two-week period in order to achieve compliance with this Order.

V. NOTIFICATION PROCEDURES

1. Where this Order requires a specific action to be performed within a certain time frame, FirstLight shall submit a written notice of compliance or noncompliance with each deadline. Notification of compliance shall be

EXHIBIT G

mailed within fourteen (14) days after each required deadline. The timely submission of a required report shall satisfy the requirement that a notice of compliance be submitted.

2. If noncompliance is reported, notification shall include the following information:
 - a. A description of the noncompliance;
 - b. A description of any actions taken or proposed by FirstLight to comply with the lapsed schedule requirements;
 - c. A description of any factors that tend to explain or mitigate the noncompliance; and
 - d. An approximate date by which FirstLight will perform the required action.
3. After a notification of noncompliance has been filed, compliance with the past-due requirement shall be reported by submitting any required documents or providing EPA with a written report indicating that the required action has been achieved.
4. Submissions required by this Order shall be in writing and shall be mailed to the following addresses:

U.S. Environmental Protection Agency
Region I
5 Post Office Square Suite 100 (OES 04-03)
Boston, MA 02109-3912
Attn: Michael Fedak

EPA shall notify FirstLight in writing of any changes to the contact person or address.

VI. GENERAL PROVISIONS

1. FirstLight may, if it desires, assert a business confidentiality claim covering part or all of the information requested, in the manner described by 40 C.F.R. § 2.203(b). Information covered by such a claim will be disclosed

EXHIBIT G

by EPA only to the extent set forth in 40 C.F.R. Part 2, Subpart B. If no such claim accompanies the information when it is received by EPA, the information may be made available to the public by EPA without further notice to FirstLight. FirstLight should carefully read the above-cited regulations before asserting a business confidentiality claim since certain categories of information are not properly the subject of such a claim. For example, the Act provides that "effluent data" shall in all cases be made available to the public. See Section 308(b) of the Act, 33 U.S.C. § 1318(b).

2. EPA reserves the right to seek any and all remedies available under Section 309 of the Act, 33 U.S.C. § 1319, as amended, for any violation cited in this Order.
3. This Order shall become effective upon receipt by FirstLight.

08/03/10
Date

Susan Studlien
Susan Studlien, Director
Office of Environmental Stewardship
Environmental Protection Agency, Region I

Boating Navigability Study

Study Report

Turners Falls Hydroelectric Project (No. 1889)

Prepared for:



Prepared by:



DECEMBER 2021

EXECUTIVE SUMMARY

The Turners Falls Hydroelectric Project (FERC No. 1889) is owned and operated by FirstLight MA Hydro LLC on the Connecticut River in Gill and Montague, Massachusetts. In November 2021, a boating navigability study was conducted to assess the potential effects of discharges from Turners Falls Dam on navigability for recreational boaters, particularly through-paddlers, in the bypass reach of the Connecticut River below Turners Falls Dam at various flows. The study reach extended from the put-in just below the Turners Falls Dam to Cabot Woods located below Rock Dam, a distance of approximately 2.5 miles. For the purpose of this study, a "navigable" reach was defined as one through which boaters can paddle recreational watercraft without having to portage around obstacles, even if minor bumping and/or scraping occurs.

This study was conducted in collaboration with representatives from the Massachusetts Department of Environmental Protection (DEP), Massachusetts Department of Conservation and Recreation (DCR), and the Connecticut River Conservancy (CRC).

The field demonstration flow study was conducted on November 9, 2021. Four different test flows (termed Flow #1 through Flow #4) ranging from 214 cfs to 545 cfs were released from Bascule Gate #1 at Turners Falls Dam. Station No. 1 generation ranged from approximately 560 cfs to 1,080 cfs during the study and the Fall River flow was measured as 71 cfs on the study date, resulting in total flows ranging from 285 cfs to 616 cfs in the upper bypass reach (above Station No. 1) and 1,007 cfs to 1,427 cfs in the lower bypass reach (below Station No. 1).

Ten boaters participated in the study utilizing four canoes and three kayaks, for a total of seven boats. Boaters paddled the study reach under each flow and were then asked to evaluate the flow based on their watercraft and skill level for various characteristics, including navigability, safety, ease of put-in, number of scrapes/bumps, and number of portages for each flow experienced.

Two areas of interest were the primary focus of the navigability evaluation: the channels around Peskeomskut Island immediately below Turners Falls Dam and the channels around Rawson Island below Station No. 1 at the downstream extent of the study reach. At Peskeomskut Island, the left¹ channel was unnavigable under all assessed flows, but boaters were able to paddle the center-right and far-right channels (with varying level of difficulty) under all flows. The center-right channel is narrow and flume-like, while the far-right channel is more riffle-like. Boater feedback was mixed on which channel would be the preferable and/or safer route under the range of flows assessed.

At Rawson Island, boaters were able to navigate the far-right channel with no issues under all assessed flows. The center-right channel was unnavigable under all flows. Several experienced whitewater boaters took the left channel around Rawson Island to paddle over Rock Dam, which was runnable but not recommended for novice paddlers.

Put-In #2, located approximately 800 feet downstream of the Spillway Ladder and Put-In #1, was determined to be an acceptable put-in option for boaters wishing to bypass Peskeomskut Island.

Flow #3 was determined to be the minimum navigable flow of those assessed during the study. This flow event was characterized by approximately 545 cfs released from Bascule Gate #1

¹ River left and river right refer to the directions when facing downstream.

(calculated), 71 cfs from the Fall River (measured), and 560 cfs from Station No. 1 (reported), for total flows of approximately 616 cfs below Peskeomskut Island (measured) and 1,007 cfs below Station No. 1 (calculated).

The difficulty of the bypass reach under Flow #3 was rated as Class II (Novice) by most boaters. At a minimum, all boaters indicated that they would at least “possibly” return to the bypass reach during conditions similar to Flow #3.

Overall, the results of the Turners Falls boating navigability study demonstrate that the bypass reach provides through-paddling opportunities for a variety of watercraft and skill levels. Flow #3 (545 cfs released from Bascule Gate #1) was determined to be the minimum navigable flow and the flow at which boaters are most likely to return to the bypass reach for recreational opportunities.

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LIST OF ABBREVIATIONS

ADCP	acoustic Doppler current profiler
AFLA	Amended Final License Application
AMC	Appalachian Mountain Club
cfs	cubic feet per second
CRC	Connecticut River Conservancy
DCR	Massachusetts Department of Conservation and Recreation
DEP	Massachusetts Department of Environmental Protection
DFG	Massachusetts Department of Fish and Game
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Hydro Generating Company
ILP	Integrated Licensing Process
NMFS	National Marine Fisheries Service
NRF	Naturally Routed Flow
TFH	Turners Falls Hydro
USFWS	United States Fish and Wildlife Service

1 INTRODUCTION

The Turners Falls Hydroelectric Project (FERC No. 1889) is owned and operated by FirstLight MA Hydro LLC² on the Connecticut River in Gill and Montague, Massachusetts. In December 2020, FirstLight filed its Amended Final License Application (AFLA) with the Federal Energy Regulatory Commission (FERC) to relicense the Project.

In November 2021, a boating navigability study was conducted to assess the potential effects of discharges from Turners Falls Dam on navigability for recreational boaters in the upper bypass reach of the Connecticut River below Turners Falls Dam at various flows. For the purpose of this study, a "navigable" reach was defined as one through which boaters can paddle recreational watercraft without having to portage around obstacles, even if minor bumping and/or scraping occurs.

This study was conducted in collaboration with representatives from the Massachusetts Department of Environmental Protection (DEP), Massachusetts Department of Conservation and Recreation (DCR), and the Connecticut River Conservancy (CRC) (collectively referred to as the Study Team).

2 BACKGROUND

2.1 Existing Information

Project Description

The Turners Falls Dam is located on the Connecticut River at approximately river mile 122 (above Long Island Sound) on the Connecticut River, in the towns of Gill and Montague in Franklin County, MA. Below the dam, a 2.7-mile-long bypassed section of the Connecticut River is paralleled by the power canal. Station No. 1 and Cabot Station discharge into the Connecticut River approximately 0.9 miles and 2.7 miles downstream of the Turners Falls Dam, respectively.

Project Operations

Flow is maintained in the bypass reach at various times of the year either through the Spillway Ladder attraction flow, fish ladder flow, or via a bascule gate. However, when the hydraulic capacity of the power canal (approximately 18,000 cubic feet per second, cfs), is exceeded and water elevations in the Turners Falls Impoundment start to rise, FirstLight will open bascule or Tainter gates accordingly to spill water at the dam and into the bypass reach.

Minimum Flow Requirements

Under the current FERC license for the Turners Falls Project, FirstLight is required to release a continuous minimum flow of 1,433 cfs or inflow, whichever is less, below the Project. FirstLight

² For purposes of this document, Northfield Mountain LLC, which owns the Northfield Mountain Pumped Storage Project and FirstLight MA Hydro LLC, which owns the Turners Falls Hydroelectric Project, are collectively referred to as FirstLight.

typically maintains the minimum flow requirement through discharges at Cabot Station and/or Station No. 1.

A continuous minimum flow of 200 cfs is also maintained in the bypass reach starting on May 1, increasing to 400 cfs when fish passage starts by releasing flow through a bascule gate. The 400 cfs continuous minimum flow is provided through July 15, unless the upstream fish passage season has concluded early, in which case the 400 cfs flow is reduced to 120 cfs. The 120 cfs continuous minimum flow is maintained in the bypass reach from the date the fish ladders are closed (or by July 16) until the river temperature drops below 7°C, which typically occurs around November 15.

In its AFLA, FirstLight proposed the Turners Falls bypass flows shown in **Table 2.1-1** below.

Table 2.1-1: Proposed Minimum Flows for Turners Falls Bypass Reach

Date	Total Bypass Flow ²	Turners Falls Dam	³ Station No. 1
01/01-03/31	1,500 cfs or the Naturally Routed Flow (NRF), whichever is less	300 cfs	1,200 cfs ⁴
04/01-05-31 ¹	6,500 cfs or the NRF, whichever is less	4,290 cfs	2,210 cfs ⁴
06/01-06/15 ¹	4,500 cfs or the NRF, whichever is less	2,990 cfs	1,510 cfs ⁴
06/16-06/30 ¹	3,500 cfs or the NRF, whichever is less	2,280 cfs	1,220 cfs ⁴
07/01-08/31	1,800 cfs or the NRF, whichever is less	670 cfs	1,130 cfs ⁴
09/01-11/30	1,500 cfs or the NRF, whichever is less	500 cfs	1,000 cfs ⁴
12/01-12/31	1,500 cfs or the NRF, whichever is less	300 cfs	1,200 cfs ⁴

¹The flow split during these periods is approximately 67% from the Turners Falls Dam and 33% from Station No. 1. If FirstLight conducts further testing, in consultation with the National Marine Fisheries Service (NMFS), US Fish and Wildlife Service (USFWS) and Massachusetts Department of Fish and Game (DFG) and determines that migratory fish are not delayed by passing a greater percentage of the bypass flow via Station No. 1, it may increase the percentage through Station No. 1 upon written concurrence of those agencies.

²If the NRF is less than 6,500 cfs (04/01-05/31), 4,500 cfs (06/01-06/15) or 3,500 cfs (06/16-06/30) the flow split will still be set at approximately 67% of the NRF from the Turners Falls Dam and 33% of the NRF from Station No. 1. If the NRF is less than 1,800 cfs (7/1-8/31), 1,500 cfs (9/1-11/30), or 1,500 cfs (12/1-3/31), the Licensee shall maintain the Turners Falls Dam discharges at 670 cfs, 500 cfs, and 300 cfs, respectively.

³To maintain the flow split, Station No. 1 must be automated, which will not occur until Year 3 of the license. FirstLight proposes to maintain the flow split such that the Turners Falls Dam discharge will be as shown above, or higher flows will be spilled, in cases where the additional flow cannot be passed through Station No. 1.

⁴The Turners Falls Hydro (TFH) project (FERC No. 2622) and Milton Hilton, LLC project (unlicensed) are located on the power canal and discharge into the bypass reach upstream of Station No. 1. The hydraulic capacity of the TFH project and Milton Hilton, LLC project is 289 and 113 cfs, respectively. If the TFH project is operating, FirstLight will reduce its Station No. 1 discharge by 289 cfs. If the Milton Hilton, LLC project is operating, FirstLight will reduce its Station No. 1 discharge by 113 cfs.

Previous Studies

During the relicensing process, FirstLight performed Study No. 3.6.3 *Whitewater Boating Evaluation* in the 2.7-mile-long Turners Falls Dam bypass reach (from Turners Falls Dam to Cabot Station) in accordance with FERC's ILP. A study report was prepared in March 2015.

The whitewater boating evaluation was conducted in July 2014. A team of whitewater boaters in various types of watercrafts ran up to six evaluation flows (2,500, 3,500, 5,000, 8,000, 10,000 and 13,000 cfs) over a three-day period. The reach was found to provide an acceptable whitewater boating experience for most watercraft types at all six of the study flows, with overall optimal boating conditions for most watercraft type occurring in the 5,000-8,000 cfs range. Additionally,

both lower and higher flows rated well with the participants, although the ratings were dependent on type of watercraft and skill level.

Bypass reach access points were also identified as part of this study. The study identified three areas (Spillway Ladder Put-In, Turners Falls Station No. 1 Fishing Access, Cabot Woods Fishing Access) that currently provide access to the bypass reach, and one site (Poplar Street Access) downstream of the bypass reach that currently serves as both the canoe portage put-in and as a take-out for those boating the bypass reach. It was determined that both the fishway put-in area and Turners Falls Station No. 1 Fishing Access could provide adequate access to the bypass reach for skilled and experienced whitewater boaters. The Cabot Woods Fishing Access is not suitable for bypass access due to steep slopes.

As part of the Turners Falls Recreation Management Plan filed with the AFLA, improvements are proposed for the put-in below the Turners Falls Dam on river-left³. There is an existing informal pathway leading to the base of the dam just downstream of the existing Spillway Ladder. The proposed access would be provided via the existing bridge spanning the power canal (known as the “IP Bridge”). Once over the canal, a formal 12-foot-wide path would lead to the riverbank put-in, with directional signs along the path.

2.2 Need for Additional Information

Additional information was needed for lower flows that could potentially allow recreational boaters to paddle through the Turners Falls bypass reach. Through consultation with the Study Team, it was agreed that navigability would be assessed at flows of approximately 500 cfs, 670 cfs, and 900 cfs. Adjustments were made to this proposed release schedule during the study based on field conditions as described below.

3 METHODOLOGY

3.1 Study Area

An overview map of the study area is shown in **Figure 3.1-1**. Detail maps of the upstream extent (Peskeomskut Island) and downstream extent (Rawson Island) are shown in **Figures 3.1-2** and **3.1-3**, respectively. The study area included the Connecticut River between the Turners Falls Dam and the Cabot Woods access point below Rawson Island. This reach is approximately 2.5 miles long (as measured by the longest paths around the islands). The Fall River joins the Connecticut River approximately 0.16 miles downstream of the dam on river-right.

The upstream segment of the study reach extends from the toe of the Turners Falls Dam to the pool upstream of the Turners Falls Road Bridge (see **Figure 3.1-2**). This area includes an expansive plunge pool at the base of the dam, which remains wetted from dam leakage and Fall River flows. Flow exiting the plunge pool has two major outlets, separated by a small island (known as Peskeomskut Island) in the center of the channel.

The river-right channel follows the western shore and immediately bifurcates upon exiting the plunge pool into a far-right channel and a center channel adjacent to the island (see **Figure 3.1-2**). The two sub-channels are divided by a bedrock outcrop and both have well-defined channel cross-

³ River-left and river-right refer in this report to the direction when facing downstream.

sections. The far-right channel is generally uniformly wide and comprised of shallow run and riffle morphologies.

The center channel is separated from the far-right channel by a bedrock terrace. It is bedrock controlled, relatively straight, and flume-like. At a dam discharge of 125 cfs, it is approximately 4 or more feet deep and fast-flowing⁴.

The river-left channel has a poorly defined channel and lacks a distinct thalweg. Flow passes over broken ledge and rubble, through crevasses, and over short vertical drops.

All channels converge near the upstream end of a large pool, approximately 1,500 feet upstream of the Turners Falls Road Bridge, where the bypass reach narrows. The channel continues relatively straight and riverine in form, with a defined thalweg on the river-left side, to the end of the upper bypass at the confluence with the Station No. 1 tailrace.

The lower segment of the study reach is approximately 1.4 miles long, extending from the Station No. 1 tailrace downstream to the Rawson Island complex and a geological feature including a natural ledge drop known as Rock Dam. The bedrock-defined channel bifurcates into left, center right, and far right channels around Rawson Island. The Rock Dam is located near the downstream end of the left channel. The reach terminates in a pool downstream of Rawson Island.

The study area included Rawson Island in order to evaluate the navigability of the river-right channels around the island so boaters could avoid the potentially hazardous Rock Dam in the river-left channel.

⁴ As observed during relicensing Study No. 3.3.1 *Instream Flow Habitat Assessments in the Bypass Reach and below Cabot Station*.

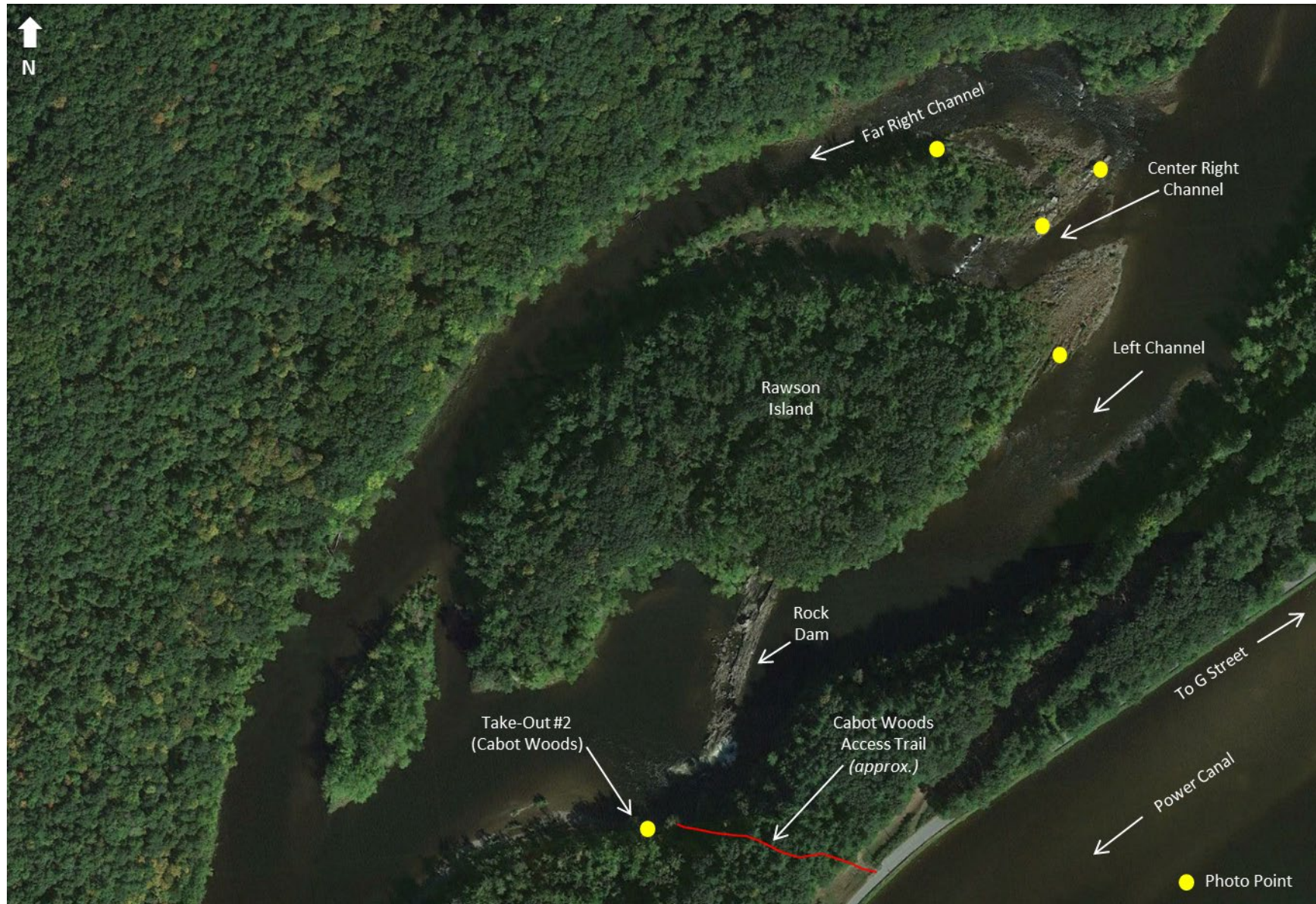
Figure 3.1-1: Study Area Map – Overview



Figure 3.1-2: Study Area Map – Peskeomskut Island / Put-In Area



Figure 3.1-3: Study Area Map – Rawson Island / Take-Out Area



3.2 Logistics

Participants

FirstLight coordinated with the Study Team to identify potential volunteer boaters for the study. Organizations contacted during boater outreach included the Appalachian Mountain Club (AMC), CRC, and other local paddling groups. Requirements for volunteer boaters included the following:

- Minimum age: 18
- Minimum paddling skill: Novice (comfortable running Class II whitewater; higher skill level and/or boater safety training preferred)
- Minimum gear:
 - Canoe or kayak (no paddleboards, rafts, or catarafts)
 - Personal flotation device (Type III or Type V)
 - Helmet
 - Closed-toe shoes
 - Wetsuit w/ splash gear OR thermals with dry suit
 - Warm hat/gloves

Access

Figure 3.1-1 shows the boat put-in and take-out areas utilized for the study. Two put-ins and two take-outs were made available for the study, though participants primarily used Put-In #1 (Spillway Ladder) and Take-Out #2 (Cabot Woods)⁵.

A close-up of the put-in area is shown in **Figure 3.1-2**. The put-ins are located near the base of the dam on river-left downstream of the existing Spillway Ladder. Both put-ins are accessible by walking across the IP Bridge and down informal pathways leading to the riverbank. Put-In #1 is located immediately downstream of the Spillway Ladder and requires paddlers to paddle around Peskeomskut Island via the left, center, or right channels. Put-In #2 is located approximately 800 feet farther downstream along the left bank and allows boaters to skip paddling around the island⁶.

Two take-out options were also made available during the study. Take-Out #1 is located on the upstream side of the Station No. 1 tailrace, which is accessible by an informal pathway leading down from the paved parking area (shown in **Figure 3.1-1**). Take-Out #2 is located downstream of the Rock Dam at the Cabot Woods Fishing Access trail (shown in **Figure 3.1-3**). Take-Out #1 (Station No. 1) was made available in case boaters needed to take-out early due to a safety concern, or to shorten the study reach and boating run time once a determination had been made regarding navigability around Rawson Island.

Rock Dam is a known hazard at certain flows. Only experienced whitewater paddlers with a trained rescue spotter (with throw bag) stationed below the rapid were permitted to navigate the left channel over Rock Dam during this study. Rock Dam navigability was not part of the assessment.

⁵ Put-In #1 was used for all flows. Take Out #2 was used for all flows except Flow #4. Boaters took out at Station No. 1 (Take-Out #1) for Flow #4 due to reduced daylight.

⁶ Note that while no boaters launched from Put-In #2 during the study, its ease of access/launching was visually assessed under the various study flows.

Flow Releases & Measurements

A range of test flows were scheduled to be released from Bascule Gate No. 1 at Turners Falls Dam. In addition, Station No. 1 was scheduled to generate during the study to be representative of FirstLight's AFLA bypass flow proposal during the paddling season, as the backwater effect of the tailwater release from the station may improve navigability upstream. The target release schedule originally proposed for the study is provided in **Table 3.2-1**. (The actual flows measured or calculated during the study varied from these targets and are provided in **Section 4**.)

Table 3.2-1: Target Flow Release Schedule

Flow No. ¹	Target Release Flow (cfs)		
	Bascule Gate #1	Station No. 1	TOTAL
1	500	1000	1500
2	670	1130	1800
3	1100	600	1700
4	900	600	1500

¹The order of Flows No. 3 & 4 were swapped in this table (with Flow 3 being the highest flow released from the bascule gate) to match the order of flows as actually released during the study.

After the adjustment of the bascule gate to release each test flow, a wait time of at least 30 minutes was provided to allow the flow to move through the bypass reach and stabilize.

The test flows were verified by collecting a flow measurement downstream of Peskeomskut Island during each flow release. This flow measurement was collected using an acoustic Doppler current profiler (ADCP). Additionally, the flow in the Fall River was measured and recorded on the day of the study using a digital flow meter.

3.3 Evaluation

For each test flow, boaters paddled the study reach and assessed navigability. Participating boaters completed a Pre-Run Boater Information Form prior to commencing the boating runs to collect contact information and background about the boater's type of watercraft, skill level, and boating history. Boaters then completed a Single Flow Evaluation Form after each flow run to evaluate the navigability of that flow. Upon completion of the final boating run, a post-evaluation discussion was facilitated to discuss the study and gather additional feedback from the participants.

A summary of the boater evaluation forms is provided in **Appendix A**. Original scanned forms are provided in **Appendix B** (Boater Information Forms) and **Appendix C** (Single Flow Evaluation Forms).

Photographs and/or videos were recorded at the following locations by the Study Team during each test flow:

- Put-In #1 (Spillway Ladder)
- Put-In #2
- Peskeomskut Island Right Channel
- Peskeomskut Island Center Channel
- Peskeomskut Island Left Channel
- Rawson Island Right Channel
- Rawson Island Center Channel

- Rawson Island Left Channel
- Rock Dam
- Cabot-Woods Take-Out

Photo/video locations are shown in **Figures 3.1-2** and **3.1-3**. Photos are provided in **Appendix D**. Videos can be viewed or downloaded from the following website⁷:

<https://gomezandsullivan.sharepoint.com/:f/s/flims/Ek0EgG4dJqNOnHUyijwDjPIBd23ruRvysUPu3CA-ema4gg?e=hIYeFS>

Table 3.3-1 below provides a list of videos available on the website.

Table 3.3-1: List of Videos Taken during Boating Study

No.	Flow No.	Flow (cfs) ¹	Location	Channel	Boater(s)
1-01	1	214	Peskeomskut	Center	1, 2
1-02	1	214	Peskeomskut	Center	5, 10
1-03	1	214	Peskeomskut	Center + Right	3,4,6,7,8,9
2-01	2	276	Peskeomskut	Center	1,2
2-02	2	276	Peskeomskut	Center	6,7,8
2-03	2	276	Peskeomskut	Center + Right	4,5,9,10
2-04	2	276	Peskeomskut	Right	3,9
2-05	2	276	Rawson	Right	1,2
2-06	2	276	Rawson	Right	9
2-07	2	276	Rock	Left	-
3-01	3	545	Peskeomskut	Center + Right	3,5,10
3-02	3	545	Peskeomskut	Right	7,8,9
3-03	3	545	Put-In 2	Center	5,10
3-04	3	545	Put-In 2	Center + Right	4,6
3-05	3	545	Put-In 2	Right	3,7,8
3-06	3	545	Rawson	Center + Right	-
3-07	3	545	Rawson	Right	1,2,5,10
3-08	3	545	Rawson	Right	3
3-09	3	545	Rock Dam	Left	7,8
4-01	4	376	Peskeomskut	Center	1,2
4-02	4	376	Peskeomskut	Center + Right	3,4,5,9,10
4-03	4	376	Put-In 2	Center + Right	All

¹Calculated release from Bascule Gate #1 based on flow measured below Peskeomskut Island less flow measured in Fall River (71 cfs). See **Table 4.1-1** for additional details on flows during the study.

Data and feedback collected from the demonstration flow study were used to evaluate navigability of the bypass reach by recreational boaters.

⁷ This website is only accessible by invited users. Contact Gomez and Sullivan for access for additional users if needed.

4 RESULTS

The boating demonstration flow study was conducted on November 9, 2021. A team of volunteer boaters, observers, and the Study Team gathered at the site to visually and directly assess navigability in the study area under various flows.

4.1 Flow Conditions

The actual flow conditions during the study varied from the original target flow releases presented previously in **Table 3.2-1**. **Table 4.1-1** below provides the actual flows experienced by boaters in the upper and lower bypass reach as well as the calculated actual flows released from Bascule Gate #1 during the study.

Table 4.1-1: Actual Flows Measured and Calculated during the Study

Flow No.	Start Time	Actual Flow (cfs)				
		<i>Measured Flow below Peskeomskut Is.</i>	<i>Measured Flow in Fall River</i>	<i>Calculated Release from Bascule Gate #1</i>	<i>Station No. 1 Generation</i>	<i>Total Flow at Rawson Island</i>
		A	B	A - B = C	D	A + D = E
1	8:30 AM	285	71	214	1010	1295
2	10:40 AM	347	71	276	1080	1427
3	12:55 PM	616	71	545	560	1176
4	2:05 PM	447	71	376	560	1007

Additionally, Cabot Station (downstream of the study area) was generating approximately 41 megawatt-hours (MWh) during the study, with about 9,000 cfs passing through the station.

4.2 Participants

Ten boaters participated in the study. The boaters utilized four canoes (solo and tandem) and three kayaks during study, for a total of seven boats. Boaters were asked to rate their skill level associated with their watercraft, ranging from novice to expert. Two boaters considered themselves novices, four considered themselves intermediate, three considered themselves advanced, and one considered himself an expert. Four of the boaters indicated that they had paddled the study reach previously, while six had not.

4.3 Navigability

Boaters were also asked to evaluate each flow based on their watercraft and skill level for various characteristics, rating each characteristic on a scale ranging from -2 (totally unacceptable) to 2 (totally acceptable). Characteristics included navigability, safety, ease of put-in, scrapes/bumps, and portages for each flow experienced. Responses for each of the rated characteristics were averaged by flow. **Table 4.3-1** summarizes the average rating of each characteristic for a given flow.

Table 4.3-1: Average Boater Ratings for Evaluated Characteristics by Flow

Characteristic	Rating ¹			
	Flow 1 (285/1,295 cfs) ²	Flow 2 (347/1,427 cfs) ²	Flow 3 (616/1,176 cfs) ²	Flow 4 (447/1,007 cfs) ²
Navigability	Neutral -0.40	Unacceptable -0.70	Acceptable 0.50	Unacceptable -0.50
Safety	Neutral 0.10	Neutral -0.20	Acceptable 0.60	Neutral 0.00
Ease of Put-In	Neutral 0.22	Neutral 0.30	Neutral 0.40	Neutral 0.20
Scrapes/Bumps	Unacceptable -0.60	Unacceptable -0.89	Neutral 0.38	Unacceptable -0.67
Portages	Neutral -0.11	Neutral -0.11	Acceptable 1.00	Neutral -0.13

¹Key to ratings available for boaters to choose from: -2 = Totally Unacceptable; -1 = Unacceptable; 0 = Neutral; 1 = Acceptable; 2 = Totally Acceptable. Average rating values were assigned to the nearest rating category.

²Flow above Station No. 1/Flow below Station No. 1.

Two areas of interest were the primary focus of the navigability evaluation: the channels around Peskeomskut Island immediately below Turners Falls Dam and the channels around Rawson Island below Station No. 1 at the downstream extent of the study reach. At Peskeomskut Island, the left channel was unnavigable under all assessed flows, but boaters were able to paddle the center-right and far-right channels (with varying level of difficulty) under all flows. The center-right channel is narrow and flume-like, while the far-right channel is more riffle-like. Boater feedback was mixed on which channel would be the preferable and/or safer route under the range of flows assessed.

At Rawson Island, boaters were able to navigate the far-right channel with no issues under all assessed flows. The center-right channel was unnavigable under all flows. Several experienced whitewater boaters took the left channel around Rawson Island to paddle over Rock Dam, which was runnable but not recommended for novice paddlers.

Put-In #2, located approximately 800 feet downstream of the Spillway Ladder and Put-In #1, was determined to be an acceptable put-in option for boaters wishing to bypass Peskeomskut Island. However, the path to access Put-In #2 would require some modification and clearing to improve ease of access.

Flow #3 was determined to be the minimum navigable flow of those assessed during the study. This flow event was characterized by approximately 545 cfs released from Bascule Gate #1 (calculated), 71 cfs from the Fall River (measured), and 560 cfs from Station No. 1 (reported), for total flows of approximately 616 cfs below Peskeomskut Island (measured) and 1,007 cfs below Station No. 1 (calculated).

The difficulty of the bypass reach under Flow #3 was rated as Class II (Novice)⁸ by most boaters (seven boaters gave a rating of Class II, while two additional boaters gave a range of ratings that included Class II).

⁸ According to the International Scale of River Difficulty, Class II runs involve straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized

Lastly, boaters were asked how likely they were to return to the bypass reach for recreation under each flow. Boaters were more likely to return under conditions similar to Flow #3 than any other flow. At a minimum, all boaters indicated that they would at least “possibly” return to the bypass reach during conditions similar to Flow #3.

Overall, the results of the Turners Falls boating navigability study demonstrate that the bypass reach provides through-paddling opportunities for a variety of watercraft and skill levels. Flow #3 (545 cfs released from Bascule Gate #1) was determined to be the minimum navigable flow and the flow at which boaters are most likely to return to the bypass reach for recreational opportunities.

waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.

APPENDIX A: SUMMARY OF EVALUATION FORMS

Table A-1: Summary of Pre-Run Boater Information Forms

Question	Paddler									
	1	2	3	4	5	6	7	8	9	10
Watercraft Type	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe
Tandem Partner	Nancy Condon	Tom Condon	N/A	N/A	Noah Pollack	N/A	Bryan Pytko	Jim Sullivan	N/A	Deb Weissman
Years of Experience with Watercraft	50	50	25	40	45	15	34	1	20	30
Skill Level with Watercraft	Advanced	Intermediate	Intermediate	Intermediate	Novice	Advanced	Expert	Intermediate	Novice	Advanced
Paddling Days per Year	30	13	25	24	40	80	170	30	7	60
Previous Boating Experience with Study Reach	No	No	No	Yes	No	Yes	Yes	Yes	No	No

Table A-2: Summary of Single-Flow Evaluation Forms – Flow 1

Question		Paddler									
		1	2	3	4	5	6	7	8	9	10
Boat	Watercraft Type	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe
	Watercraft Loading	Light	Light	None	Light	None	Yes	None	None	Light	None
Route	Put-In Location	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1
	Take-Out Location	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2
	Channel around Peskeomskut Island	Center Right	Center Right	Far Right	Center Right	Center Right	Far Right	Far Right	Left	Far Right	Center Right
	Channel around Rawson Island	Far Right	Far Right	Far Right	Far Right	Far Right	Center Right	Left (Ctr. Right not possible due to ledge)	Left (Ctr. Right un-runnable, no water)	Far Right	Far Right
No.	Scrapes/Bumps	5	5	5	11	1	5	10	10	11	2
	Portages	0	N/A	0	0	0	0	1	1	0	0
Rating ¹	Navigability	-1	1	-2	-1	1	1	-1	-1	-1	0
	Safety	1	1	-1	0	1	0	-1	-1	0	1
	Ease of Put-In	1	1	2	N/A	0	-1	-2	-1	1	1
	Scrapes/Bumps	-1	0	-2	-1	1	0	-1	-1	-1	0
	Portages	0	0	0	0	0	0	0	-1	0	N/A
Evaluation	Likelihood of Return	Possibly	Possibly	N/A	Definitely Not	Probably	Possibly	Possibly	Definitely Not	Definitely Not	Possibly
	Difficulty Rating ²	2	2	N/A	1	1	4	2	2	2	2
	Min. Recommended Skill Level	Intermediate	Intermediate	N/A	Novice	Novice	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Other	Difficulties	Lots of maneuvering needed to avoid pillows and exposed rocks	Navigating many pillows and exposed rocks in center right channel of Peskeomskut Island and 3 places throughout bypass	N/A	Got completely stopped once in center right channel of Peskeomskut Island	N/A	Opening ledges tough to read near Put-In #1	Peskeomskut Island: much scraping, some pushing. Improvements are needed for dry land access to be more accessible to a wider range of paddlers.	Center channel at Rawson Island is un-passable; rock ledge out of the water	Stuck in upper far right channel around Peskeomskut Island	Shallow water in ctr. R channel around Peskeomskut required careful river running. Boulder garden above Rawson requires maneuvering in quickly moving water.
	Comments	Whitewater reading and paddling skills necessary to maneuver through rock gardens	It is necessary to have an ability to maneuver a boat with confidence, although not life threatening if breached	Flow around Rawson Island was ok	N/A	N/A	Low - only to be done out of necessity	More water would provide a much better experience at the 1st rapid (Peskeomskut). The rest was decent water.	Novice paddlers would struggle around Peskeomskut Island	Upper far-right channel around Peskeomskut was bony; too low to "navigate" successfully for a novice. The rest of the reach was ok. The far-right channel around Rawson was ok.	Paddlers must be able to "read" the river to avoid hazards, mostly boulders, as flow increases below Station #1. Far-right channel around Peskeomskut Island is not recommended.

¹Key to Ratings: -2 = *Totally Unacceptable*; -1 = *Unacceptable*; 0 = *Neutral*; 1 = *Acceptable*; 2 = *Totally Acceptable*

²Based on the International Scale of River Difficulty: Class I, Class II (Novice), Class III (Intermediate), Class IV (Advanced), Class V (Expert)

Note: Some responses edited for clarity. See **Appendix B** for original evaluation forms.

Table A-3: Summary of Single-Flow Evaluation Forms – Flow 2

Question		Paddler									
		1	2	3	4	5	6	7	8	9	10
Boat	Watercraft Type	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe
	Watercraft Loading	Light	Light	None	Light	None	Yes	None	None	Light	None
Route	Put-In Location	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1
	Take-Out Location	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2
	Channel around Peskeomskut Island	Center Right	Center Right	Far Right	Center Right	Center Right	Far Right	Center Right	Center Right	Far Right	Center Right
	Channel around Rawson Island	Far Right	Far Right	Far Right	Left	Far Right	Center Right	Left	Left (Center Right was un-runnable)	Far Right	Far Right
No.	Scrapes/Bumps	7	8	5	9	7	5	10	N/A	10	7
	Portages	0	0	0	0	0	0	1	N/A	0	0
Rating ¹	Navigability	-2	-1	-2	-1	0	1	-1	-1	-1	1
	Safety	0	-1	-1	0	1	0	-1	-1	0	1
	Ease of Put-In	1	1	1	0	1	-1	-1	-1	1	1
	Scrapes/Bumps	-2	-1	N/A	-1	-1	0	-1	-1	-1	0
	Portages	0	1	N/A	0	0	0	-1	-1	0	0
Evaluation	Likelihood of Return	Possibly	Probably	Definitely Not	Definitely Not	Possibly	Possibly	Probably	Definitely Not	Definitely Not	Possibly
	Difficulty Rating ²	2	2	2	1	1	4	2	2	2	2
	Min. Recommended Skill Level	Intermediate	Intermediate	Intermediate	Novice	Novice	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Other	Difficulties	Center Right at Peskeomskut Island was worse than during Flow #1.	More difficulty around Peskeomskut this time. Two absolute stops and more scrapes. Other sections much the same. After Sta. 1, more water made for just nice, navigable runs.	Stuck on rocks at top island, far right.	One stop at center right channel at Peskeomskut Island. Pushed off the rock with the paddle.	Stuck once at right center of top island. Scraped 7 times mostly right center of top island.	Opening ledges tough to read near Put-In #1.	Got stuck at bottom of Center Right chute. Run felt like the same flow as previous.	No noticeable difference from Flow #1	Stuck in upper far right channel	Hit more rocks in center chute, oddly enough
	Comments	Top section around Peskeomskut Is. was worse or at least no better than at Flow #1. Lower section below Sta. 1 was easier to paddle with more flow covering some rocks and making others more noticeable.	Same or bonier in Center Right chute around Peskeomskut Island as the previous, lower level	Flow around Rawson Island was acceptable	There really wasn't any difference from Flow #1. One or two less scrapes, but this might have been an effect of learning the channel.	N/A	Low - only to be done out of necessity	No noticeable difference from the previous run	Very easy to get "lost" in center channel first rapids	This was the same experience as Flow #1	The additional flow did not materially change the experience

¹Key to Ratings: -2 = *Totally Unacceptable*; -1 = *Unacceptable*; 0 = *Neutral*; 1 = *Acceptable*; 2 = *Totally Acceptable*
²Based on the International Scale of River Difficulty: *Class I, Class II (Novice), Class III (Intermediate), Class IV (Advanced), Class V (Expert)*
Note: Some responses edited for clarity. See **Appendix C** for original evaluation forms.

Table A-4: Summary of Single-Flow Evaluation Forms – Flow 3

Question		Paddler									
		1	2	3	4	5	6	7	8	9	10
Boat	Watercraft Type	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe
	Watercraft Loading	Light	Light	None	Light	None	Yes	None	None	Light	None
Route	Put-In Location	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1
	Take-Out Location	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2	Take-Out #2
	Channel around Peskeomskut Island	Center Right	Center Right	Far Right	Center Right	Center Right	Far Right	Far Right	Far Right	Far Right	Center Right
	Channel around Rawson Island	Far Right	Far Right	Far Right	Left	Far Right	Far Right	Left	Left	Far Right	Far Right
No.	Scrapes/Bumps	1	1	3	3	3	4	3	3	5	N/A
	Portages	0	0	0	0	0	0	0	0	0	N/A
Rating ¹	Navigability	1	2	-1	0	1	1	-1	0	0	2
	Safety	1	1	0	0	1	0	0	0	1	2
	Ease of Put-In	1	1	1	0	1	-1	0	-1	1	1
	Scrapes/Bumps	1	2	N/A	0	1	0	-1	0	0	N/A
	Portages	1	2	N/A	0	2	0	N/A	1	1	N/A
Evaluation	Likelihood of Return	Probably	Definitely Yes	Possibly	Possibly	Probably	Possibly	Definitely Yes	Possibly	Probably	Definitely Yes
	Difficulty Rating ²	2	2	2	2	1 to 2	4	2	2	2	2 to 3
	Min. Recommended Skill Level	Intermediate	Intermediate	Intermediate	Novice	Novice	Intermediate	Intermediate	Intermediate	Novice	Novice (summer) and Intermediate (winter temps)
Other	Difficulties	Top around Peskeomskut Island much better at this flow	Fun. Only one scrape. Still skillful navigation helpful. Must maintain heading in Ctr. Right of Peskeomskut. Pillows require navigability in Far Right of Rawson.	N/A	This flow was better. No significant issues. Just a few bumps around the first island.	Just scrapes.	Pinned at Far Right ledges at opening ledges.	First rapid Class II, Rock dam Class III. We didn't get stuck this time, but it's still scrape-y. Below first rapid was about the same level of sufficient flow.	N/A	Bumps upper Far Right channel around Peskeomskut	Two minor bumps in Center Right chute around Peskeomskut
	Comments	Still requires river reading and maneuverability skills	Much improved from previous run levels. Not as long but ability to direct a canoe is still necessary (adds to the fun)	N/A	N/A	N/A	Tougher to navigate rocks	Getting better. A little more water would make it a fluid run but at this level it is much more passable.	Not great, but far better than the AM runs. Still not appropriate for beginners, the rapid lines are scratchy and hard to follow. At this level, first rapid is a real class II.	I feel this was minimum acceptable flow	Nice level. Still a little bumpy up high, but fun and pretty. Difficult to get around gate before pedestrian bridge with canoe. Need larger opening.

¹Key to Ratings: -2 = Totally Unacceptable; -1 = Unacceptable; 0 = Neutral; 1 = Acceptable; 2 = Totally Acceptable

²Based on the International Scale of River Difficulty: Class I, Class II (Novice), Class III (Intermediate), Class IV (Advanced), Class V (Expert)

Note: Some responses edited for clarity. See **Appendix C** for original evaluation forms.

Table A-5: Summary of Single-Flow Evaluation Forms – Flow 4

Question		Paddler									
		1	2	3	4	5	6	7	8	9	10
Boat	Watercraft Type	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe	Canoe	Kayak	Canoe
	Watercraft Loading	Light	Light	None	Light	Yes	Yes	None	None	Light	Yes
Route	Put-In Location	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1	Put-In #1
	Take-Out Location	Take-Out #1	Take-Out #1	Take-Out #1	Take-Out #1	Take-Out #1	Take-Out #1	Take-Out #1	Take-Out #1	Take-Out #2	Take-Out #2
	Channel around Peskeomskut Island	Center Right	Center Right	Center Right	Center Right	Far Right	Center Right	Center Right	Center Right	Far Right	Far Right
	Channel around Rawson Island	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
No.	Scrapes/Bumps	4	3	3	6	8	3	10	10	7	4
	Portages	0	0	0	0	0	0	1	0	0	0
Rating ¹	Navigability	-1	-1	-1	-1	0	1	-1	-1	-1	1
	Safety	1	-1	0	0	1	0	-1	-1	0	1
	Ease of Put-In	1	1	1	0	0	-1	-1	-1	1	1
	Scrapes/Bumps	-1	-1	N/A	-1	-1	0	-1	-1	-1	1
	Portages	0	0	N/A	N/A	0	0	-1	-1	0	1
Evaluation	Likelihood of Return	Possibly	Possibly	Possibly	Definitely Not	Definitely Not	Possibly	Definitely Yes	Definitely Not	Possibly	Probably
	Difficulty Rating ²	2	2	2	2	1	4	2	2	2	2 to 3
	Min. Recommended Skill Level	Intermediate	Intermediate	Intermediate	Novice	Novice	Intermediate	Intermediate	Intermediate	Intermediate	Novice
Other	Difficulties	Difficult maneuvering around Peskeomskut Island	More scrapes than Flow #3 in Center Right of Peskeomskut island. Bony; difficult for through-paddlers or novices.	N/A	Experienced one stop (also 6 scrapes) in the Center Right channel around Peskeomskut Island. The stop turned me sideways and I had to push off the bottom with my paddle to get free.	Far Right of Peskeomskut Island much too low. Like being in a pinball machine.	Paddler needs to know lines at opening ledges	Went exploring in Center Right chute around Peskeomskut. The two ledges were fun, but we got stuck. Could have scratched down left.	N/A	Bumps and stuck in upper Far Right channel around Peskeomskut	"Pin ball" around Peskeomskut Island. More water would have made it easier.
	Comments	Requires maneuvering skills and river reading skill.	Hard to find a paddle-able route at this flow.	N/A	N/A	N/A	I ran different lines in Flow #3 out #4 was far better than #1 or #2	Lower than desired	All levels today were too low. 600 cfs [Flow #3] was close. 670 would be good to try.	Too low to "navigate" successfully.	Would have been difficult with fully loaded canoe, but generally enough water to get down with occasional bouncing off rocks

¹Key to Ratings: -2 = Totally Unacceptable; -1 = Unacceptable; 0 = Neutral; 1 = Acceptable; 2 = Totally Acceptable
²Based on the International Scale of River Difficulty: Class I, Class II (Novice), Class III (Intermediate), Class IV (Advanced), Class V (Expert)
Note: Some responses edited for clarity. See **Appendix C** for original evaluation forms.

APPENDIX B: PRE-RUN BOATER INFORMATION FORMS

Pre-Run Boater Information Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/6/21

Name: E. BRADLEY WACHIA

Email Address: BRAD@ADVENTUREEAST.COM

1. What type of watercraft will you be using for this boating flow evaluation? (Check one)

☐ Canoe

☒ Kayak

☐ Other (describe): _____

(TOWING)

2. Please provide the name of your tandem paddling partner (in the same boat with you), if any:

X

3. How many years have you been using this type of watercraft? 15 years

4. How would you rate your skill level with this type of watercraft? (Check one)

Whitewater classifications defined on next page.

☐ Novice (comfortable running Class II whitewater)

☐ Intermediate (comfortable running Class III whitewater)

☒ Advanced (comfortable running Class IV whitewater) Sea kayak

☐ Expert (comfortable running Class V whitewater)

5. In general, how many days per year do you spend paddling? 80 days

(Please use a whole number rather than a range; it's fine to estimate.)

6. What is your age? 45 (must be at least 18 years old to participate)

7. Have you boated this reach before? ☒ Yes ☐ No

8. Will you be using the provided shuttle services for this study? (Check all that apply)

☒ Boat Shuttle

☒ Person Shuttle (must be vaccinated and masked)

Pre-Run Boater Information Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Name: Paul Jahnige

Email Address: pjahnige@gmail.com

1. What type of watercraft will you be using for this boating flow evaluation? *(Check one)*

☐ Canoe

☒ Kayak

☐ Other (describe): _____

(TWINING)

2. Please provide the name of your tandem paddling partner (in the same boat with you), if any:

3. How many years have you been using this type of watercraft? 20 years

4. How would you rate your skill level with this type of watercraft? *(Check one)*

Whitewater classifications defined on next page.

☒ Novice (comfortable running Class II whitewater)

☐ Intermediate (comfortable running Class III whitewater)

☐ Advanced (comfortable running Class IV whitewater)

☐ Expert (comfortable running Class V whitewater)

5. In general, how many days per year do you spend paddling? 7 days
(Please use a whole number rather than a range; it's fine to estimate.)

6. What is your age? 54 *(must be at least 18 years old to participate)*

7. Have you boated this reach before? ☐ Yes ☒ No

8. Will you be using the provided shuttle services for this study? *(Check all that apply)*

☒ Boat Shuttle

☒ Person Shuttle *(must be vaccinated and masked)*

Pre-Run Boater Information Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/2021
Name: Debra Weisenstein
Email Address: dkweis@alum.mit.edu

1. What type of watercraft will you be using for this boating flow evaluation? *(Check one)*
☒ Canoe ☐ Kayak ☐ Other (describe): _____
2. Please provide the name of your tandem paddling partner (in the same boat with you), if any:
Noah Pollack
3. How many years have you been using this type of watercraft? 45 years
4. How would you rate your skill level with this type of watercraft? *(Check one)*
Whitewater classifications defined on next page.
☒ Novice (comfortable running Class II whitewater)
☐ Intermediate (comfortable running Class III whitewater)
☐ Advanced (comfortable running Class IV whitewater)
☐ Expert (comfortable running Class V whitewater)
5. In general, how many days per year do you spend paddling? 40 days
(Please use a whole number rather than a range; it's fine to estimate.)
6. What is your age? 65 *(must be at least 18 years old to participate)*
7. Have you boated this reach before? ☐ Yes ☒ No
8. Will you be using the provided shuttle services for this study? *(Check all that apply)*
☒ Boat Shuttle ☒ Person Shuttle *(must be vaccinated and masked)*

Pre-Run Boater Information Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21
Name: Jack Gill
Email Address: jackgill@yahoo.com

1. What type of watercraft will you be using for this boating flow evaluation? *(Check one)*
☒ Canoe ☐ Kayak ☐ Other (describe): _____
(OCI WW)
2. Please provide the name of your tandem paddling partner (in the same boat with you), if any:
Solo
3. How many years have you been using this type of watercraft? 40+ years
4. How would you rate your skill level with this type of watercraft? *(Check one)*
Whitewater classifications defined on next page.
☐ Novice (comfortable running Class II whitewater)
☒ Intermediate (comfortable running Class III whitewater)
☐ Advanced (comfortable running Class IV whitewater)
☐ Expert (comfortable running Class V whitewater)
5. In general, how many days per year do you spend paddling? 24 days
(Please use a whole number rather than a range; it's fine to estimate.)
6. What is your age? 67 *(must be at least 18 years old to participate)*
7. Have you boated this reach before? ☒ Yes ☐ No
8. Will you be using the provided shuttle services for this study? *(Check all that apply)*
☒ Boat Shuttle ☒ Person Shuttle *(must be vaccinated and masked)*

Boating Demonstration Flow Study

Email Address: ccn12@live.com

- ☒ Person Shuttle (must be vaccinated and masked)

Pre-Run Boater Information Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11-9-21
Name: Nancy Condon
Email Address: nancy@paddleforwater.net

1. What type of watercraft will you be using for this boating flow evaluation? (Check one)

☒ Canoe

☐ Kayak

☐ Other (describe): _____

2. Please provide the name of your tandem paddling partner (in the same boat with you), if any:

Tom Condon

3. How many years have you been using this type of watercraft? 50 years

4. How would you rate your skill level with this type of watercraft? (Check one)

Whitewater classifications defined on next page.

☐ Novice (comfortable running Class II whitewater)

☒ Intermediate (comfortable running Class III whitewater)

☐ Advanced (comfortable running Class IV whitewater)

☐ Expert (comfortable running Class V whitewater)

5. In general, how many days per year do you spend paddling? 5-20 days
(Please use a whole number rather than a range; it's fine to estimate.)

6. What is your age? 61 (must be at least 18 years old to participate)

7. Have you boated this reach before? ☐ Yes ☒ No

8. Will you be using the provided shuttle services for this study? (Check all that apply)

☒ Boat Shuttle

☒ Person Shuttle (must be vaccinated and masked)

Pre-Run Boater Information Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21
Name: Tom Condon
Email Address: science@condon.net

1. What type of watercraft will you be using for this boating flow evaluation? *(Check one)*

☒ Canoe ☐ Kayak ☐ Other (describe): _____

2. Please provide the name of your tandem paddling partner (in the same boat with you), if any:

Danny Condon

3. How many years have you been using this type of watercraft? 50+ years

4. How would you rate your skill level with this type of watercraft? *(Check one)*

Whitewater classifications defined on next page.

- ☐ Novice (comfortable running Class II whitewater)
☐ Intermediate (comfortable running Class III whitewater)
☒ Advanced (comfortable running Class IV whitewater)
☒ Expert (comfortable running Class V whitewater)

5. In general, how many days per year do you spend paddling? 30 days

(Please use a whole number rather than a range; it's fine to estimate.)

6. What is your age? 61 *(must be at least 18 years old to participate)*

7. Have you boated this reach before? ☐ Yes ☒ No

8. Will you be using the provided shuttle services for this study? *(Check all that apply)*

☒ Boat Shuttle ☒ Person Shuttle *(must be vaccinated and masked)*

Pre-Run Boater Information Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/14/21
Name: Nate Pollock
Email Address: Nate@VermontRiverConservancy.org

1. What type of watercraft will you be using for this boating flow evaluation? *(Check one)*
☒ Canoe ☐ Kayak ☐ Other (describe): _____
2. Please provide the name of your tandem paddling partner (in the same boat with you), if any:
Deb Weisman
3. How many years have you been using this type of watercraft? 30 years
4. How would you rate your skill level with this type of watercraft? *(Check one)*
Whitewater classifications defined on next page.
☐ Novice (comfortable running Class II whitewater)
☐ Intermediate (comfortable running Class III whitewater)
☒ Advanced (comfortable running Class IV whitewater)
☐ Expert (comfortable running Class V whitewater)
5. In general, how many days per year do you spend paddling? 60 days
(Please use a whole number rather than a range; it's fine to estimate.)
6. What is your age? 40 *(must be at least 18 years old to participate)*
7. Have you boated this reach before? ☐ Yes ☒ No
8. Will you be using the provided shuttle services for this study? *(Check all that apply)*
☐ Boat Shuttle ☒ Person Shuttle *(must be vaccinated and masked)*

Pre-Run Boater Information Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Name: Brian Pytko

Email Address: _____

1. What type of watercraft will you be using for this boating flow evaluation? *(Check one)*

☒ Canoe

☐ Kayak

☐ Other (describe): _____

Mad River Legend 16'

2. Please provide the name of your tandem paddling partner (in the same boat with you), if any:

Jim Sullivan

3. How many years have you been using this type of watercraft? 1 years

4. How would you rate your skill level with this type of watercraft? *(Check one)*

Whitewater classifications defined on next page.

☐ Novice (comfortable running Class II whitewater)

☒ Intermediate (comfortable running Class III whitewater)

☐ Advanced (comfortable running Class IV whitewater)

☐ Expert (comfortable running Class V whitewater)

5. In general, how many days per year do you spend paddling? 30 days
(Please use a whole number rather than a range; it's fine to estimate.)

6. What is your age? 46 *(must be at least 18 years old to participate)*

7. Have you boated this reach before? ☒ Yes ☐ No

8. Will you be using the provided shuttle services for this study? *(Check all that apply)*

☒ Boat Shuttle

☒ Person Shuttle *(must be vaccinated and masked)*

Pre-Run Boater Information Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Name: James Sullivan

Email Address: _____

1. What type of watercraft will you be using for this boating flow evaluation? *(Check one)*

☒ Canoe

☐ Kayak

☐ Other (describe): _____

Mad River Legend 16'

2. Please provide the name of your tandem paddling partner (in the same boat with you), if any:

Brian Pytko

3. How many years have you been using this type of watercraft? 34 years

4. How would you rate your skill level with this type of watercraft? *(Check one)*

Whitewater classifications defined on next page.

☐ Novice (comfortable running Class II whitewater)

☐ Intermediate (comfortable running Class III whitewater)

☐ Advanced (comfortable running Class IV whitewater)

☒ Expert (comfortable running Class V whitewater)

5. In general, how many days per year do you spend paddling? 170 days

(Please use a whole number rather than a range; it's fine to estimate.)

6. What is your age? 40 *(must be at least 18 years old to participate)*

7. Have you boated this reach before? ☒ Yes ☐ No

8. Will you be using the provided shuttle services for this study? *(Check all that apply)*

☒ Boat Shuttle

☒ Person Shuttle *(must be vaccinated and masked)*

APPENDIX C: SINGLE-FLOW EVALUATION FORMS

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21
Time: 11:30 AM
Name: Tom Condon

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs #1 ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note: "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.

(Check one box for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2	✓	
Safety	-2	-1	0	1	2		
Ease of put-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: 5	-2	-1	0	1	2	✓	
Portages ¹ No. of times: 0	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
lots of maneuvering needed to avoid pillows, exposed rocks.	

9. Are you likely to return for future boating along this reach at **this** flow? (Check one)
- ☐ Definitely not
 ☒ Possibly
 ☐ Probably
 ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this** flow? (If appropriate, provide a range of classification for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at **this** flow?

☐ Beginner
 ☐ Novice
 ☒ Intermediate
 ☐ Advanced
 ☐ Expert

12. Please provide any additional comments about **this** flow below.

whitewater reading and paddling skills
necessary to maneuver through rock gardens

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with some training. Risk to swimmers is high; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an inexperienced paddler. Complex maneuvers, fast current and good boat control in tight passages or around ledges are often required. Large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: _____

Name: Tom Condon

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☒ 670 cfs
#2

☐ 900 cfs

☐ Other: _____

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☒ Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☒ Far Right

☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.

(Check one for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	<u>-2</u>	-1	0	1	2	☒	
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps	<u>-2</u>	-1	0	1	2	☒	
No. of times: <u>7</u>							
Portages ¹	-2	-1	<u>0</u>	1	2		
No. of times: <u>0</u>							

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Center Right @ P. Island was worse than at 500 cfs.	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not

☒ Possibly

☐ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

Top section around P. Island was worse or at least no better than @ 500 cfs.
Lower section below Station #1 was easier to paddle with more flow covering some rocks & making others more noticeable

International Whitewater Scale

- Class I - Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with a good roll. Self-rescue is easy.
- Class II - Straightforward rapids with wide, clear channels which are evident without scouting. Occasional portage or covering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance is seldom needed.
- Class III - Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers, fast current and good boat control in tight passages or around ledges are often required. Large waves or strong eddies may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long portages.
- Class IV - Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V - Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21
Time: 2:30
Name: Tom Condon

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☒ 900 cfs

☐ Other: _____

~~N/A~~

600 #3

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note: "left" & "right" refer to direction facing downstream.)

☐ Left



Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right



Far Right

☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle grade number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	<u>1</u>	2		
Safety	-2	-1	0	<u>1</u>	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>1</u>	-2	-1	0	<u>1</u>	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	<u>1</u>	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Top around P. island much better at this flow	

9. Are you likely to return for future boating along this reach at this flow? (Check only one)

☐ Definitely not

☐ Possibly

☒ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check only one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

still requires river reading & maneuverability skills!

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little warning. Risk to swimmers slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance while helpful is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers, fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable body turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: _____

Name: Tom Condon

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☐ 900 cfs

☒ Other: 4th flow

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☒ Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☐ Far Right

☒ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2	☒	
Safety	-2	-1	0	<u>1</u>	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>4</u>	-2	<u>-1</u>	0	1	2	☒	
Portages ¹ No. of times: <u>0</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
difficult maneuvering around P. Island	

9. Are you likely to return for future boating along this reach at **this flow**? (Check all)

☐ Definitely not

☒ Possibly

☐ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this flow**? (If appropriate, provide a range of classification for **this flow**)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at **this flow**? (Check all)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about **this flow** below.

Requires strong maneuvering skills and river reading skill.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with care. **Swimming**. Self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance is helpful but seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers – fast current and good boat control in tight passages or around ledges are often required. Large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11-9-21

Time: 11:30

Name: Nancy Condon

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____
#1

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☒ No *slight*

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	<u>1</u>	2		
Safety	-2	-1	0	<u>1</u>	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>5x</u>	-2	-1	<u>0</u>	1	2		
Portages ¹ No. of times: _____	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
navigating many pillows & exposed rocks	Center R. channel of Peskeomskut 2sl. → 3 places throughout Bypass

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not

☒ Possibly

☐ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

It is necessary to have ~~navigability~~ an ability to maneuver a boat with confidence. Although not life threatening if breached.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11-9-21
Time: 2nd run
Name: Nancy Condon

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☒ 670 cfs ☐ 900 cfs ☐ Other: _____
#2

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2		
Safety	-2	<u>-1</u>	0	1	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>8x</u>	-2	<u>-1</u>	0	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	<u>1</u>	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

Some or more bumps in center R chute of Peskeomskut sl. as the previous, "lower" level.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
More difficulty around Peskumokut this time. Some absolute stops & more scrapes. Other sections much the same, not after station 1 & more water made for just nice, navigable runs.	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not

☐ Possibly

☒ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

International White water Scale

- Class I – Fast moving water with ripples and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11-9-21
Time: 3rd run
Name: Kenny Gordon

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☐ 670 cfs ☒ 900 cfs ☐ Other: _____

#3

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2		
Safety	-2	-1	0	1	2		
Ease of put-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: <u>1</u>	-2	-1	0	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

none

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Fun - waves - only 1 scrape - still skillful navigation helpful. Must maintain heading here. Pillows require maneuverability.	Center R of Peskonnasket For R of Rowson

9. Are you likely to return for future boating along this reach at this flow? (Check one)
- ☐ Definitely not
 ☐ Possibly
 ☐ Probably
 ☒ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner
 ☐ Novice
 ☒ Intermediate
 ☐ Advanced
 ☐ Expert

12. Please provide any additional comments about this flow below.

Much improved from previous run levels. Not as long but ability to direct a canoe is still necessary (adds to the fun)

International Whitewater Scale

- Class I - Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II - Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- Class III - Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV - Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V - Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11-9-21
Time: 4th run
Name: Nancy Condon

#4

1. Please indicate which flow release this survey corresponds to. (Check one) 500 cfs / 480
☐ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)
☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island: N/A
☐ Left (Rock Dam) ☐ Center Right ☐ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2		
Safety	-2	<u>-1</u>	0	1	2		
Ease of put-in	-2	<u>-1</u>	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>3x</u>	-2	<u>-1</u>	0	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
More scrapes than 3 rd run - long - difficult for thru paddlers or novices.	Center R. of P. 2sl.

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not

☒ Possibly

☐ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

Hard to find a paddle-able route at this flow.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require “must” moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21
Time: 9:30 AM
Name: Conrad Northrup

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____
#1

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)
☐ Left ☐ Center Right (deep chute) ☒ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:
☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2	☒	
Safety	-2	-1	0	1	2		
Ease of put-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: <u>5</u>	-2	-1	0	1	2		
Portages ¹ <u>None</u> No. of times: _____	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

Note: Flow around Rawson Island was OK.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not ☐ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: _____

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☐ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/2021

Time: 12:30 PM

Name: Conrad Nuthmann

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☒ 670 cfs ☐ 900 cfs ☐ Other: _____
#2

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☐ Center Right (deep chute) ☒ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	<u>-2</u>	-1	0	1	2	☒	
Safety	-2	<u>-1</u>	0	1	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>5</u>	-2	-1	0	1	2		
Portages ¹ <u>None</u> No. of times: _____	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

Note: Flow around Rawson was acceptable

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Srq ck on Rocks	Top Island Far Right

9. Are you likely to return for future boating along this reach at **this** flow? (Check one)

☒ Definitely not ☐ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this** flow? (If appropriate, provide a range of classifications for **this** flow.)

This flow rates as Class: 2

11. What skill level do you think a paddler needs to safely paddle the bypass at **this** flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about **this** flow below.

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21
Time: 1:30
Name: Conrad Nathmann

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☐ 670 cfs ☒ 900 cfs ☐ Other: _____

#3

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☐ Center Right (deep chute) ☒ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	<u>0</u>	1	2		
Safety	-2	-1	<u>0</u>	<u>1</u>	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>3</u>	-2	-1	0	1	2		
Portages ¹ <u>None</u> No. of times: _____	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass

9. Are you likely to return for future boating along this reach at **this** flow? (Check one)

☐ Definitely not ☒ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this** flow? (If appropriate, provide a range of classifications for **this** flow.)

This flow rates as Class: 2

11. What skill level do you think a paddler needs to safely paddle the bypass at **this** flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about **this** flow below.

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form

Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21
Time: 2:30
Name: Conrad Nixhman

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☐ 900 cfs

☒ Other: 500
#4

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☒ Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☐ Far Right

☒ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	<u>0</u>	<u>1</u>	2	☒	
Safety	-2	-1	<u>0</u>	<u>1</u>	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>3</u>	-2	-1	0	1	2		
Portages ¹ <u>NONE</u> No. of times: <u> </u>	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass

9. Are you likely to return for future boating along this reach at **this** flow? (Check one)

☐ Definitely not ☒ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this** flow? (If appropriate, provide a range of classifications for **this** flow.)

This flow rates as Class: 2

11. What skill level do you think a paddler needs to safely paddle the bypass at **this** flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about **this** flow below.

Jill is nice!

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 11:15 AM

Name: Jack Gill

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No *Loaded just with a sm. Dry bag, water and throw bag.*

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics. (Circle the number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2	☒	
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: <u>11</u>	-2	<u>-1</u>	0	1	2	☒	
Portages ¹ No. of times: <u>6</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Got completely stopped once Center Rt. channel at Peskeom. Island	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☒ Definitely not ☐ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification for this flow.)

This flow rates as Class: 1

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☒ Novice ☐ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little planning. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 12:30 PM

Name: Jack Gill

1. Please indicate which flow release this survey corresponds to. (Check one) 2nd Flow
- ☐ 500 cfs ☒ 670 cfs ☐ 900 cfs ☐ Other: _____
- #2
2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No Just a day trip load,
3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)
4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)
5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)
- ☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)
6. Channel taken past Rawson Island:
- ☒ Left (Rock Dam) ☐ Center Right ☐ Far Right ☐ N/A (took out above island)
7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2	☒	
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	-1	<u>0</u>	1	2		
Scrapes/bumps No. of times: <u>9</u>	-2	<u>-1</u>	0	1	2	☒	
Portages ¹ No. of times: <u>0</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
One Stop at center Rt. Channel ent	Peskeom Island. Pushed off the rock with the paddle

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☒ Definitely not

☐ Possibly

☐ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: 1

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☒ Novice

☐ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

There really wasn't any difference from 500 cfs. One or two less scrapes than 570 cfs but this might have been an effect of learning the channel.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9

Time: 2:50

Name: Jack Gill

1. Please indicate which flow release this survey corresponds to (Check one)

☐ 500 cfs

☐ 670 cfs

☒ 900 cfs

☐ Other: _____

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

A day trip load

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☒ Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☒ Left (Rock Dam)

☐ Center Right

☐ Far Right

☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	<u>0</u>	1	2		
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	-1	<u>0</u>	1	2		
Scrapes/bumps No. of times: <u>3</u>	-2	-1	<u>0</u>	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
This flow was better. No significant issues. Just a few bumps around the 1st island	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not

☒ Possibly

☐ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: 2

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☒ Novice

☐ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require “must” moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 3:30 PM

Name: Jack Gill

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☐ 900 cfs

☒ Other: 4th Flow

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

Just a day trip load

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☒ Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☐ Far Right

☒ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	<u>0</u>	1	2	☒	
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	-1	<u>0</u>	1	2		
Scrapes/bumps No. of times: <u>6</u>	-2	<u>-1</u>	0	1	2	☒	
Portages ¹ No. of times: <u>0</u>	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Experienced one stop (also 6 scrapes) in the center of channel around Peskeom. Island. The stop turned me sideways and I had to push off the bottom with my paddle to get free.	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☒ Definitely not

☐ Possibly

☐ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: 2 minus

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☒ Novice

☐ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

International Whitewater Scale

- **Class I** – Fast moving water with ripples and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 11:30 am

Name: Debra Weisenstein

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

#1

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2		
Safety	-2	-1	0	1	2		
Ease of put-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: <u>1</u>	-2	-1	0	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty. None

Difficulty	Location in Bypass

9. Are you likely to return for future boating along this reach at this flow? (Check one)
- ☐ Definitely not ☐ Possibly ☒ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification for this flow.)

This flow rates as Class: I

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☒ Novice ☐ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/2021
Time: 12:50
Name: Debra Weisenstein

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☒ 670 cfs ☐ 900 cfs ☐ Other: _____

#2

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2		
Safety	-2	-1	0	1	2		
Ease of put-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: <u>7</u>	-2	-1	0	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Stuck once scraped 7 times	R. Center of top island mostly R. Center of top island

9. Are you likely to return for future boating along this reach at this flow? (Check one)
- ☐ Definitely not
 ☒ Possibly
 ☐ Probably
 ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification at this flow)

This flow rates as Class: I

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner
 ☒ Novice
 ☐ Intermediate
 ☐ Advanced
 ☐ Expert

12. Please provide any additional comments about this flow below.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers are required; fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/2021
Time: 2:45
Name: Deb Weisenstein

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☐ 670 cfs ☒ 900 cfs ☐ Other: _____
#3

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2		
Safety	-2	-1	0	1	2		
Ease of put-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: 3	-2	-1	0	1	2		
Portages ¹ No. of times: 0	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location or Bypass
Just scrape	

9. Are you likely to return for future boating along this reach **at this flow**? (Check one)
- ☐ Definitely not ☐ Possibly ☒ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run **at this flow**? (If appropriate, provide a range of classifications for this flow)

This flow rates as Class: I-II

11. What skill level do you think a paddler needs to safely paddle the bypass **at this flow**? (Check one)
- ☐ Beginner ☒ Novice ☐ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about **this flow** below.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little scouting. Risk to swimmers is high; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers, fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/2021

Time: 3:30 PM

Name: Deb Weisenstein

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☐ 900 cfs

☒ Other: 450

#4

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☐ Center Right (deep chute)

☒ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☐ Far Right

☒ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2		
Safety	-2	-1	0	1	2		
Ease of out-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: <u>8</u>	-2	-1	0	1	2		
Portages No. of times: <u>0</u>	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Far R of island much too low like being in a pinball machine	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☒ Definitely not ☐ Possibly ☐ Probably ☐ Definitely yes
Not far Right

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification this flow)

This flow rates as Class: I+

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☒ Novice ☐ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little scouting. Risk to swimmers is high; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance while helpful is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an inexperienced paddler. Complex maneuvers are required. Fast current and good boat control in tight passages or around ledges are often required, large waves or strong currents may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 11:30 AM

Name: BRAD WALKER

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____
#1

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☐ Center Right (deep chute) ☒ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☒ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	<u>1</u>	2		
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	<u>-1</u>	0	1	2		
Scrapes/bumps No. of times: <u>5</u>	-2	-1	<u>0</u>	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Opening Ledges back to head	Rt In #1

9. Are you likely to return for future boating along this reach at **this flow**? (Check one)

☐ Definitely not

☒ Possibly

☐ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this flow**? (If appropriate, provide a range of classifications for **this flow**.)

This flow rates as Class: III

11. What skill level do you think a paddler needs to safely paddle the bypass at **this flow**? (Check one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about **this flow** below.

Low - only to be done out of necessity -

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require “must” moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 12:45 PM

Name: Bo Walker

EFFECTIVELY THE SAME AS 500 cfs

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☒ 670 cfs

☐ 900 cfs

☐ Other: _____

#2

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☐ Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☐ Far Right

☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2		
Safety	-2	-1	0	1	2		
Ease of put-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: _____	-2	-1	0	1	2		
Portages ¹ No. of times: _____	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass

9. Are you likely to return for future boating along this reach at **this** flow? (Check one)

☐ Definitely not ☐ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this** flow? (If appropriate, provide a range of classifications for **this** flow.)

This flow rates as Class: _____

11. What skill level do you think a paddler needs to safely paddle the bypass at **this** flow? (Check one)

☐ Beginner ☐ Novice ☐ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about **this** flow below.

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 2:45 PM

Name: Brian Warner

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☒ 900 cfs

☐ Other: _____

#3

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☐ Center Right (deep chute)

☒ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☒ Far Right

☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	<u>1</u>	2		
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	<u>-1</u>	0	1	2		
Scrapes/bumps No. of times: <u>4</u>	-2	-1	<u>0</u>	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Pinned off by first ledge	Open ledge

9. Are you likely to return for future boating along this reach at **this** flow? (Check one)

☐ Definitely not ☒ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this** flow? (If appropriate, provide a range of classifications for **this** flow.)

This flow rates as Class: II/III

11. What skill level do you think a paddler needs to safely paddle the bypass at **this** flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about **this** flow below.

toe to navigate sharp rocks

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21
Time: 3:30 PM
Name: Brian Walsh

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☐ 670 cfs ☐ 900 cfs ☒ Other: #4

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☐ Far Right ☒ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	<u>1</u>	2		
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	<u>0</u>	0	1	2		
Scrapes/bumps No. of times: <u>3</u>	-2	-1	<u>0</u>	1	2		
Portages ¹ No. of times: <u>8</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
paddler needs to learn lines	openly ledges

9. Are you likely to return for future boating along this reach at **this** flow? (Check one)

☐ Definitely not ☒ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this** flow? (If appropriate, provide a range of classifications for **this** flow.)

This flow rates as Class: III

11. What skill level do you think a paddler needs to safely paddle the bypass at **this** flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about **this** flow below.

Iron differt line in flow #3 out #4 was for
Gaffer the #1,2

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require “must” moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 11:27

Name: Jim Sullivan

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

#1

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No Just Brian

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☐ Center Right (deep chute) ☒ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☒ Left (Rock Dam) ☐ Center Right ☐ Far Right ☐ N/A (took out above island)

NOT
passable 1' rock ledge

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2	☒	
Safety	-2	<u>-1</u>	0	1	2	☒	
Ease of put-in	<u>-2</u>	-1	0	1	2	<u>NA</u>	
Scrapes/bumps No. of times: <u>10+</u>	-2	<u>-1</u>	0	1	2	☒	
Portages ¹ No. of times: <u>1</u>	-2	-1	<u>0</u>	1	2	☒	

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
1st Island much scraping some rushing far right much talk about improving dryland access to be more accessible to a wider range of paddlers	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not

☒ Possibly

☐ Probably

☒ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: 2

1st rapid is a scrape (chute) is a III

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

more water would provide a much better
experience at the 1st rapid. The rest was
decent water.

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require “must” moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 12:46

Name: Jim Sullivan

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☒ 670 cfs

☐ 900 cfs

☐ Other: _____

#2

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No Just Bring again

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☒ Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

The Bottom is not deep

6. Channel taken past Rawson Island:

☒ Left (Rock Dam)

☐ Center Right

☐ Far Right

☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2	☒	
Safety	-2	<u>-1</u>	0	1	2	☒	
Ease of put-in	-2	<u>-1</u>	0	1	2	☒	
Scrapes/bumps No. of times: <u>10</u>	-2	<u>-1</u>	0	1	2	☒	
Portages ¹ No. of times: <u>1</u>	-2	<u>-1</u>	0	1	2	☒	

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
got stuck at bottom of center right chute	
Run felt like the same flow as previous	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not

☐ Possibly

☒ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: 2

1st rapid still too low Rock dam C III

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

No noticeable difference from previous run

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 2:45

Name: Jim Sullivan

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☒ 900 cfs

☐ Other: _____

600?

#3

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No Just Brian

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☐ Center Right (deep chute)

☒ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☒ Left (Rock Dam)

☐ Center Right

☐ Far Right

☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.

(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2		
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	-1	<u>0</u>	1	2		
Scrapes/bumps No. of times: <u>3</u>	-2	<u>-1</u>	0	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
we didn't get stuck this time But it's still scrappy	Far right 1st rapid
Below first rapid was about the same level Sufficient flow	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not ☐ Possibly ☐ Probably ☒ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: 2
1st rapid class II Rock dam class III

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

Getting better a little more water
would make it a fluid run but at this
level it is much more passable

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21
Time: 3:30?
Name: Jim Sullivan

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☒ 670 cfs ☐ 900 cfs ☐ Other: _____

cap 4 #4

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No still got Brian

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

went exploring

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☐ Far Right ☒ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.

(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2		
Safety	-2	<u>-1</u>	0	1	2		
Ease of put-in	-2	<u>-1</u>	0	1	2		
Scrapes/bumps No. of times: <u>10+</u>	-2	<u>-1</u>	0	1	2		
Portages ¹ No. of times: <u>1</u>	-2	<u>-1</u>	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run **at this flow** (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Went exploring in center chute the 2 ledges were run but we got stuck	center chute
could have scratched down 1st FT	

9. Are you likely to return for future boating along this reach at **this flow**? (Check one)

☐ Definitely not

☐ Possibly

☐ Probably

☒ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at **this flow**? (If appropriate, provide a range of classifications for **this flow**.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at **this flow**? (Check one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about **this flow** below.

Lower than desired.

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 11:27

Name: Brian Pytko

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

#1

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☒ Left ☐ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☒ Left (Rock Dam) ☒ Center Right ☐ Far Right ☐ N/A (took out above island)

*Unrunnable
No water*

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2	☒	
Safety	-2	<u>-1</u>	0	1	2	☒	
Ease of put-in	-2	<u>-1</u>	0	1	2	☒	
Scrapes/bumps No. of times: <u>10</u>	-2	<u>-1</u>	0	1	2	☒	
Portages ¹ No. of times: <u>1</u>	-2	<u>0</u>	0	1	2	☒	

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Center Channel at Rawson Island is unpassable. Rock ledge out of the water.	Rawson Island

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☒ Definitely not

☐ Possibly

☐ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☐ Novice

☒ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

~~Intermediate~~
Novice paddlers would struggle around Peskeomskut

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 2nd Run 11-Noon

Name: Brian Pytko

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☒ 670 cfs

☐ 900 cfs

☐ Other: _____

2

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☒ Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☒ Left (Rock Dam)

☐ Center Right

☐ Far Right

☐ N/A (took out above island)

Unrunnable

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2		
Safety	-2	-1	0	1	2		
Ease of put-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: _____	-2	-1	0	1	2		
Portages ¹ No. of times: _____	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
No noticeable difference from 500 cfs.	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☒ Definitely not ☐ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

Very easy to get "lost" in center channel
15+ rapids

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/21
Time: 3rd Run
Name: Brian Pytko

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☐ 670 cfs ☒ 900 cfs ☐ Other: _____

? #3

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☐ Center Right (deep chute) ☒ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

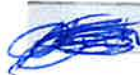
☒ Left (Rock Dam) ☐ Center Right ☐ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	<u>0</u>	1	2		
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	<u>-1</u>	0	1	2		
Scrapes/bumps No. of times: <u>3</u>	-2	-1	<u>0</u>	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	<u>1</u>	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not ☒ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

Not great, but far better than the Am runs. Still not appropriate for beginners, the rapid lines are scratchy and hard to follow. At this level, 1st rapid is a real class II

International Whitewater Scale

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- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/2
Time: Last Run 3:30
Name: Brian Pytko

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

4

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☐ Far Right ☒ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	(-1)	0	1	2		
Safety	-2	(-1)	0	1	2		
Ease of put-in	-2	(-1)	0	1	2		
Scrapes/bumps No. of times: <u>10</u>	-2	(-1)	0	1	2		
Portages ¹ No. of times: <u>0</u>	-2	(-1)	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☒ Definitely not ☐ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

All levels today were too low. 600 cfs. was close. 670 would be good to try.

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
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Single Flow Evaluation Form

Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 10 a.m.

Name: Paul Jahnige

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

#1

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

(Some)

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☐ Center Right (deep chute) ☒ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2	<u>X</u>	
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>9-12</u>	-2	<u>-1</u>	0	1	2	<u>X</u>	
Portages ¹ No. of times: <u>0</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

Struck once

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Stuck	Upper Far Right

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☒ Definitely not ☐ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

Upper far Right was boney. Too Low to "Navigate" successfully for a novice. Rest was OK. Right of Rawson, OK.

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
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Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 17:30

Name: Paul Jahnig

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs ☒ 670 cfs ☐ 900 cfs ☐ Other: _____

#2

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

Sound

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left ☐ Center Right (deep chute) ☒ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	(-1)	(0)	1	2	X	
Safety	-2	-1	(0)	1	2		
Ease of put-in	-2	-1	0	(1)	2		
Scrapes/bumps No. of times: <u>9+1</u>	-2	(-1)	0	1	2	X	
Portages ¹ No. of times: <u>10</u> <u>0</u>	-2	-1	(0)	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

1 stuck

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
stuck upper far Right —	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not ☒ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

This was the same experience as 500

International Whitewater Scale

- **Class I** — Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** — Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** — Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** — Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
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Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 10/9/21

Time: 1:30

Name: Paul Jahng

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☒ 900 cfs
3rd

☐ Other: _____

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) *Some* ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☐ Center Right (deep chute)

☒ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☒ Far Right

☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	<u>0</u>	1	2		
Safety	-2	-1	0	<u>1</u>	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>5</u>	-2	-1	<u>0</u>	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	<u>1</u>	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Bumps	upper Far Right

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not ☐ Possibly ☒ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☒ Novice ☐ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

I feel this was minimum acceptable Flow.

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
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Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 3 pm

Name: Paul Jahnige

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☐ 900 cfs

☒ Other: 4 ft 500?

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

some

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☐ Center Right (deep chute)

☒ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☐ Far Right

☒ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	<u>-1</u>	0	1	2		
Safety	-2	-1	<u>0</u>	1	2		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps No. of times: <u>7</u>	-2	<u>-1</u>	0	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	<u>0</u>	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Bumps & Stuck	Upper Far Right

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not ☒ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classifications for this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

Too Low to "navigate" successfully

International Whitewater Scale

- **Class I** – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- **Class II** – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful is seldom needed.
- **Class III** – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- **Class IV** – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- **Class V** – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 11:30 AM

Name: Noah Pollock

1. Please indicate which flow release this survey corresponds to. (Check one)

☒ 500 cfs #1 (300 cfs) ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note: "left" & "right" refer to direction facing downstream.)

☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Check one box for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	2		
Safety	-2	-1	0	1	2		
Ease of out-in	-2	-1	0	1	2		
Scrapes/bumps No. of times: <u>2</u>	-2	-1	0	1	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Shallow water in "deep chute" required careful river running.	Peskeomiscut Island
A boulder garden above Rawson Island requires maneuvering in quickly moving water.	Rawson Island

9. Are you likely to return for future boating along this reach at this flow? (Check one)
- ☐ Definitely not ☒ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range in classification: at this flow)

This flow rates as Class: II (Check den: III)

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

Paddlers must be able to "read" the river to avoid hazards, mostly boulders, as flow increases below Station One. For right part Peskeomiscut Island is not recommended.

International Whitewater Scale

- Class I - Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with close timing. Risk to swimmers is slight; self-rescue is easy.
- Class II - Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance while helpful is seldom needed.
- Class III - Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers in fast current and good boat control in tight passages or around ledges are often required; large waves or strong eddies may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV - Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V - Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 12:45 PM

Name: Noah Pollock

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☒ ~~670 cfs~~ 330 cfs #2

☐ 900 cfs

☐ Other: _____

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☒ Center Right (deep chute)

☐ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☒ Far Right

☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	(1)	2		
Safety	-2	-1	0	(1)	2		
Ease of put-in	-2	-1	0	(1)	2		
Scrapes/bumps No. of times: <u>7</u>	-2	-1	(0)	1	2		
Portages ¹ No. of times: _____	-2	-1	(0)	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Hit more rocks in center chute, oddity enough.	Center chute

9. Are you likely to return for future boating along this reach at this flow? (Check one)
- ☐ Definitely not ☒ Possibly ☐ Probably ☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification at this flow.)

This flow rates as Class: II

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner ☐ Novice ☒ Intermediate ☐ Advanced ☐ Expert

12. Please provide any additional comments about this flow below.

The additional flow did not materially change the experience.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an inexperienced paddler. Complex maneuvers, lost current and good boat control in tight passages or around ledges are often required; large waves or strong currents may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 2:45 PM

Name: Noah Pollock

1. Please indicate which flow release this survey corresponds to. (Check one) ☒ #3 (600 cfs)
☐ 500 cfs ☐ 670 cfs ☐ 900 cfs ☐ Other: _____

2. Did you load your boat with gear or other weights for this run? ☐ Yes ☒ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☐ Take-Out #1 (Station No. 1) ☒ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note: "left" & "right" refer to direction facing downstream.)
☐ Left ☒ Center Right (deep chute) ☐ Far Right ☐ N/A (put in below island)

6. Channel taken past Rawson Island:
☐ Left (Rock Dam) ☐ Center Right ☒ Far Right ☐ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Circle one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	0	1	<u>2</u>		
Safety	-2	-1	0	1	<u>2</u>		
Ease of put-in	-2	-1	0	<u>1</u>	2		
Scrapes/bumps: No. of times: _____	-2	-1	0	1	2		
Portages: No. of times: _____	-2	-1	0	1	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

Difficult to get around gate before pedestrian bridge w/ canoe - need larger opening.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
Two minor bumps	(center chute)

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not

☐ Possibly

☒ ~~Probably~~

☒ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification) this flow

This flow rates as Class: II-III

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☒ Novice

☒ Intermediate

☐ Advanced

☐ Expert

Summer

Fall/Spring (water temps)

12. Please provide any additional comments about this flow below.

Nice run. Still a little bumpy up high, but fun + pretty.

International Whitewater Scale

- Class I – Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with due timing. Risks to swimmers slight; self-rescue is easy.
- Class II – Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.
- Class III – Rapids with moderate, irregular waves which may be difficult to avoid, and which can swamp an open canoe. Complex maneuvers – fast current and good boat control in tight passages or around ledges are often required; large waves or strainers may be present but are easily avoided. Strong eddies and powerful current effects can be found, particularly on large-volume rivers. Scouting is advisable for inexperienced parties. Injuries while swimming are rare; self-rescue is usually easy, but group assistance may be required to avoid long swims.
- Class IV – Intense, powerful but predictable rapids requiring precise boat handling in turbulent water. Depending on the character of the river, it may feature large, unavoidable waves and holes or constricted passages demanding fast maneuvers under pressure. A fast, reliable eddy turn may be needed to initiate maneuvers, scout rapids, or rest. Rapids may require "must" moves above dangerous hazards. Scouting may be necessary the first time down. Risk of injury to swimmers is moderate to high, and water conditions may make self-rescue difficult. Group assistance for rescue is often essential but requires practiced skills. A strong eskimo roll is highly recommended.
- Class V – Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

Single Flow Evaluation Form
Turners Falls Hydroelectric Project, FERC No. 1889
Boating Demonstration Flow Study

Date: 11/9/21

Time: 3:30 PM

Name: Nah Pollock

1. Please indicate which flow release this survey corresponds to. (Check one)

☐ 500 cfs

☐ 670 cfs

☐ 900 cfs

☒ Other: 450 cfs
#4

2. Did you load your boat with gear or other weights for this run? ☒ Yes ☐ No

3. Put-in location for this run: ☒ Put-In #1 (at fish ladder) ☐ Put-In #2 (below Peskeomskut Island)

4. Take-out location for this run: ☒ Take-Out #1 (Station No. 1) ☐ Take-Out #2 (Cabot Woods)

5. Channel taken past Peskeomskut Island: (Note "left" & "right" refer to direction facing downstream.)

☐ Left

☐ Center Right (deep chute)

☒ Far Right

☐ N/A (put in below island)

6. Channel taken past Rawson Island:

☐ Left (Rock Dam)

☐ Center Right

☐ Far Right

☒ N/A (took out above island)

7. Please evaluate this flow for your watercraft and skill level for each of the following characteristics.
(Enter one number for each characteristic.)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	If unacceptable, was flow:	
						Too low	Too high
Navigability	-2	-1	☒	☒	2		
Safety	-2	-1	0	☒	2		
Ease of put-in	-2	-1	0	☒	2		
Scrapes/bumps No. of times: <u>4</u>	-2	-1	0	☒	2		
Portages ¹ No. of times: <u>0</u>	-2	-1	0	☒	2		

¹Include any instances where you needed to get out of your boat and carry/drag the boat over or around an obstacle.

8. Did you experience any difficulties during your run at this flow (e.g., stuck on obstacles, had to portage, etc.)? Provide a brief description and location of any difficulty.

Difficulty	Location in Bypass
"Pin ball" around Peskemoit Island - more water would have been made made it easier.	

9. Are you likely to return for future boating along this reach at this flow? (Check one)

☐ Definitely not

☐ Possibly

☒ Probably

☐ Definitely yes

10. Based on the International Whitewater Scale (defined below), how would you rate the whitewater difficulty of the run at this flow? (If appropriate, provide a range of classification for this flow.)

This flow rates as Class: II-III

11. What skill level do you think a paddler needs to safely paddle the bypass at this flow? (Check one)

☐ Beginner

☒ Novice

☐ Intermediate

☐ Advanced

☐ Expert

12. Please provide any additional comments about this flow below.

⊙ Would have been difficult w/ fully loaded canoe, but generally enough water to set down - with occasional bouncing off rocks.

International Whitewater Scale

- Class I - Fast moving water with riffles and small waves. Few obstructions, all obvious and easily missed with little training. Risk to swimmers is high; self-rescue is easy.
- Class II - Straightforward rapids with wide, clear channels which are evident without scouting. Occasional maneuvering may be required, but rocks and medium-sized waves are easily missed by trained paddlers. Swimmers are seldom injured and group assistance, while helpful, is seldom needed.
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- Class V - Extremely long, obstructed, or very violent rapids which expose a paddler to added risk. Drops may contain large, unavoidable waves and holes or steep, congested chutes with complex demanding routes. Rapids may continue for long distances between pools, demanding a high level of fitness. What eddies exist may be small, turbulent, or difficult to reach. At the high end of the scale, several of these factors may be combined. Scouting is recommended but may be difficult. Swims are dangerous, and rescue is often difficult even for experts. A very reliable eskimo roll, proper equipment, extensive experience, and practiced rescue skills are essential.

APPENDIX D: PHOTOGRAPHS

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Flow #1



Photo 1-01: View from Put-In #1



Photo 1-02: View from Put-In #1



Photo 1-03: Peskeomskut Island – Center Channel – Upstream View



Photo 1-04: Peskeomskut Island – Center Channel – Upstream View – Boaters 1, 2



Photo 1-05: Peskeomskut Island – Center Channel – Downstream View – Boaters 1, 2



Photo 1-06: Peskeomskut Island – Right Channel – Boaters 7, 8, 9



Photo 1-07: View from Put-In #2 Upstream toward Peskeomskut – Center Channel – Boaters 5, 10



Photo 1-08: View from Put-In #2 Upstream toward Peskeomskut – Center Channel – Boaters 5, 10



Photo 1-09: Rawson Island – Right Channel Entrance – Upstream View – Boaters 9, 5, 10



Photo 1-10: Rawson Island – Right Channel Entrance – Downstream View – Boaters 1, 2, 9

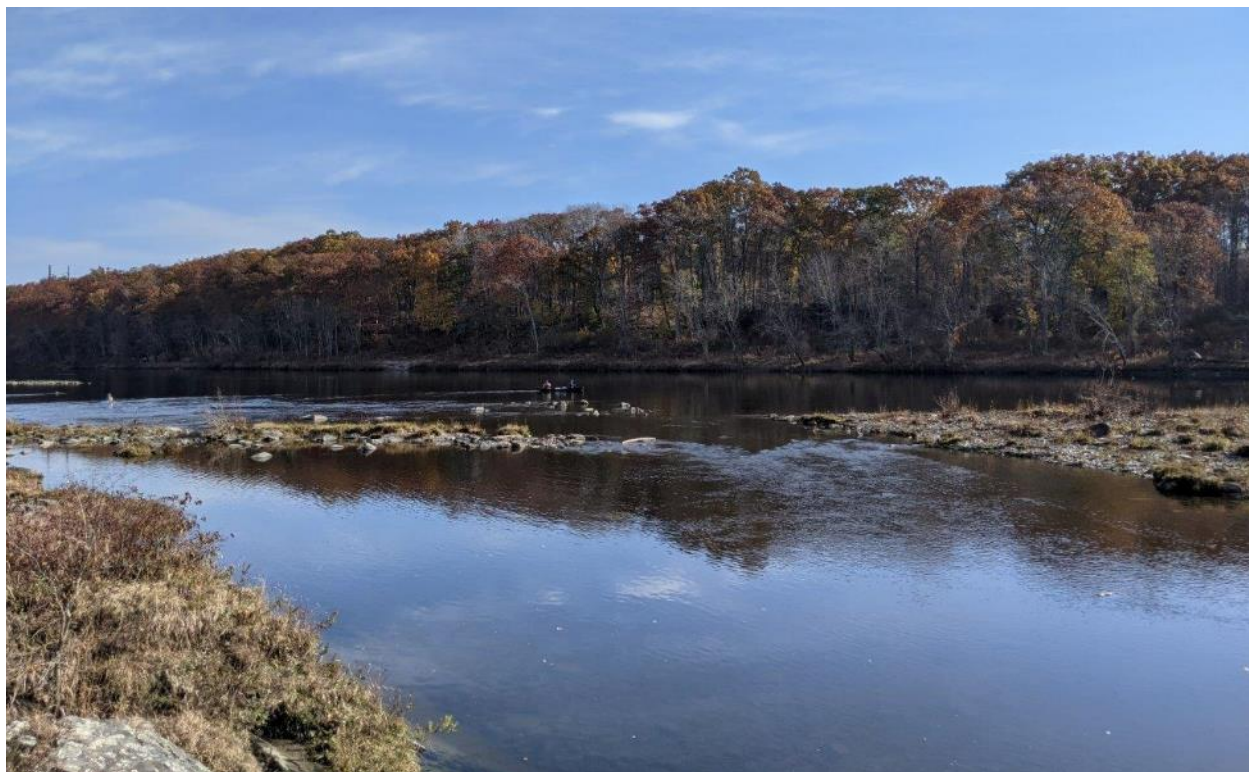


Photo 1-11: Rawson Island – Center Channel Entrance – Upstream View – Boaters 7, 8

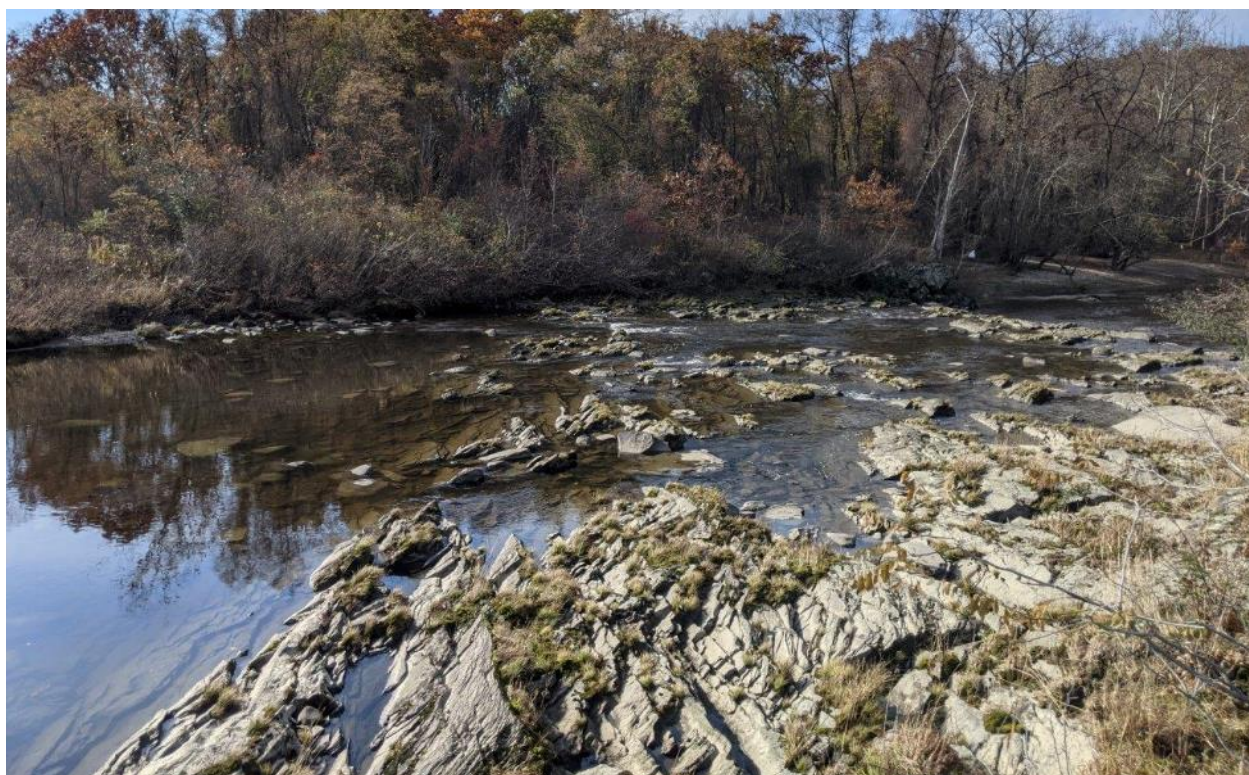


Photo 1-12: Rawson Island – Center Channel Entrance – Downstream View

Flow #2



Photo 2-01: Put-In #1

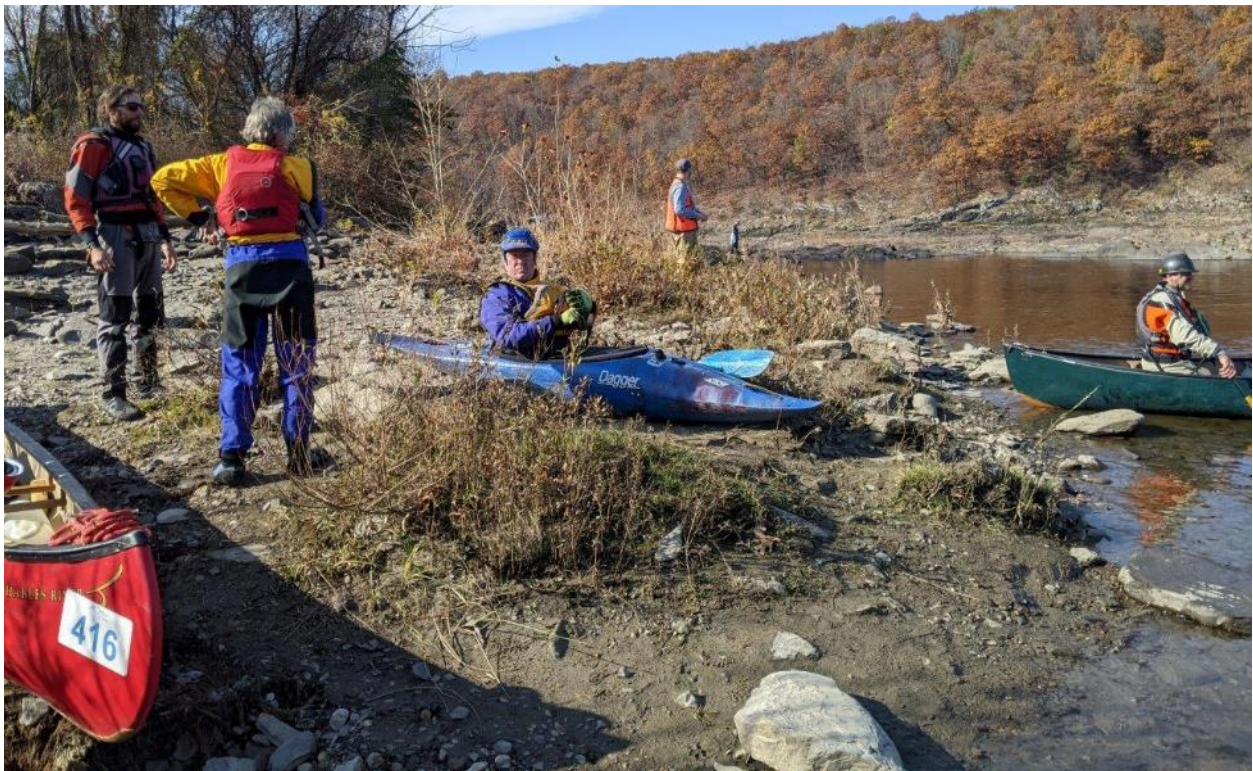


Photo 2-02: Put-In #1



Photo 2-03: View from Put-In #1



Photo 2-04: Peskeomskut Island – Center Channel – Upstream View



Photo 2-05: Peskeomskut Island – Center Channel – Upstream View – Boaters 1, 2



Photo 2-06: Peskeomskut Island – Center Channel – Downstream View – Boaters 1, 2



Photo 2-07: Peskeomskut Island – Center (foreground) + Right (background) Channels – Boaters 4, 9



Photo 2-08: View from Put-In #2 Upstream toward Peskeomskut – Center Channel – Boater 4



Photo 2-09: View from Put-In #2 Upstream toward Peskeomskut – Center Channel – Boater 4



Photo 2-10: Rawson Island – Right Channel Entrance – Upstream View – Boaters 1, 2, 5, 10



Photo 2-11: Rawson Island – Right Channel Entrance – Downstream View – Boaters 1, 2, 5, 10



Photo 2-12: Rawson Island – Right Channel Midsection– Upstream View – Boaters 5, 10

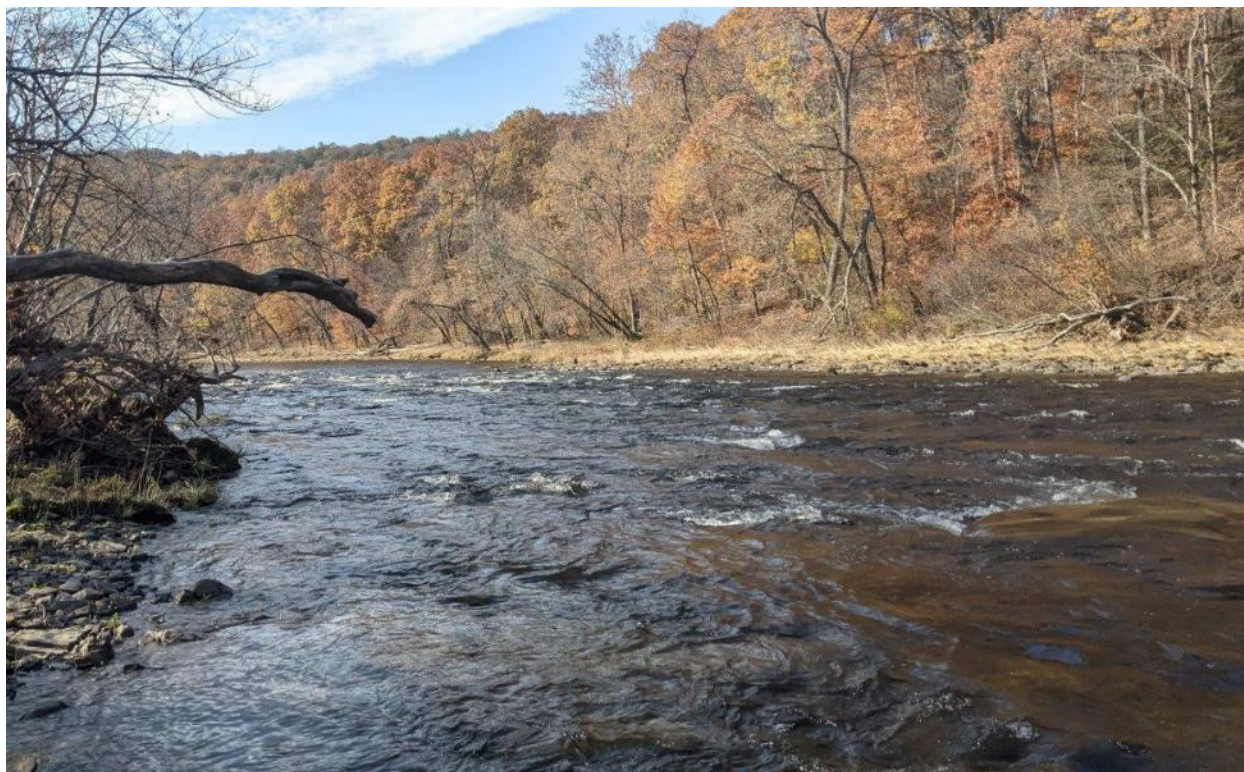


Photo 2-13: Rawson Island – Right Channel Midsection – Downstream View



Photo 2-14: Rawson Island – Center Channel Entrance – Upstream View



Photo 2-15: Rawson Island – Center Channel Entrance – South View



Photo 2-16: Rawson Island – Center Channel Entrance – Downstream View



Photo 2-17: Rawson Island – Left Channel – Upstream View



Photo 2-18: Rawson Island – Left Channel – Downstream View – Boaters 4, 7, 8



Photo 2-19: Rock Dam



Photo 2-20: Take-Out #2 – Upstream View



Photo 2-21: Take-Out #2 – Downstream View

Flow #3



Photo 3-01: Peskeomskut Island – Center Channel – Upstream View – Boaters, 1, 2



Photo 3-02: Peskeomskut Island – Center Channel – Downstream View – Boaters, 1, 2



Photo 3-03: Peskeomskut Island – Center (foreground) + Right (background) Channels – Boater 6



Photo 3-04: Peskeomskut Island – Center (foreground) + Right (background) Channels – Boaters 4, 9



Photo 3-05: Peskeomskut Island – Left Channel – North View



Photo 3-06: Put-In #2 – Access Trail – Upstream View



Photo 3-07: Put-In #2 – Access Trail – Downstream View



Photo 3-08: View from Put-In #2 Upstream toward Peskeomskut – Center Channel – Boaters 1, 2



Photo 3-09: View from Put-In #2 Upstream toward Peskeomskut – Center Channel – Boaters 1, 2



Photo 3-10: View from Put-In #2 Upstream toward Peskeomskut – Right Channel – Boater 6



Photo 3-11: Rawson Island – Right Channel Entrance – Upstream View – Boaters 5, 10



Photo 3-12: Rawson Island – Right Channel Entrance – Downstream View – Boaters 5, 10



Photo 3-13: Rawson Island – Right Channel Midsection – Upstream View – Boater 6

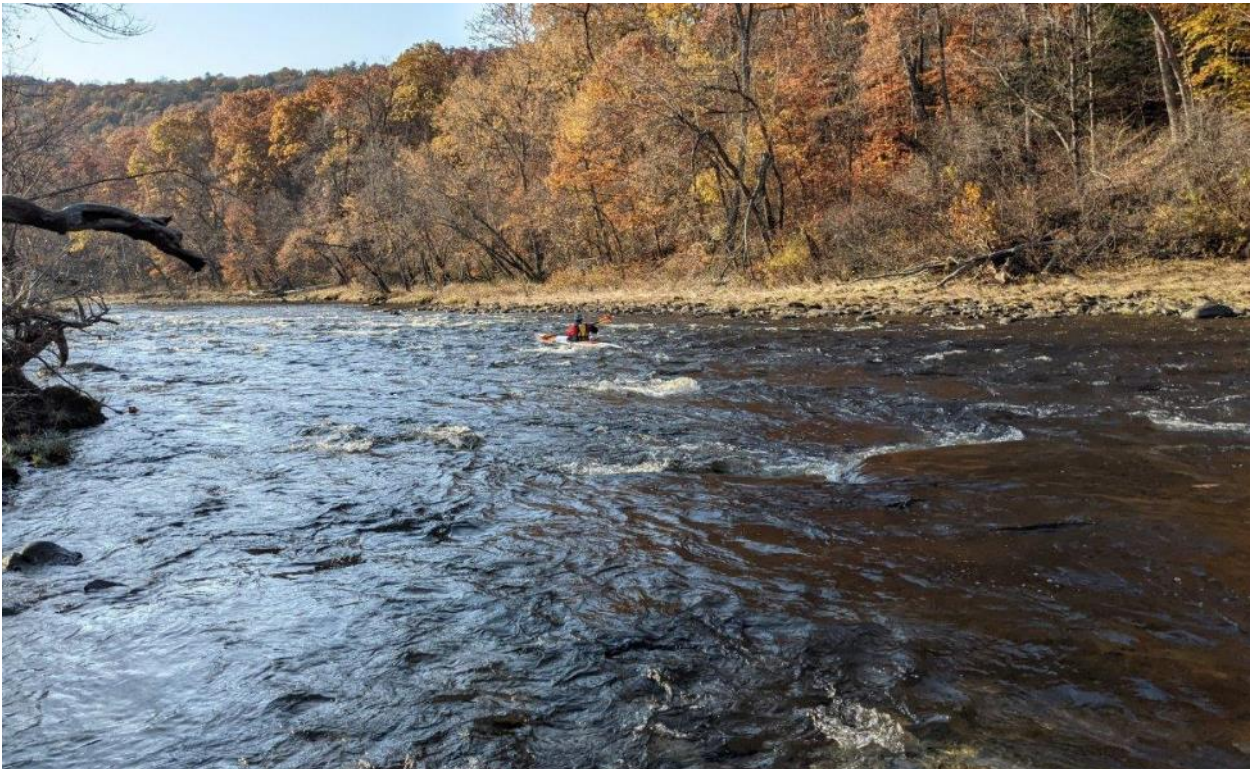


Photo 3-14: Rawson Island – Right Channel Midsection – Downstream View – Boater 6



Photo 3-15: Rawson Island – Center Channel Entrance – Upstream View



Photo 3-16: Rawson Island – Center Channel Entrance – South View



Photo 3-17: Rawson Island – Center Channel Entrance – Downstream View

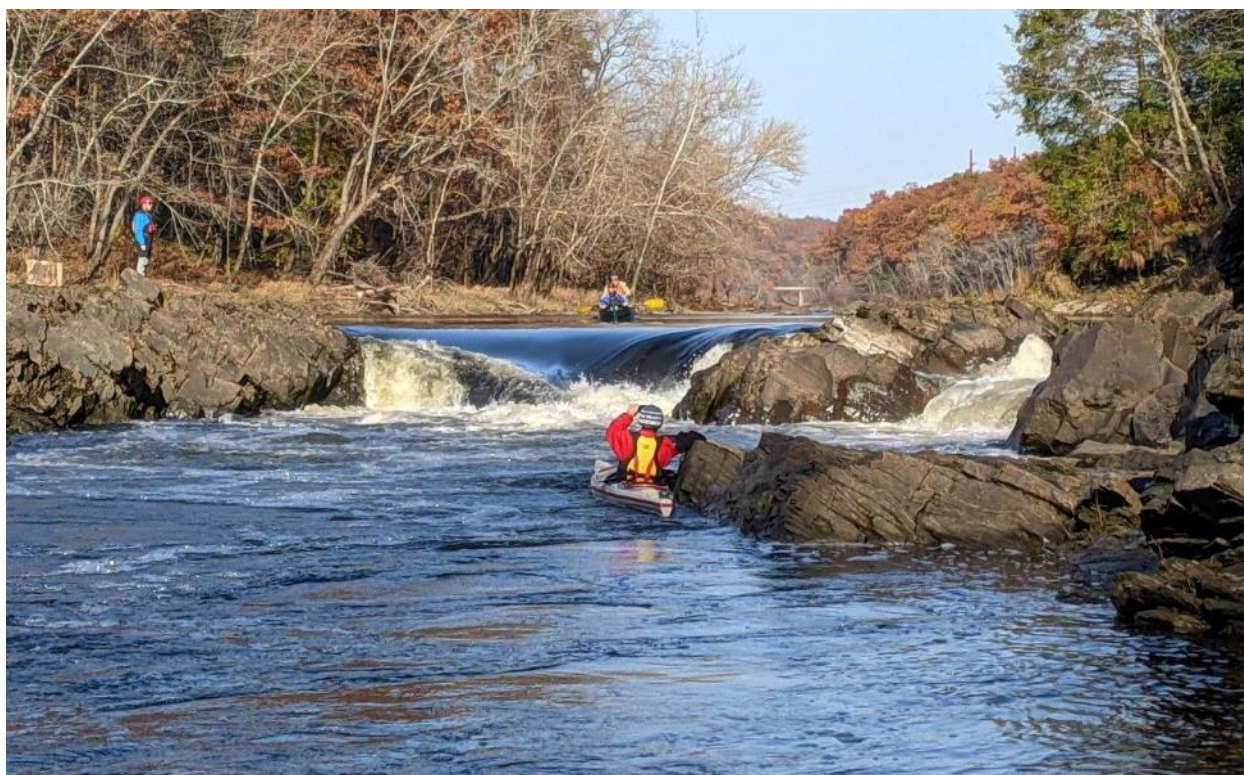


Photo 3-18: Rock Dam – Boaters 7, 8



Photo 3-19: Take-Out #2 – Downstream View

Flow #4



Photo 4-01: Put-In #1

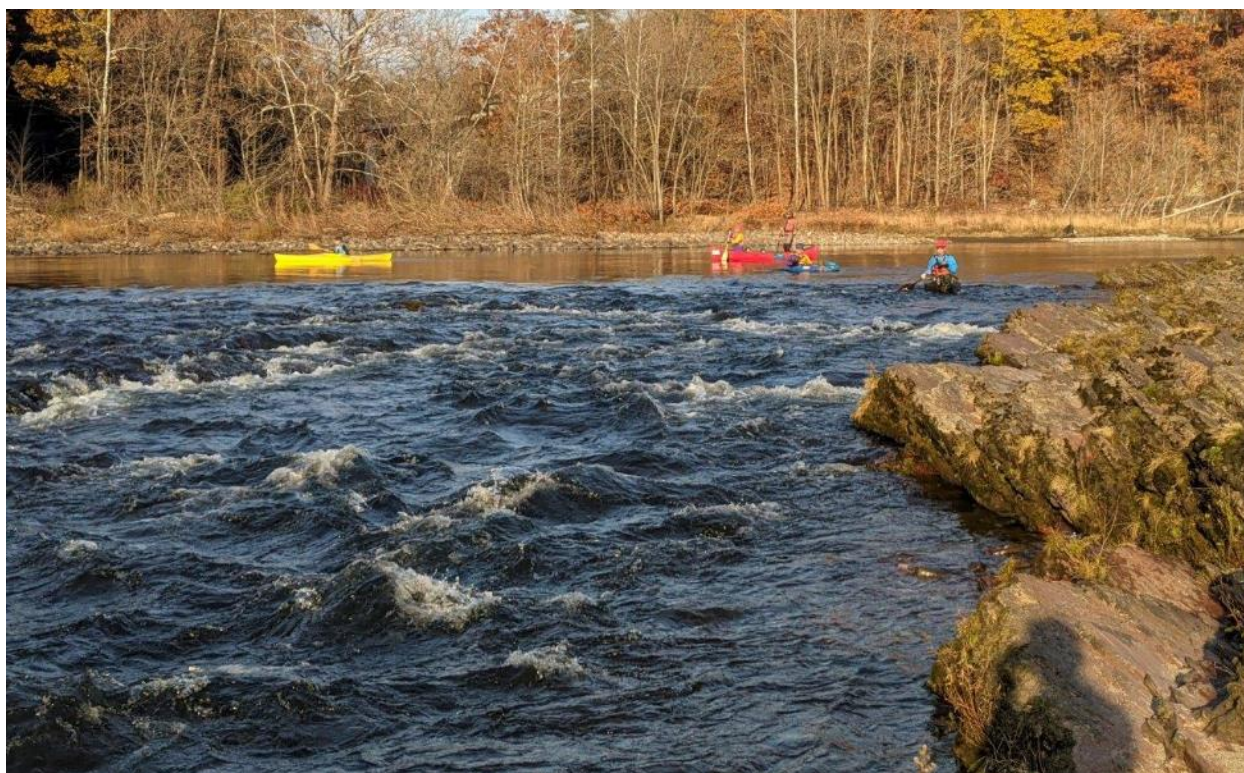


Photo 4-02: Peskeomskut Island – Center Channel – Upstream View



Photo 4-03: Peskeomskut Island – Center Channel – Upstream View – Boaters 7, 8



Photo 4-04: Peskeomskut Island – Center (foreground) + Right (background) Channels – Boaters 4, 5, 10



Photo 4-05: Peskeomskut Island – Center Channel – Downstream View – Boaters 3, 4



Photo 4-06: Peskeomskut Island – Right Channel –Boaters 5, 10

May 24, 2023

The Honorable Kimberly Bose, Secretary
Federal Energy Regulatory Commission
88 First Street, NE
Washington, DSC 20426

Notice to Intervene: RE Projects P-2485 and P-1889

Dear Secretary Bose,

The Nolumbeka Project in coalition with the Chaubunagungammaug Band of Nipmuck Indians and the Elnu Abenaki Tribe, request to comment in the relicensing for the above listed hydro projects P-2485 and P-1889 proposal for the Fish and Flows Settlement Agreement submitted to FERC by FirstLight Power on March 31, 2023. The projects include the Northfield Mountain Pump Storage Project (NMPS) P-2485 and the Turners Falls Hydro Projects, P-1889.

We have been participating collectively as stakeholders in the relicensing process since early 2013. We intervene on the basis that over the term of the previous license operations we have witnessed that these projects have repeatedly failed to meet the standards of the Clean Water Act of 1972, and continue to have adverse effects on the Navigable Waters of the United States, the aquatic and land-based natural resources, and have continued to adversely impact the 10,000 years of indigenous cultural history and resources located in the areas of potential effect (APE) covered in this new license approval.

It is our hope to bring to your attention a number of non-compliance issues with the standards of the Clean Water Act of 1972 that were not adequately addressed in the recently signed and submitted Fish and Flows Settlement Agreement, or during the duration of the previous licenses. We also feel the protections afforded in federal and state clean water standards have failed to be properly implemented for the better part of the last 50 years and also have not been fully addressed with this new license agreement.

We feel prior to the issuance of these new licenses that this is the time to assure full compliance with the Clean Water Act CWA going forward over the next 40 or 50 years.

We learned recently that the Northfield Mountain project failed to come online until after the implementation of the Clean Water Act in 1972, and its failure since that time to meet the standards of the CWA have compromised the river and its surrounding cultural and natural ecosystems. These include the cultural integrity and ancient historical indigenous relationship tribal peoples have traditionally experienced on both shores of the Connecticut River.

Wissatinnewag, Over ten thousand years of continuous indigenous occupation.

There have been indigenous life-ways cultural cycles for the last 10,000 years that have been interrupted for the last 150 years and more so over the last 50 years by the fact there is no longer a natural seasonal hydrological cycle occurring in the upper bypass reach at the shoreline of Wissatinnewag as a result of the operations of these two permits. Historically these cycles included large seasonal gatherings in around the area of the Great Falls, (now the Turners Falls Dam), for the harvest of the shad, salmon, alewives and eels. Tribal peoples from as far away as the Ohio Valley traveled to this spot on the Connecticut River to partake in the harvesting of the migrating fish as well the river overtime to exchange technologies and spiritual traditional practices including diverse burial traditions. This natural environment created an abundance of shared resources that allowed for tribal bonds to be made stronger by the marriages and exchanges of bloodlines all a result of these natural resources. Traditional life-ways practices for all intents and purposes are no longer accessible for tribal people attempting to revisit and experience their ancient cultural heritage on this stretch of river.

Changes to the river over time

The Connecticut River for centuries prior to being modified and licensed to operate these modern hydro electric facilities, operated primarily as a continuously flowing glacial river with its natural seasonal hydrologic cycles. Around these natural cycles this ancient glacial river provided over 10,000 years of sustenance and cultural advancement and prosperity to multigenerational indigenous peoples. This fact has been archaeologically revealed in the waters and on the shores of this ancient river.

It is precisely these cultural and spiritual practices that have been adversely affected by the dewatering of the ancient riverbed in this stretch, the Wissatinnewag run of the Connecticut River. This dewatered section of the Connecticut River located at river mile 122 and continues downstream approximately 2 1/2 miles, is the locus of a once proud and prosperous indigenous landscape which included multiple village sites. These villages were centered in and around clan gatherings and diverse cultural groups who gathered together at the Falls on an annual basis for thousands of years. They left behind in the ground on the hills and in the waters in this stretch of the Connecticut River, a rich and important legacy of an ancient culture nearly lost to industrial development which lead indirectly to the cultural erasure of these peoples and their history.

Ceremony at the Falls and the importance of the mists and a Ceremonial Stone Landscape District recently established by the Department Of The Interior

In 2009 during an airport expansion project overseen by the Federal Aviation Administration, a number of federally recognized tribes and the Massachusetts Historical Commission met in Washington DC with Department of the Interior to discuss their concerns for the preservation of the Ceremonial Hill at the Turners Falls Airport. These discussions involved educating the federal government and the Massachusetts Historical Commission as to certain ceremonial practices occurring in these areas on the Connecticut River and elsewhere in the Northeast. When the conversations wrapped up in December of that year the Department of the Interior acknowledged the existence of a Ceremonial Stone Landscape District and its' eligibility to be included in the National Register of Historic Places. The Ceremonial Stone Landscape District centered on the Hill at the Turners Falls Airport was appointed to extend out in a 16 mile radius around that hill and to include the river the rivers' edge and many of its tributaries as an important indigenous ceremonial landscape. This not only included stone structures and placements created eons ago for special ceremony on the land, but also those stone structures and placements created for the health of the fish and the river that exist in and around the waters of The Great Falls within that 16 mile radius. These included fishing weirs and fishing stations which often included ceremonial objects which now are at risk due to the dewatering of the Wissatinnewag Run of the river.

Two important things to consider are number one, for thousands of years ceremony and prayers conducted in the presence of the mists of the ancient Falls which carried those prayers on up to the heavens, were profoundly important to indigenous peoples part of that cultural process. These processes included creating stone monuments on the land and in the water to acknowledge the power and importance of the changes of the season, the migration of the fish and the health of the river and the people. Once the dam was built on the River and the mist were no longer there, the ability to send prayers up to the heavens on these mists were terminated without ceremony or consideration. Secondly the Ceremonial Stone Landscape District established in December of 2009 was meant to bring an extra layer of protection for all that is sacred to indigenous people in this area. This not only included healthy water flows, it also included the mists that are no longer available.

The last licenses issued for these projects over 50 years ago were absent any indigenous voices or considerations at that time in the licensing of those Hydro projects. Going forward for the next 40 or 50 years, and giving consideration for the many ways that cultural erasure can happen to indigenous people, it's profoundly important to recognize the knowledge that is now currently available through indigenous historians, science, archaeology, and accumulated research in consideration for the relicensing of these projects. This new license must include an accurate and complete Traditional Cultural Properties Study as the current TCP offered by the applicant is absent any acknowledgment of peoples or their traditional cultural properties as existing anywhere in the Area of Potential Effect (APE).

That important body of knowledge needed in these conversations surrounding the issuance of new licenses and the importance of acknowledging the failure of those old protocols and processes that have contributed to the destruction, deterioration and marginalization of the cultural heritage that was left behind by these ancient people, and most particularly in the Wissatinnewag Run of the river and in the impoundment area above the Falls, is needed now more than ever.

Nearly 2 1/2 miles of the Connecticut River dewatered and dry History culture and ecology at risk

When the waters that historically flowed through this stretch of the ancient riverbed are nearly completely diverted away from the river into the power canal, much historical cultural heritage is placed at risk.

The ancient shale beds once covered with a healthy flow of water year round are now exposed to the light a day when water is diverted from the river to the canal for hydropower. This condition leaves exposed to anyone who wishes to walk out on the dry land that was once river bottom, the ability to access ancient cultural resources that represented a people, who for generations have not been here to request the protection of the ancient resources of their people, are now unceremoniously assigned to the coffee tables and bookshelves of looters and sightseers.

Ceremony once practiced on these shores were created for the celebration of the changes of the season and the harvesting of the fish and the burial of their loved ones who passed during that seasonal occupation, are no longer available for indigenous people to re-experience their ancient practices.

As articulated in "Article A110 Minimal Flows Below the Dam," flow rates as low as 500 cfs during many months of the year, including late summer and winter, are insufficient for the reversal of the adverse effects on the health and ecology of the fish and other invertebrates known to have existed all up and down the Connecticut River but most especially in this historical stretch of the river.

In our conversations with FirstLight and other stakeholders surrounding the Fish and Flow Agreements, which we did not sign, we strongly advocated for a minimum flow of 1600 cfs to assist in re-watering this de-watered stretch of the Connecticut River. It should not be difficult to understand that the proposed minimum flow of 500 cfs during a significant part of the year, fails to provide sufficient habitat for fluvial species and macro invertebrates. Also this deficiency cannot allow this culturally important stretch of the river to return with the life force it once experienced when tribal people occupied this land, and considering that this stretch of the river was a sacred piece of their life experience, 500 cfs fails to provide any level of health for protection for those species or those resources that is needed. A number of species have been denied adequate access to the ancient fishing ground that once existed here due to the dewatering of this stretch of river.

Without these fish returning, tribal peoples will no longer be able to access the Wissatinnewag properties fishing and fish processing sites to practice their ancient fishing and food processing cultural heritage so necessary to help them rediscover who they were as a people, and what ceremony looked like for their ancestors. Once again a reminder that the Clean Water Act of 1972 could not possibly support the dewatering of over a 2 1/2 mile stretch of the Waters Of the United States' only Blue Way River, the Connecticut River.

The impacts of increasing the storage capacity of the Northfield Mountain project

We understand FirstLight is seeking the possibility to increase its upper reservoir storage capacity up to 30%. The adverse effects that we have witnessed including aggressive erosion occurring during the operations of the Northfield Mountain Project, when the river flows North for a period of time and then reverses flow to flow South again, would suggest that a 30% increase in and elevation rise and fall of this river could only serve to aggravate the already aggressive ongoing erosion we have witnessed both in the upper reservoir above the dam and in the lower areas of the Bypass Reach in the discharge area of Cabot Station.

It has been suggested by first light that a significant amount of erosion occurring in the upper reservoir is caused boat wakes. Pause on this statement for a few minutes and consider this fact. There are no powerboats allowed in the lower stretch of the river yet the same challenge with erosion is occurring there as well as is in the upper reach. Also for consideration is the fact the hydro electric generation operational impacts on the river are a 365 days a year occurrence, and power boats are only on the river in the upper reach a little over 90 days year. An additional fact for consideration is that what was once a free flowing glacier river in the upper reach, not conducive for the use of powerboats, now more closely represents that of the lake created for the storage of water needed to operate the utilities. In other words power boats did not cause the upper reach to become accessible as a recreational resource, the utilities did. And the fact that the ancient glacial rivers' edges were created by the deposition of stone large and small and highly resistant erosion. It wasn't until the water elevation rose above the ancient glacial riverbed in this stretch of the river, that the land was exposed to the kind of erosion that operational conditions have created.

A new form of river bank erosion

We have also witnessed over a number of winters now the aggressive loss of vegetation and land on the rivers edge when during the deep of winter expansive shore to shore ice plates have formed. These ice plates connect the East shore to the West shore of the river. During especially hard freezes the ice can reach thicknesses of 10 to 14 inches and weigh hundreds of tons. The expanse of these ice plates connecting shore to shore often exceed 300 feet. Understanding that without the buoyancy of

water directly below to support these ice sheets they will fail and slump toward the center the river.

We've documented this phenomena occurring in recent years. Lack of water for buoyancy to prevent these ice sheets from failing have created both an environmental and health hazard to wildlife and human beings which can occur when the waters are drawn down aggressively after the ice sheets are formed at a higher water elevation leaving the massive weight of the suspensions from shore too shore guaranteed to fail. When they do fail, they take land, root systems and vegetation with them creating an aggressive wintertime erosion effect. This is not caused by powerboats nor is it caused by natural conditions, it is caused by the aggressive operational activities of the Northfield Mountain Projects' water level elevation rise and fall cycles. This fact has never been taking into consideration by FirstLight or their research teams. Two of the adverse effects that occur when these ice sheets fail are the environmental and cultural loss of historical resources on the Rivers edge and the risk to human life and safety. These ice sheets will never be safe or stable under the conditions with which they form.

A Pump Storage Utilities relationship with a Nuclear Power Plant The issues of fire and ice

When the first licenses were issued for the Northfield Mountain Project over 50 years ago, the project was engineered to mitigate the inability of the Vernon Vt. Nuclear Power Plant to quickly ramp up or down its electric generation capacity. Vernon needed a source to purchase that excess electricity being generated at certain times of day. The Northfield Mountain project purchased that electricity at a wholesale rate to pump water into their upper reservoir. This arrangement allowed the Vernon Power Plant the ability to run at a predictable stable pace. One of the characteristics of that relationship was the fact that the nuclear plant discharged extremely hot water all winter long upstream of the impoundment into the Connecticut River. This activity made ice conditions occurring in the upper reach of the Connecticut River Impoundment a rare event. With the recent permanent dismantling of the Vernon Nuclear Plant, those unusual warm water condition no longer exists. Now with the colder waters all winter long, we've witnessed the negative environmental results that occur when these massive ice sheets fail. FERC should seriously take this new fact of ice sheet failure erosion impacts into consideration on the potential request by FirstLight to expand the upper reservoir storage capacity by nearly 30%. The higher in elevation on the shoreline the ice sheets can take hold prior to failure, the more aggressive the erosion like characteristics of this phenomena will occur. Ice sheet failures will continue to negatively impact the natural, environmental, and cultural resources on the rivers edge as well as being a danger to the wildlife and people who attempt to cross the river over these ice plates.

And endangered species

The History of Shortnose Sturgeon in the upper impoundment

Anglers fishing in the upper reaches of the impoundment below the Vernon Dam and other places in Northfield, have on a number of occasions, documented the catch and release of Shortnose Sturgeon. Historically this endangered species presence in this section of the river has not been taken into serious consideration in relation to the environmental challenges the aggressive practices of the Northfield Mountain Projects' pump and release schedules as they are playing out on that stretch of the river.

The reasoning to write off Shortnose Sturgeon's existence is historically flawed. It has been stated by some environmentalist that the Shortnose Sturgeon could never have made it up and over the Great Falls to inhabit the upper reach of the Connecticut River. What's missing, and profoundly misunderstood, is the fact that they didn't need to make it up and over the Great Falls to inhabit that stretch of river, they simply swam up the Connecticut River around the West side of Rocky Mountain to reach the foot of the Plunge Pools now located in Barton Cove above the Great Falls.

During that time period, the Connecticut River flowed on the Western beachfront of Rocky Mountain. Archaeology conducted in Riverside Gill by Dr. Peter Thomas in the 1970s revealed that somewhere around 7000 years ago the river had a course flow on the West side of Rocky Mountain as well as on the East side, but in a single high water event during that time period, the earthen damn that channeled the river to flow over the falls of the plunge pools, at what is now called Barton Cove, failed. When that catastrophic change occurred in a singular event, the river shifted fully to the East side of Rocky Mountain. Once that occurred the Great Falls would've occupied the dominant channel for the entire river. But somewhere between 10,000 to 7000 years ago, Shortnose Sturgeon had unimpeded access to the upper reach of the Connecticut River above the Falls to the foot of the Falls at the Plunge Pools on the Rivers Western bank. It appears they managed to keep their species intact as is revealed in documented catch and releases of the Short Nose Sturgeon in the Upper Reach of the Connecticut River below the Vernon Dam. That fact Needs to be fully taken into consideration on the environmental impacts of the operational activities of the utilities in the Upper Reach of the Connecticut River

A future barrier net and its future for the Northfield Mountain project

A seven year delayed deployment of an experimental barrier net being guaranteed by the utilities to be built at the intake of the Northfield Mountain project is intended to mitigate high mortality rates of eggs, and young species of fish and aquatic life that are likely to be drawn up through the turbines or impinged upon experimental net and die. During this seven year delay untold numbers of aquatic species will continually be destroyed. There is no successful track record with which to weigh the value of this

offer. We believe the Clean Water Act cannot support a delayed experimental entrainment mechanical structure.

The health of the river and its environmental and cultural relationship to indigenous peoples is paramount to our shared concerns and hopes for the future of this river. If an untested barrier net is to be deployed it should be done immediately to determine if failure is part of its future sooner rather than later. Global warming and other environmental challenges including drought can only add to the immediacy of us taking correctional actions to preserve the health and well-being of this river. The ongoing loss of fish species is painful for indigenous people to witness as these species played an important role in the spiritual and physical presence of indigenous peoples living in this valley for thousands of years.

To close this correspondence we'd like to inform the public and FERC that as of this writing, our many months of negotiations with the utilities have failed to produce any measurable level of agreement. We have not given up, but we acknowledge that the clock is running out on our ability to respond to FERC with our concerns relating to the Fish and Flow agreements, therefore we need to do so now.

We sincerely hope that all the agencies involved in this relicensing process will seriously consider the myriad of ways that Cultural Erasure can occur to marginalized groups of people, most especially indigenous people whose lives and history for millennia played out in the waters and on the Shores of this once flourishing river now called the Connecticut River (The Long living being). When our history is erased we also are erased.

With Kindest Regards,

Joe Graveline: Senior Advisor the Nolumbeka Project

David Brule: President of the Nolumbeka Project

Liz Coldwind Santana-Kiser: THPO The Chaubunagungamaug Band of Nipmuck Indians

Richard Holschuh: THPO The Elnu Abenaki Tribe

Document Content(s)

Flows FERC 4.pdf.....1



Franklin Regional Council of Governments

June 3, 2024

Mr. Timothy M. Jones
Legal and Policy Analyst
MassDEP Bureau of Water Resources
100 Cambridge Street, Suite 900
Boston, MA 02114

Re: Northfield Mountain Pumped Storage Project No. 2485-071
Turners Falls Project No. 1889-085
**Comments on FirstLight's 401 Water Quality Certificate Application Submitted for
Consideration by the Franklin Regional Council of Governments**

Sent electronically via email to dep.hydro@mass.gov

Dear Mr. Jones:

The Franklin Regional Council of Governments (FRCOG) hereby submits comments and recommended terms for the 401 Water Quality Certification Application for the Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project. With this comment letter, FRCOG is also submitting our May 22, 2024 comments to FERC along with a technical review from Dr. Evan Dethier. These three documents are our comment package. In addition, we are filing a number of other FRCOG comment letters and documents so that they are part of the public docket for this 401 Certification. This current proceeding represents the first opportunity for MassDEP to issue a 401 Water Quality Certificate for the two projects, because the facilities have been operating under existing licenses that were issued prior to the adoption of the modern Clean Water Act.

Executive Summary

The Connecticut River is the life blood of the communities located in the Connecticut River watershed. The River is the source of ecological and economic health, benefiting the quality of life of the Massachusetts residents and visitors to the Franklin County region. This vital resource is, however, at risk due to FirstLight's operations. The entire Massachusetts part of the river upstream of the Turners Falls Dam is listed as impaired (i.e. not in compliance with the Massachusetts Surface Water Quality Standards) in the 2022 Massachusetts Integrated List of Waters due to the current operations at the Turners Falls Dam and Northfield Mountain Pumped Storage Project. Those operations include fluctuations that can range over 4.8 ft., but more typically range 1.2 to 1.6 feet, measured at Turners Falls Dam on a daily basis.¹ The fluctuations in water surface elevations are, in

¹ Data source: Figure 3.3.2.2.1-8 in the 2020 Amended Final License Application Exhibit E filed to by FirstLight on December 4, 2020.

turn, causing significant river bank erosion with associated pollution and impairment of designated uses.

The obvious practical and primary response to these facts should be to include conditions that require FirstLight to avoid this impact by reducing the fluctuation in daily flows. Yet, FirstLight is instead seeking to be allowed to fluctuate daily water surface elevations as much as 9 feet on a daily basis, measured at Turners Falls Dam, and expand the licensed range of the upper reservoir by 24% in a license that will have a term of decades. That result is absurd on its face due to the potentially devastating level of erosion that could result. Further, allowing that level of fluctuation in water elevations would give FirstLight carte blanche to violate Massachusetts water quality standards.

MassDEP has the opportunity and obligation to avoid this result. Section 401 of the Clean Water Act gives the Commonwealth of Massachusetts both the authority and responsibility to protect the Connecticut River. This section of the law was passed by Congress in the 1972 Clean Water Act because, prior to the passage of the Act, federally authorized projects were harming waterways across the nation and states had no say in protecting vital resources like the Connecticut River. On behalf of our member communities, FRCOG asks that MassDEP use its Section 401 Water Quality Certification authority to protect the River and uphold the Massachusetts Surface Water Quality Standards.

Pursuant to the Massachusetts Surface Water Quality Standards, specifically pursuant to the anti-degradation provisions in those standards, MassDEP is required to maintain all designated uses and cannot issue a water quality certification that allows impairment of those uses. As noted above, MassDEP has already determined that designated uses are impaired based on conditions created by the current operations. FRCOG offers recommendations below that would reduce the current operational flows documented by FirstLight by 25%, limiting the daily fluctuations to a range of no more than 2.1 feet, measured at Turners Falls Dam and no more than 2.7 feet measured at the USGS gage just upstream of the Route 10 bridge in Northfield. FRCOG also offers recommendations to ensure that FirstLight monitors the impacts of its operation and responds accordingly, controls invasive species that threaten bank stability, and require riparian buffers, among other conditions.

About FRCOG

FRCOG is a statutorily created regional service organization comprised of and serving the 26 municipalities of Franklin County, Massachusetts. FRCOG replaced the former county government. The Connecticut River bisects Franklin County and is a major economic, recreational, and environmental resource for the residents of our member towns. We advocate on behalf of our communities and the county at the federal, state, and regional levels. FRCOG also serves as the Regional Planning Agency for the 26 municipalities in Franklin County.

For almost three decades, FRCOG (and its predecessor organization, the Franklin County Commission) and its Connecticut River Streambank Erosion Committee (CRSEC) have been actively involved with landowners and organizations concerned about the ongoing and extensive erosion in the Turners

Falls Power Pool. The Federal Energy Regulatory Commission (FERC) recognized FRCOG's CRSEC in 1999 as an Ad Hoc Committee that would work with the power company to develop and implement bioengineering bank stabilization projects pursuant to an Erosion Control Plan ordered and approved by the FERC.

As part of the work under the Erosion Control Plan, FRCOG/CRSEC secured over \$900,000 in Federal funds to help pay for innovative bank stabilization projects and active stakeholder involvement. Grant funding secured by FRCOG, much of it provided by MassDEP under s. 319 grants, helped to stabilize over 3,000-feet of shoreline in the impoundment, and led to an evolution of new riverbank restoration techniques to satisfy landowner concerns and be more protective of state-listed dragonflies.²

For more information about FRCOG and the history of FRCOG's involvement with the hydropower projects and the relicensing process, in addition to our interests, please see the Motion to Intervene that we filed with FERC on April 16, 2024, included as an attachment to this letter.

About the Hydropower Projects and Relicensing

The relicensing of Turners Falls Dam and Northfield Mountain Pumped Storage Project began in late 2012, when FirstLight filed their Notice of Intent and Pre-Application Document (PAD) with the Federal Energy Regulatory Commission (FERC). Over 11 years and 40 studies, dozens of meetings, and multiple settlement negotiations later, on February 22, 2024, FERC issued a Notice of Application Accepted for Filing, Soliciting Motions to Intervene and Protests, Ready for Environmental Analysis, and Soliciting Comments, Recommendations, Preliminary Terms and Conditions, and Fishway Prescriptions, requiring motions to intervene to be filed on or before April 22, 2024. FERC extended this deadline to May 22, 2024 in a Notice dated April 10, 2024. FirstLight filed a 2024 Supplemental BSTEM Report with FERC on March 22, 2024. FirstLight filed their 401 Water Quality Certificate Application ("401 Application") with the Massachusetts Department of Environmental Protection (MassDEP) on April 22, 2024. MassDEP filed a letter with FERC on the very same day stating that the 401 Application was complete.

Turners Falls Project

The Turners Falls Project is a 67.8-MW hydroelectric project that includes the Turners Falls Dam, which creates the Turners Falls Impoundment (TFI) on the Connecticut River. The Turners Falls Dam was re-constructed in 1868 for hydropower and is located at approximately river mile 122 (above Long Island Sound) on the Connecticut River in the towns of Gill and Montague, MA. The Turners Falls Dam consists of two individual concrete gravity dams that are connected by a natural rock island

² None of this publicly-funded work was recognized on page 21 of FirstLight's 401 Water Quality Certificate application submitted to MassDEP on April 22, 2024. Grant funds include those from the EPA Targeted Watershed Grant WS-97122001-0; and three from MassDEP's s.319 grant program 96-03/319, 00-04/319 and 03-07/319.

known as Great Island. The Montague Dam connects Great Island to the west bank of the Connecticut River and includes four bascule type gates. The Gill Dam extends from the Gill shoreline (east bank) to Great Island and includes three tainter spillway gates.

Adjacent to the Montague Dam is the gatehouse equipped with 15 operable gates controlling flow from the TFI to a power canal. The power canal is approximately 2.1 miles long and has a design capacity of approximately 18,000 cubic feet per second (cfs). The bypassed section of the Connecticut River flows parallel to the power canal. FirstLight generates power from two locations along the canal, Station No. 1 (located closer to the beginning of the power canal) and Cabot Station (located at the end of the power canal). The generation and hydraulic capacity of Station No. 1 are 5,693 kW and 2,210 cfs, respectively. The generation and hydraulic capacity of Cabot Station are 62.016 MW and 13,728 cfs, respectively.

The Turners Falls Impoundment (TFI) extends approximately 20 miles upstream to just below the Vernon Hydroelectric Project (FERC No. 1904) in Vernon, VT and Hinsdale, NH. The Vernon project is owned and operated by Great River Hydro (GRH). To provide storage capacity for the Northfield Mountain Project, the TFI elevation may vary, per the existing FERC license, from a minimum elevation of 176.0 feet to a maximum elevation of 185.0 feet constituting a 9-foot range as measured at the Turners Falls Dam. The usable storage capacity in this 9-foot range, as measured at the Turners Falls Dam, is approximately 16,150 acre-feet, of which 12,600 acre-feet were created for Northfield Mountain by raising the dam.

Northfield Mountain

The Northfield Mountain Project is a 1,166.8 MW pumped-storage facility located on the eastern bank of the Connecticut River in Northfield, Massachusetts, and is located at river mile 127 (upstream of Long Island Sound) approximately 5.2 miles upstream of Turners Falls Dam. The Turners Falls Impoundment (TFI) serves as its lower reservoir. This Project's Upper Reservoir is a man-made pond built on top of Northfield Mountain in Erving, MA, to the east of the Connecticut River. During pumping operations, water is pumped from the TFI to the Upper Reservoir. When generating, water is passed from the Upper Reservoir through an underground pressure shaft to a powerhouse cavern and then a tailrace tunnel delivers the water back to the TFI.

Construction of the Northfield Project began in 1968 and was completed when the first unit went into commercial operation in 1972. The remaining units became operational through 1973. The Northfield Mountain Pumped Storage Project consists of an Upper Reservoir and dam/dikes, an intake, pressure shaft, underground powerhouse and tailrace. The current license allows the Upper Reservoir elevation to vary from a minimum elevation of 938 feet to a maximum elevation of 1,000.5 feet, constituting a 62.5-foot fluctuation zone and a total volume of 12,318 acre-ft of water. FirstLight is requesting permission to permanently increase the maximum and minimum elevation to 1004.5 feet and 920 feet, respectively, which is an 84.5-foot fluctuation zone and a total volume of 15,327 acre-ft of water.

The intake channel directs water from the Upper Reservoir into the pressure conduit intake and eventually to the underground powerhouse. When operating at maximum pumping mode (water is withdrawn from the Connecticut River uphill to the Upper Reservoir), the approximate hydraulic capacity is 15,200 cfs. When operating at maximum generation mode (water is spilled back to the Connecticut River), the approximate hydraulic capacity is 20,000 cfs. Flows going in and out of Northfield Mountain often exceed the flow rate of the mainstem Connecticut River and, under certain conditions, actually reverse the flow of the river.

A note about project benefits

FRCOG is concerned about FirstLight's efforts to tout Project benefits, most of which have nothing to do with water quality. The purpose of this § 401 process is to assure compliance with the Massachusetts Surface Water Quality Standards over the next many decades. This § 401 water quality certification process is not equipped to weigh so-called project benefits, and for good reason. The CWA sets a floor and does not allow for violations in the name of Project benefits. To the contrary, the CWA requires compliance, particularly here where the Connecticut River is impaired because of Project operations.

MassDEP must condition the 401 Water Quality Certificate to ensure that water quality is improved and protected

The entire Massachusetts part of the river upstream of the Turners Falls Dam is listed as impaired in the 2022 Massachusetts Integrated List of Waters due to the Turners Falls Dam impoundment and pumped storage project operations. The 2018-2020 Massachusetts Integrated List contained an Assessment and Listing Methodology for the Connecticut River mainstem watershed.³ Appendix 15 to the 2018-2020 Massachusetts Integrated List states that these segments are "not supporting" the Fish, other Aquatic Life and Wildlife Use because of the impairments described below.⁴ These impairments, except for *E. coli* bacteria and PCBs, are related to the existence of the impoundment and project operations.

- Segment 34-01 is the 3.5-mile segment between the Vermont/New Hampshire/Massachusetts state line and the Route 10 bridge. This segment is listed as impaired for alteration in streamside or littoral vegetative covers, flow regime modification, and PCBs in fish tissue.
- Segment 34-02 is the 11.4-mile segment between the Route 10 bridge and the Turners Falls Dam, excluding Barton Cove. This segment is listed as impaired for alteration in stream-side or littoral vegetative covers, flow regime modification, water chestnut, and PCBs in fish tissue.

³ This is the most recent such assessment for the Connecticut River segments.

⁴ <https://www.mass.gov/doc/20182020-integrated-list-of-waters-appendix-15-connecticut-river-watershed-assessment-and-listing-decision-summary/download>

- Barton Cove is MA34-122, a 160-acre cove of the Connecticut River upstream of the Turners Falls Dam, is listed as impaired for curly-leaf pondweed, Eurasian water milfoil (*Myriophyllum spicatum*), fanwort, water chestnut, *Escherichia coli* (E. coli), and PCBs in fish tissue.⁵

All of these impairments have an asterisk in the Integrated list indicating that a “TMDL (Total Maximum Daily Load) is not required.” **The relicensing of these two projects, triggering this 401 Water Quality Certification Application, is really the opportunity for the project-related impairments to be addressed.**

FRCOG presents the following rationale for MassDEP to condition the 401 WQC:

1. Under the federal Clean Water Act (section 401), Massachusetts has the authority to deny a 401 Water Quality Certificate, or issue a certificate with conditions as necessary to ensure that water quality is protected.
2. Under the Massachusetts Clean Waters Act (M.G.L. Chapter 21, Section 27), and its own regulations (314 CMR 4), MassDEP has a duty to take all actions to secure to Massachusetts the benefits of the federal Clean Water Act, to adopt water quality standards identifying the uses to be protected in Massachusetts waters, and to require flows from hydropower facilities as necessary to protect those uses.
3. MassDEP has adopted water quality standards for the Connecticut River segments affected by FirstLight’s hydropower projects.
4. The Connecticut River segments at issue are designated as Class B waters, and are “designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation.”
5. Pursuant to the anti-degradation provisions of the Massachusetts Surface Water Quality Standards, MassDEP must protect these designated uses.
6. FirstLight’s hydropower projects have caused and will cause significant riverbank erosion. FRCOG’s comments below and in attached documents provide detailed descriptions about this concern.
7. The erosion is a form of pollution because it destroys aquatic vegetation and fish habitat, and contributes to suspended sediment that contributes to the dissolved oxygen impairment in Long Island Sound as addressed in the 2000 Long Island Sound Total Maximum Daily Load (TMDL) and the continual work under EPA’s Nitrogen Reduction Strategy.⁶

⁵ Final Massachusetts Integrated List of Waters for the Clean Water Act 2022 Reporting Cycle. CN 568.1. Prepared by the Massachusetts Department of Environmental Protection Watershed Planning Program. May 2023.

⁶ <https://www.epa.gov/tmdl/tmdls-work-long-island-sound> and <https://longislandsoundstudy.net/our-vision-and-plan/clean-waters-and-healthy-watersheds/nitrogen-strategy/>.

8. The erosion is the result of the FirstLight's project operations and so is the cause of the water quality impairment.
9. The portion of the Connecticut River between the Turners Falls Dam and the New Hampshire and Vermont borders are classified by MassDEP as impaired due to "flow regime" and "alteration in stream-side or littoral vegetative covers." Project operations has been listed in the Integrated Lists as the cause of these impairments.
10. The FERC license will have a lengthy term of 30 to 50 years and the 401 Water Quality Certification is the single most important authority granted to the state to be able to protect its interests in the biological, chemical and physical integrity of the Connecticut River.
11. In the absence of conditions, such as the ones proposed by FRCOG in this letter, the FirstLight project will cause ongoing harm for decades.

FRCOG's Comments

FRCOG's comments filed in this letter and its attachment focus on the issue of streambank erosion and the connection to Massachusetts Surface Water Quality Standards.

As a party to the recreation settlement agreement filed with FERC on June 12, 2023, the FRCOG fully supports the recreation provisions in the settlement agreement and requests FERC to accept the Recreation Management Plan (RMP). The RMP and recreation settlement agreement satisfy the FRCOG's recreational interests with regard to both projects, and if kept intact in the final license, its provisions will be a great asset to the region.

In accordance with Section 2.2 of the Recreation Settlement Agreement, although we were not a party to the flows and fish passage settlement agreement, the FRCOG has agreed not to oppose any of the terms of the flows and fish passage settlement agreement ("FFP Agreement"). The FRCOG has an interest in the Connecticut River being a healthy river ecosystem.

Summary of FRCOG's comments

FirstLight's proposed operations and "Comprehensive Proposal" as articulated in the 401 Application, together with their Draft Water Quality Mitigation and Enhancement Plan (Attachment C) and Draft Long-Term Sampling and Analysis Plan (Attachment D) will not resolve the water quality impairments in the Massachusetts part of the Connecticut River between the Vernon Dam and the Turners Falls Dam, and may cause further impairment. FRCOG's recommendations later in this letter suggest a number of conditions that are aimed at meeting water quality standards in this part of the Connecticut River.

FirstLight describes three relicensing studies that were the basis for addressing erosion-related impacts. Those studies were as follows:

Study 3.1.1 – Full River Reconnaissance

Study 3.1.2 -- Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report (commonly referred to as the Causation Study)⁷

Study 3.1.3 – Sediment Management Plan

FirstLight's sediment and erosion studies were each over 500 pages long with numerous appendices and addenda, with subjective analyses and conclusions cloaked in a veneer of technical competence aimed at eliminating or reducing their responsibility for erosion.

The Northfield Mountain proposed operations would expand the facility's upper reservoir operating range (increasing the usable volume by 24%) and allow FirstLight to move larger quantities of water into and out of the Connecticut River during pumping and generation cycles. Use of an expanded upper range in the upper reservoir has the *potential* to result in more riverbank exposed to destabilizing wetting and drying cycles. FirstLight on page Att C-5 of the 401 Application states that "TFI storage must be used as a buffer" when touting the more stabilized flow regime in the Connecticut River below the Cabot Station. FirstLight has provided no data to back up the claim that the TFI must be a sacrificial zone to provide improved operations downstream. FirstLight has provided no indication of an alternatives analysis to explore options for TFI limits, other than proposed license article A190 that limits the rate of rise of the Turners Falls Impoundment water level to be less than 0.9 feet/hour from May 15 to August 15 from 8:00 am to 2:00 pm.⁸ FirstLight has provided no data to understand the magnitude and frequency of daily river fluctuations in the TFI under project operations proposed under the FFP Agreement.

With its BSTEM model, FirstLight has been overly focused on arriving at a precise estimate of the percentage of responsibility for erosion under existing operations, and FirstLight is also using the BSTEM model to predict erosion under future modeled operations. Study 3.1.2 did not adequately capture the interplay between all causes of erosion in the TFI. FRCOG's extensive comments on BSTEM model and its use can be found in our attached comments submitted to FERC on May 22, 20124. In addition, we are also submitting an analysis and review of Study 3.1.2 by Dr. Evan Dethier. Previously, the Connecticut River Watershed Council, now Connecticut River Conservancy (CRC) submitted to FERC a peer review of Study 3.1.2 by Princeton Hydro.

⁷ FirstLight's 401 Application at Att C-2 states that the March 2024 Supplemental BSTEM report filed to FERC on March 22, 2024 (not filed with the 401 Application) "supercedes all of the previous reports." We assume they mean that the BSTEM analysis in the 2024 supercedes the BSTEM analysis in the 2017 Study 3.1.2, since there were many additional components to Study 3.1.2 that were not included in the 2024 Supplemental BSTEM report. Even so, the BSTEM analysis in Study 3.1.2 provides the basis for the 2024 Supplemental BSTEM report.

⁸ FirstLight has never provided information indicating if this is any different than current operations, or how different.

FirstLight's proposal to address only the erosion that its BSTEM model has found to be caused by project effects is scientifically unsound and inadequate given documented water quality impairments in the TFI. Please see our comment letter filed with FERC on May 22, 2024 for more details.

Understanding the Extent of Erosion and Compliance with the 1999 Erosion Control Plan

FRCOG is submitting our comment letters on the final Study Report and Addendum for Study 3.1.1 Full River Reconnaissance (FRR) so that MassDEP can understand the issues that FRCOG has been raising about this study from the start. Previous FRRs were conducted in 2001, 2004, and 2008, and were required under the 1999 Erosion Control Plan (ECP).⁹ The ECP committed the licensee to conduct FRRs every 4-5 until the end of the license. The 2013 FRR was already planned and it was turned into a Relicensing Study. No FRR has taken place since 2013.

For years, members of the CRSEC had complained about shifting methodologies, making it impossible to compare the results of one FRR to previous FRRs. CRSEC members had also complained about the methodology of the FRR being too prone to subjectivity. In MassDEP's comments on FirstLight's Updated Proposed Study Plan submitted to FERC on July 12, 2013, MassDEP wrote, "It is clear that MassDEP, FRCOG, and CRWC are in agreement that the process historically used by FirstLight to study erosion (the FRR) has not generated sufficient reliable information upon which MassDEP can issue a Water Quality Certification." MassDEP's letter goes on to describe a desire for a process under which evaluations are "based upon scientifically reproducible geomorphologic criteria that has been established and is free from potential observer bias or prejudice."

Because of the concerns about subjectivity, FirstLight was required to produce a Quality Assurance Project Plan (QAPP) for the 2013 FRR. The QAPP was in the process of being drafted when relicensing began. In January of 2013, FRCOG provided FirstLight with comments on the second draft of this QAPP, and these were filed with FERC and are included in our list of attachments. In the 2013 FRR, an August 2013 version of the QAPP was included as Appendix D. The QAPP shown in Appendix D has no signatures of approval from MassDEP or USEPA. FRCOG consulted FirstLight's Table 5.5.1-1 in the 401 Application. Table 5.5.1-1 provides the consultation record between FirstLight and MassDEP on the FRR and Erosion Causation Study. It lists nothing related to the QAPP. We have no evidence that the QAPP was ever approved.

MassDEP articulated the need to have a consistent set of definitions free from observer bias so that it could eventually perform an analysis for the 401 WQC. In MassDEP's study request letter dated March 1, 2013, MassDEP requested that FirstLight "accurately map and scientifically describe that portion of the Turners Falls Pool where active or recent "bank" "erosion" is occurring...-- **all terms should be precisely defined in any such study, and linked to jurisdictional definitions whenever possible.**" (emphasis ours)

⁹ FRCOG has years of CRSEC meeting minutes, comment letters, and other filings related to previous FRRs that we can furnish upon request.

Despite having a (draft) QAPP, the 2013 FRR continued to be plagued by definition problems and observer bias. For example, here is an excerpt from FRCOG’s CRSEC comments on Study 3.1.1 dated November 14, 2014:

In Table 6.1 (page 6-6), the FRR reports the stages of erosion in the Impoundment, and calculates that 83.5% of the banks were stable, 9.1% eroded, 5.5% potential future erosion, 1.3% in the process of being stabilized, and 0.6% active erosion. “Stable” is defined in Table 5.2 (page 5-5) as “riverbank segment does not exhibit types or indicators of erosion.” Looking at the Table in Appendix I of the FRR, it is evident that many segments were characterized as having types or indicators of erosion, but were nevertheless classified as being “stable.” In fact, using the FRR GIS database, we were able to calculate that, using their own definition (that stable is having no types or indicators of erosion), only 43.5% of riverbanks were “stable.” The percentage of banks that had an erosion type and/or an indicator of erosion, seemingly not stable according to their definition but nevertheless labeled as stable by FirstLight, was 40.0% of the banks. The percentage of banks that had both a type of erosion and at least one indicator of erosion labeled as “stable” was 26.2% of the banks.

FirstLight’s 2013 FRR did not follow their own definition of stable and considered more banks stable than was observed. We note that even FirstLight’s definition of riverbank classification terms was problematic. For example, as shown in the image below, FirstLight added two categories of definitions to the list of Riverbank Classification Definitions (Stages of Erosion and Extent of Current Erosion) that are entirely subjective and used vague language like “evidence of recent erosion activity” and “active erosion present”.¹⁰ Rather than using a scientifically valid approach to a temporal classification of the stages of erosion, as offered in Field 2007, FirstLight’s made-up categories and subjective language serve to effectively skew all of the data and results in favor of FirstLight’s position that project operations do not impair water quality in the Connecticut River. This is the kind of bias FRCOG has long recommended avoiding. The QAPP had these and other biases that would likely have been eliminated if the document had undergone a rigorous review by MassDEP. We note that some of the results of the 2013 FRR were used as input data for BSTEM and this, along with our other concerns regarding BSTEM, further undermines FirstLight’s assertion that project operations have limited impact on bank stability and water quality in the TFI.

Stage(s) of Erosion	Potential Future Erosion – riverbank segment exhibits multiple or extensive indicators of potential erosion
	Active Erosion – riverbank segment exhibits one or more types of erosion as well as evidence of recent erosion activity
	Eroded – riverbank segment exhibits indicators that erosion has occurred (e.g. lack of vegetation, etc.), however, recent erosion activity is not observed. A segment classified as Eroded would typically be between Active Erosion and Stable on the temporal scale of erosion.
	Stable – riverbank segment does not exhibit types or indicators of erosion

¹⁰ Table 6: Riverbank Classification Definitions on pages 24 and 25 in the FirstLight Full River Reconnaissance QAPP, Revision No.2 included as Appendix D in the 2013 FRR Final Report September 2014 (FERC Study 3.1.1).

Extent of Current Erosion	None/Little ¹¹ – generally stable bank where the total surface area of the bank segment has approximately less than 10% active erosion present.
	Some – riverbank segment where the total surface area of the bank segment has approximately 10-40% active erosion present
	Some to Extensive – riverbank segment where the total surface area of the bank segment has approximately 40-70% active erosion present
	Extensive – riverbank segment where the total surface area of the bank segment has approximately more than 70% active erosion present

Invasive Species Management and Bank Erosion

With regard to terrestrial and aquatic invasive species management plans, we refer to FRCOG’s comments and recommendations filed with FERC on May 22, 2024.

Additionally, we refer to Attachment B of the Addendum to the Full River Reconnaissance Study 3.1.1. Attachment B showed riverbank photos taken by Field Geology Services in 2007 and compared them to photos at the same location in 2014. The images from page B-11 of Site 8, located near the old railroad bridge in Northfield, MA, are copied below. The comment at the bottom of this page states, “Bank conditions appear similar in both sets of photographs *but oriental bittersweet has become more established since 2007 at this location.*” This is the effect of a “no management” approach that FirstLight is proposing for terrestrial invasive plants in its Invasive Species Management Plans. And since 2014, another 10 years has passed.

PHOTO SET #8

2007 Photo: Downstream from the old Railroad Bridge: Located on the left bank of the River.



2014 Photo: Downstream from the old Railroad Bridge



Observations: Bank conditions appear similar in both sets of photographs but oriental bittersweet has become more established since 2007 at this location. There is a kingfisher nest cavity in the 2014 photograph (white arrow).

Study 3.1.2 and Operational Impacts

FRCOG is submitting our comment letters on the interim study report, the updated study report, and the final Study Report for Study 3.1.2 so that MassDEP can understand the issues that FRCOG has been raising about this study from the start.

FRCOG's comments to FERC dated May 22, 2024 together with Dr. Evan Dethier's review (submitted as an attachment to this letter) provide an explanation for why FRCOG does not accept the results of the BSTEM model as an accurate means of assessing existing project impacts, nor do we endorse its use as a predictive model to accurately assess future project impacts. The bottom line is that the BSTEM model does not match our observations on erosion along the Connecticut River over the past 20+ years, the river segments are already considered impaired, and MassDEP should set conditions by which the river can meet water quality standards.

Our May 22, 2024 letter also explains that FRCOG does not believe that modeling future operations based on 14 years of previous operations is an accurate way to assess project impacts over the next 50 years. FirstLight's proposal provides no safeguards to ensure that project operations will remain similar to what the model may predict. In other words, there is ample room for impacts to increase, rather than decrease.

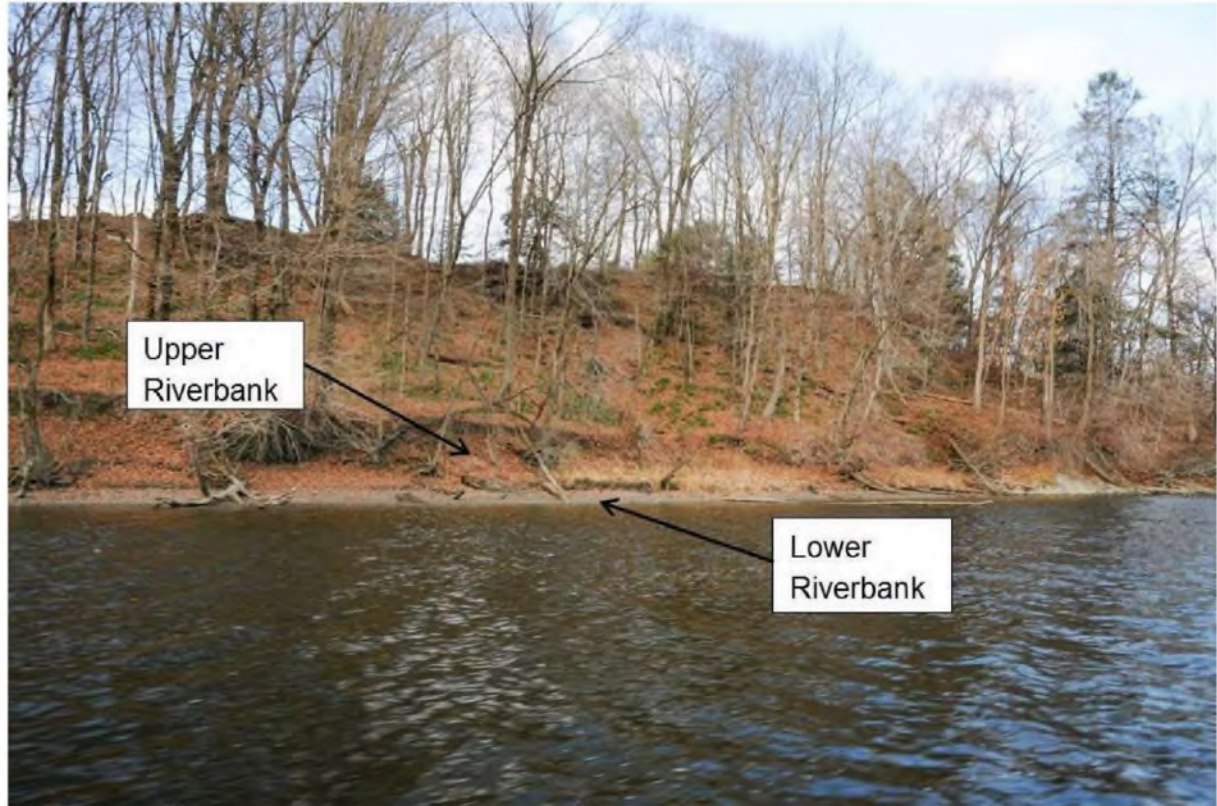
In addition to the comments we have previously provided, below are several more comments that are specifically geared towards the 401 Application.

Definition of "Bank" has been a problem from the beginning

During a meeting FirstLight held with stakeholders in June of 2014 to discuss Study 3.1.2 field efforts and the detailed study sites report, stakeholders raised concerns over FirstLight's use of the terms "upper" and "lower" (river) bank. Afterwards, FirstLight sent a memo to Interested Stakeholders dated June 27, 2014 attempting to clarify the working definition of upper vs. lower riverbank. They described the upper bank as "that portion of the bank that is frequently above water but can be inundated during high flows" whereas the lower bank is "that portion of the bank that is frequently below water, typically lies at a relatively flat slope, and is mostly barren of vegetation other than some scattered aquatic vegetation." FirstLight never clarified where the upper extent of the upper bank ended, or where the lower extent of the lower bank ended.

The June 27, 2014 memorandum from FirstLight included several visual examples, such as the one copied below, which was Example 2 and Figure 4 in that memorandum. The arrows and text boxes were provided by FirstLight in the memorandum.

Figure 4. Upper vs. Lower Riverbank – Example 2



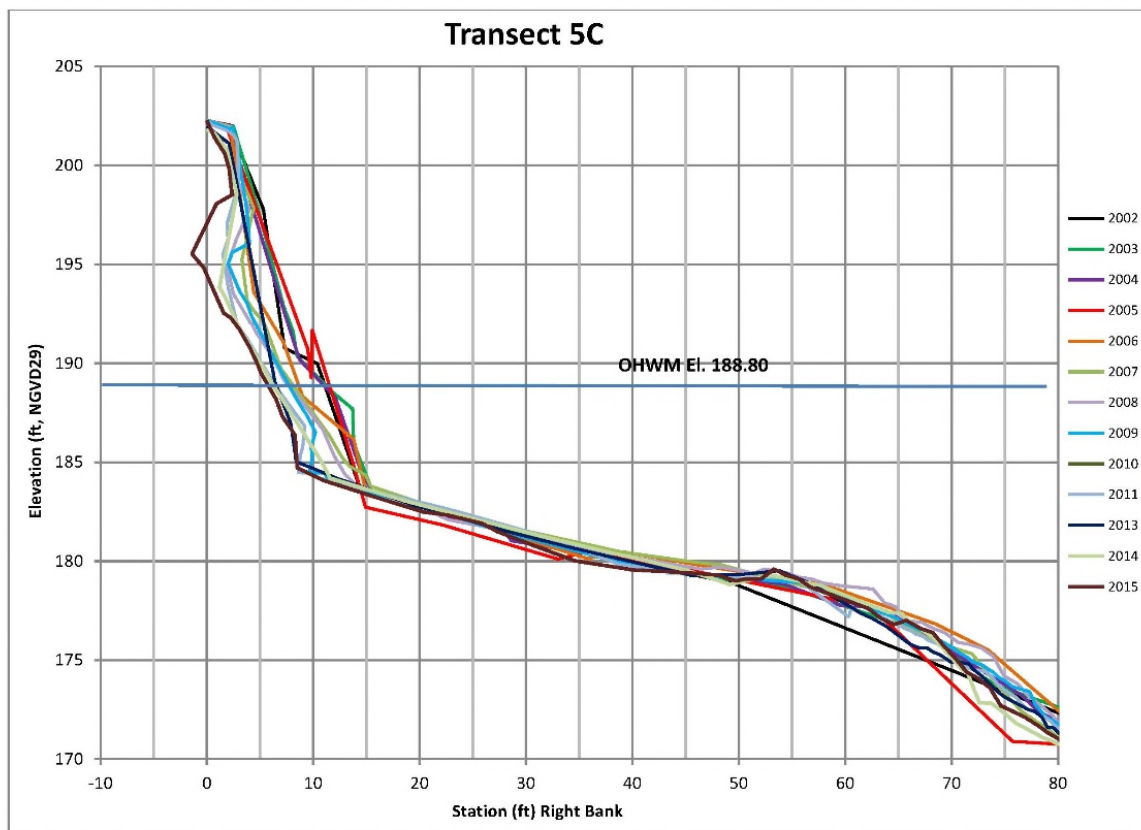
The June 27, 2014 memorandum further explained,

The definitions do not necessarily correspond to regulatory definitions used in state and federal environmental regulations. For example, the definition of “bank” used in this document may be broader than the regulatory definitions of bank used in the Massachusetts Wetlands Protection Act rules at 310 CMR 10. FirstLight believes using non-regulatory definitions is appropriate at this stage because the intent of Study No. 3.1.2 is not to assess erosion solely on “banks” as defined in the regulations but rather to take a more holistic view of the river system. FirstLight agrees that the regulatory definitions will ultimately be important during relicensing and will work with state and federal regulatory agencies and affected stakeholders in that regard.

Despite FirstLight agreeing that the regulatory definitions will ultimately be important during relicensing, there is no mention in the 401 Application about any refinement of the definitions of upper and lower bank in relation to jurisdictional authority in Massachusetts. The Wetlands Protection Act regulations, 310 CMR 10.54(2)(c), for example, define Bank in freshwater systems as follows: “the upper boundary of a bank as the first observable break in the slope or the mean annual flood level, whichever is lower. The lower boundary of a Bank is the mean annual low flow level.” Despite MassDEP’s prior requests, FirstLight has never presented study results in a way that conforms to MassDEP’s regulatory authority.

Appendix E to Study 3.1.2 showed the transects for 2002 to 2015. Below is the Transect 5C on the right bank as shown in Appendix E, for example. Figure 3.1-1 in FirstLight’s 2024 Supplemental BSTEM report submitted on March 22, 2024 to FERC shows that water levels at Transect 5C vary between an elevation of 179 and 190 ft msl. On the transect image below, the Ordinary High Water Mark (OHWM) is given as 188.8 ft. This transect below, however, shows the “bank” as being between 170 and 200+ ft. It appears that FirstLight included a 9-foot high and 30-foot wide section of riverbed as “bank.” How this transect geometry was entered into BSTEM is unclear, and it has never been clear how FirstLight’s different definition of bank from the regulatory definition may affect study results, including and importantly, the BSTEM results.

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)
STUDY 3.1.2 NORTHFIELD MOUNTAIN / TURNERS FALLS OPERATIONS IMPACTS ON EXISTING EROSION AND POTENTIAL BANK INSTABILITY



Appendix E-30

Quality Control on BSTEM Model inputs lacking

As FRCOG has argued above and in our May 22, 2024 letter to FERC, we do not think it is possible to accurately model the many causes of erosion in the TFI, nor do we think it is possible to predict future operations or the impact of future operations. As with any model, there are always uncertainties. The quality of the data input into the model is critically important, as is its usage compared to what it was designed to be able to do. FirstLight, in their 2024 Supplemental BSTEM

report, is asking a lot of the model by presuming that it can accurately predict how much erosion will occur and exactly which eroding banks are due to project operations.

The BSTEM User's Manual from 2013 has a section called "How to best use the Bank Stability and Toe Erosion Model."¹¹ On this page (Figure 3), it says that **the validity of model outputs is subject to the two major constraints**, as quoted below (emphasis ours):

- a) **the model is a simplification of a complex natural system, and that simplification must be appropriate to the field situation in order for the results to be meaningful.**
- b) **The output is only as good as the input data.**

Data Collection and BSTEM Model Input Discrepancies

There was no QAPP for Study 3.1.2, and no reviewer to date has looked at the BSTEM input values reported in Study 3.1.2 Appendix L and compared them with the long-term transects (Study 3.1.2 Appendix E); the detailed drawings, photos, and bank stratigraphy in the detailed study site assessments (Study 3.1.2 Appendix D); the equations and assumptions and the tables related to jet testing and borehole tests (for example, Tables 4.2.6.5-1 and 4.2.6.6-1), to see if these all make sense, and whether other values would be more appropriate and how that would change the results. The exception that we are aware of are the comments on pages 44 to 51 in Dr. Evan Dethier's review.

The BSTEM model input data provided by FirstLight in Appendix L of Volume III does not include bank Input Geometry. Figure 4 from the 2013 BSTEM User's Manual is copied below. As the figure below shows, this is a critical data set for BSTEM and Section 2 of the 2013 BSTEM User's Manual states that this step is key to model output.

Instead, FirstLight chose Option B – Enter a bank height and angle and let the model generate a bank profile. In section 4.2.6 BSTEM Input Data Collection, FirstLight states that rough surveys of the 25 detailed study sites were done using a tape and Brunton compass to provide bank heights, angles and stratigraphic layering. "The data collected in the field were used by Cardno to populate BSTEM-Dynamic 2.3." According to the BSTEM-Dynamic 2.0 User Manual, "[Option B]...should be used where a detailed bank profile is unavailable or hypothetical scenarios are being run." Option B generates a simplified bank profile.

Why was Option B chosen over Option A, which would have yielded a detailed bank profile? No rationale is provided by FirstLight. Option A could have been done using the survey data available for the 20 permanent transects and detailed surveys could have been done for the new study sites, which would have provided more accurate bank profiles than those from Option B.

¹¹ Available for download at <https://www.hec.usace.army.mil/confluence/rasdocs/rassed1d/1d-sediment-transport-user-s-manual/bstem-user-s-manual#>.

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

1) Select **NEITHER** Option A or Option B for Bank Profile and enter the data in the relevant box-cells in the alternative option are ignored in the simulation and may be left blank if desired.

2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).

3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

☐ Option A

Point	Station	Elevation
A	0.00	5000.04
B	9.39	5000.04
C	9.78	4999.88
D	9.80	4999.75
E	9.80	4999.65
F	9.80	4999.45
G	9.83	4999.28
H	10.09	4999.09
I	10.20	4998.85
J	10.40	4998.65
K	10.69	4998.47
L	10.88	4998.20
M	10.93	4997.99
N	11.13	4997.91
O	11.23	4997.71
P	11.81	4997.88
Q	11.84	4997.52
R	12.72	4997.38
S	13.26	4997.14
T	13.46	4996.77
U	14.14	4996.66
V	14.97	4996.56
W	17.00	4996.56

Option B - Enter a bank height and angle, the model will generate a bank profile

☒ Option B

Bank height (m):

Bank angle (degrees):

Toe Length (m):

Toe angle (degrees):

Elevation of layer base (m)

Top Layer

1.60

1.90

1.50

1.50

1.50

Bottom Layer

3.40

1.50

1.50

1.50

1.50

Parallel layers, starting from point B

Definition of points used in bank profile

A - bank top; place beyond start of shear surface
B - bank edge
C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
Q - top of bank toe
R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
V - base of bank toe
W - end point (typically mid point of channel)

Bank material

Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

Input reach length (m):

Input reach slope (m/m):

View Bank Geometry

Run Bank Geometry Macro

Figure 4 – Screen shot of the ‘Input Geometry’ sheet where bank geometry, layer depth and flow parameters are input.

BSTEM input data in Appendix L to Study 3.1.2 shows that for each of the study sites, four layers were used. For site 5CR, for example, the profile that we copied earlier in this letter (page 15), has layer depths that add up to 7.12 feet deep. Which 7 feet of the ~32 feet of the profile were entered into the model, and why? This is another example of inconsistencies in data collection and model input as well as an impediment to being able to replicate the study and review its results.

Our review of the field data in Section 4 of Volume II of Study 3.1.2 and the BSTEM model input data provided for each detailed study site in Appendix L indicates that model default values for Geotechnical Properties and Hydraulic Conductivity were used for Bank Model Input Data and Groundwater Model Input Data. In the case of Toe Model Input Data, it is even more confusing because the input values in the two columns in Appendix L often don't match the reported Jet Test Data in Table 4.2.6.6-1 or Table 4.2.6.6-2.

Despite over 30 pages of narrative, tables and scatter plots in Section 4 Field Studies, Data Collection and Modeling in Volume II of Study 3.1.2, **it is unclear how the data gathered from the field studies was QA/QC checked, processed and used as BSTEM model input data.** There is no clear relation between the site-specific data presented in Section 4 and the model input data presented in Appendix L. The reader should be provided with enough information to understand these connections. Uncertainty values should be provided, and information about quality checking should be given. Instead, the presentation of apparently unused site-specific data and overall general lack of clarity in the narrative supports our serious concerns about the data processing and input, and the results of the BSTEM model.

No 3rd party reviewer has ever seen the actual model output to see if the results have accurately been given in FirstLight's reports. FirstLight has said that providing model output would be very long and cumbersome and that may very well be true. However, they could have provided full input and output for a small (random or stakeholder-selected) subset of the study sites in order for reviewers to better understand the output. As a comparison, for the fish passage studies that used PIT tags, the PIT tag readings involved millions of data points. FirstLight's consultants provided the raw data to reviewers upon request. Because the agency and nonprofit reviewers had expertise in PIT tag data analysis, they were able to independently screen and review the results, and in that process, noted some errors. FirstLight's consultants re-ran the analysis, and the study results were corrected. Nothing like this has been done for the erosion study.

Unlike BSTEM-Dynamic 2.0, the modified BSTEM-Dynamic model (ver. 2.3) used on the TFI has no available user manual and was not peer-reviewed and tested in similar settings. We could find no peer-reviewed articles about the use of BSTEM-Dynamic 2.0 to predict future conditions and future responses of a river system to climate change impacts, which supports our concerns about its application and conclusions for the TFI. FirstLight coupled the HEC-RAS model to BSTEM-Dynamic (ver.2.3). Again, we are concerned about this approach since limited information was provided about the coupling of these models.¹² We note that a March 2015 Army Corps of Engineers Technical Reference & User's Manual for HEC-RAS and BSTEM (USDA's publically available static version) is over 60 pages long and, not surprisingly, very complex. We assert that, in the absence of a QAPP and robust technical documentation, FirstLight's coupling of HEC-RAS with their version of BSTEM-Dynamic (ver.2.3) and the results of the modeling should be viewed with a high degree of skepticism and likely do not represent conditions in the TFI and the projects' impact on water quality. Once again, the TFI has been used as an experiment – this time for a black box computer model with no documentation, no QAPP and no scientifically valid basis for its use as a predictive tool for the TFI and project operations 50 years into the future.

¹² Appendix F – BSTEM Technical Background provided as part of Study 3.1.2 was inadequate and consisted, in part, of random copied and pasted sections from the 2013 BSTEM-Dynamic 2.0 User Manual. No information was provided in Appendix F about how HEC-RAS results were used in the BSTEM model. Narrative about the HEC-RAS results was provided in Section 5.4.1 BSTEM Input Data of Vol II of Study 3.1.2 but the model runs could not be replicated by a 3rd party reviewer due to the lack of technical documentation and a QAPP.

Riparian Buffer Area

MassDEP's March 1, 2013 Study Request letter requested a bank stability study that had many objectives, one of which was, "Map land use practices that are directly observationally linked to 'bank' 'erosion' directly beneath and/or proximate to them, and target these areas for employment of best management practices." Consequently, Study Report 3.1.2 included Section 5.5.4 "Land Management Practices and Anthropogenic Influences to the Riparian Zone." Volume I of Study 3.1.2 on pages 35-36 describes the conclusions drawn from this part of the study:

As a result of the correlation observed between adjacent land-use and bank stability any riverbank segment where the adjacent land-use was classified as Agriculture or Developed and the riparian buffer width was 50 feet or less was classified as having land-use or land management practices as a potential contributing cause of erosion. This equated to approximately 101,000 feet (19 mi.) or 44% of all riverbank segments in the TFI.

Furthermore, riparian vegetation provides a stabilizing influence to riverbanks damping out hydraulic forces and providing soil stability through its supporting root structure. Where land-use removes or reduces vegetation in the riparian corridor, riverbank stability is generally decreased. A riparian buffer zone between land-use such as agriculture and a river provides an important component that adds to riverbank stability. The Connecticut River Joint Commissions (CRJC), in a brochure entitled "Introduction to Riparian Buffers," state:

Riparian buffer vegetation helps stabilize streambanks and reduce erosion. Roots hold bank soil together, and stems protect banks by deflecting the cutting action of waves, ice, boat wakes, and storm runoff.

They warn that, "Natural riparian buffers have been lost in many places over the years," and recommend a minimum width of riparian buffer of "at least 50 feet" to stabilize eroding riverbanks. They further state that "Riparian buffers are the single most effective protection for our water resources in Vermont and New Hampshire," and that restoring riparian buffers will be "an important step forward" regarding riverbank stability.

Despite the analysis that 44% of all riverbank segments in the TFI have less than a 50 ft riparian buffer, and FirstLight's report cited 50 ft. as the minimum width to help stabilize eroding riverbanks, and despite the fact that FirstLight owns much of the shoreline or has the flowage rights to the shoreline lands,¹³ FirstLight has proposed nothing in the way of managing their lands with a 50 ft. buffer. On December 21, 2010, FirstLight filed a report with FERC evaluating erosion and runoff potential at properties FirstLight owns that are used for nonproject purposes, such as private clubs and seasonal or year-round "camp" dwellings. This report spoke of a 10-foot wide vegetated buffer that FirstLight was "formalizing." There is no mention of this in the 401 Application, and it appears 10 feet runs counter to their 50-foot recommendation.

¹³ Maps of licensee-owned lands were provided in a revision of Relicensing Study 3.6.5, located in FirstLight's response to stakeholder comment document dated May 31, 2016.

Managing Sediment Releases during Maintenance Activities at Northfield Mountain

The issue of managing sediment in the upper reservoir came under regulatory scrutiny in 2010, when FirstLight drained their upper reservoir at Northfield Mountain for maintenance purposes, and things went drastically wrong. Sediment filled the shaft between the river and the upper reservoir, shutting operations down for six months. FirstLight excavated the material and dumped it into the Connecticut River until the U.S. Environmental Protection Agency (USEPA) issued a cease and desist order. Administrative and Enforcement orders came from USEPA and MassDEP. FERC required that FirstLight file a plan for future maintenance activities to avoid similar occurrences in the future.

Recognizing that sediment releases like the one described above present a problem for Long Island Sound, which has a multi-state TMDL for low oxygen impairment caused by nutrients, MassDEP's study request letter dated March 1, 2013 requested that FirstLight conduct a study that will, "Evaluate strategies to manage the release of accumulated sediment through Northfield Mountain Project works during upper reservoir drawdown or dewatering activities."

FirstLight produced Relicensing Study 3.1.3 Sediment Management Plan, which included extensive information about sediment levels in the Connecticut River, bathymetric surveys of the upper reservoir at Northfield Mountain, and possible sediment barriers at the tailrace. Despite the August 3, 2010 Administrative Order issued by USEPA, Study 3.1.3 lacked any real plan when it was submitted to FERC as a final study report in October 2016. FERC consequently required that FirstLight file an addendum with the dewatering protocol, and on June 30, 2017, FirstLight filed their Upper Reservoir Dewatering Protocol document with FERC, MassDEP, and USEPA. The 2017 Dewatering Protocol document is included as Appendix D in FirstLight's 401 Application.

Section 5.4 of FirstLight's 401 Application describes the conditions that would lead FirstLight to dewater the upper reservoir to dredge and remove sediment. Prior to a dewatering event, the 2017 Dewatering Protocols explains in section 4.3 that FirstLight will notify MassDEP, USEPA, and FERC in advance to document the specific plan and provide BMPs (Best Management Practices). Section 4.2 of the Dewatering Protocol describes a three-tiered approach to monitoring during a dewatering event – 1) visual monitoring, 2) continuous monitoring of turbidity readings, and 3) grab sample collection and laboratory analysis. The Dewatering Protocol do not explain what will happen to the sediment that is dredged, i.e., where it will be stored, where it will ultimately be disposed. To our knowledge, the sediment dredged as part of the 2010 maintenance procedure was stored at the upper reservoir.

On August 25, 2023, FERC's Regional Engineer, John Spain, filed a letter sent to FirstLight regarding follow-up to a Dam Safety Inspection that took place on August 10, 2023. This letter in section 2 (Monitoring during Upper Reservoir Drawdown and Refilling) stated, "We were informed that the Upper Reservoir will be completely dewatered in September 2023 to perform planned maintenance of the pumped storage facility." FRCOG is unaware of any other communication to FERC or DEP or USEPA regarding this drawdown. It is unclear if a specific plan and BMPs were part of FirstLight's

notification, as outlined in FirstLight’s Dewatering Protocol, or if any monitoring described in their Dewatering Protocol took place. There is no mention of this in FirstLight’s 401 Application.

FRCOG Recommendations

FRCOG’s recommendations for terms of the new license are based on the following values:

- MassDEP’s goal should be to bring Project operations into compliance with WQS and other appropriate requirements of state law, and assure compliance over the license term.
- License conditions must be set to bring the Projects into compliance. Reducing the range of river level fluctuations will reduce project impacts.
- FirstLight should provide good stewardship of a vegetative riparian buffer the Connecticut River.
- FirstLight should conduct and make public more and better monitoring of project operations and river conditions.

Erosion Recommendations

To achieve water quality standards, FRCOG expects MassDEP to develop a set of conditions that establish the following requirements.

1. Target TFI elevation and typical operating range

Present Project operations – water level fluctuations – cause erosion and led to the River designation as impaired. FRCOG recommends the following limitations on TFI fluctuations to limit erosion, address the erosion-related pollution that led to the impairment, and to meet related water quality standards.

The water quality certification for the Turners Falls Dam and Northfield Pump Station projects should include a management goal for the Turners Falls Impoundment similar to that in the Great River Hydro agreement, which is “creating more stable impoundment water surface elevations.” Great River Hydro’s agreement #9 limits a fluctuation range per project (no more than a 1.5 ft) and #21 sets a target elevation and target 1.0-ft water surface elevation bandwidth. Because Northfield Mountain is a pumped storage project, the bandwidth would need to be wider.

A target elevation and target water surface elevation bandwidth should be established for the location at the Turners Falls Dam where the current license limit is measured, as well as at a new location at the USGS Gage at the Route 10 bridge in Northfield. The target elevation should be the same as what has been typical in the past, and the target bandwidth should be less than what was typical between 2000 and 2014, to reduce project impacts and ensure that operations do not instigate a new increased round of erosion. “Target bandwidth” would mean that the river elevation as measured at the dam and at the USGS gage would stay within the bandwidth a certain percentage of the time.

Target elevation at the dam. Page 3-24 of the Pre-Application Document (PAD) cited a “target” TFI elevation of 180.3¹⁴ and page 3-25 cites typical elevation of 180.5 feet msl.¹⁵ Study Report 3.3.9 stated on page iii that the median elevation as measured at the dam for 2000 to 2010 was 181.3 msl. Figure 4.3.1.3-7 in the PAD showed approximately 181.5 as the 50% equaled or exceeded elevation in an annual duration curve between 2000-2009. Figures 3.3.2.2.1-1 through -4 shows modeled baseline monthly water surface elevation level (WSEL) duration curves at the Turners Falls Dam. The 50% elevation ranges from approximately 181 to 182.5 ft. msl. FRCOG assumes the annual target elevation is 181.5 ft., based on the information in the PAD.

Target bandwidth at the dam: In the AFLA Exhibit E, Figure 3.3.2.2.1-8 showed an Annual Maximum Daily Change Histogram at the Turners Falls Dam for “baseline” conditions. This graph shows that 50% of the time, the daily change is less than 1.6 ft; 75% of the time, the daily change is less than 2 ft.; and 90% of the time, the daily change is less than 2.8 ft. License conditions should ensure that the frequency of daily water surface elevation fluctuations be reduced and not skew higher. FRCOG is recommending a 25% reduction in these statistics to reduce the wetted bandwidth and reduce erosion, which translates into limits at the dam of:

- 50% of the total hours in a year < 1.2 ft daily change
- 75% of the total hours in a year < 1.5 ft daily change
- 90% of the total hours in a year < 2.1 ft daily change

A similar requirement would be set for the USGS gage at the Route 10 bridge in Northfield. The 2024 Supplemental BSTEM Modeling Report’s Figure 3.1-1 shows a distribution of water surface elevations at transect site 5CR, which is near the USGS gage location. The 50% elevation is approximately 182 ft. This would be the target elevation. For target bandwidth, Figure 5.1.3.1-6 in Volume II of Study 3.1.2 shows a Maximum Daily Change Histogram at Transect 5CR. This graph shows that 50% of the time, the daily change is less than 2 ft; 75% of the time, the daily change is less than 2.8 ft.; and 90% of the time, the daily change is less than 3.6 ft. License conditions should ensure that the frequency of daily water surface elevation fluctuations be reduced and not skew higher. FRCOG is recommending a 25% reduction in these statistics to reduce the wetted bandwidth and reduce erosion, which translates into limits at the USGS gage at the Route 10 bridge of:

- 1.5 ft daily change at least 50% of the time
- 2.1 ft daily change no more than 25% of the time
- 2.7 ft daily change no more than 10% of the time

¹⁴ “Under most common operating scenarios, FirstLight targets an impoundment elevation of 181.3 msl at the dam and 173.5 feet msl in the power canal (as measured in the Cabot forebay).”

¹⁵ “Under moderate flow conditions, i.e., naturally routed flows are between 1,433 cfs and 13,728 cfs (river flow exceeds 13,728 cfs approximately 34% of the time), the Turners Falls Impoundment elevation is typically managed around elevation 180.5 feet msl, but fluctuates under these inflow conditions due to Cabot peaking operations and the pumping/generating cycle at the Northfield Mountain Project.”

To the extent that fluctuations outside of these ranges are required to respond to emergencies or re-regulation of Cabot Station as prescribed in the FFP Agreement, the language authorizing flows below or above the ranges described above should narrowly circumscribe those circumstances. FirstLight's graphs showing WSEL duration curves at the Turners Falls Dam as presented in the AFLA (Figures 3.3.2.2.1-1 through -4) show that the WSEL ranges between 179 and 184 ft. more than 90% of the time, and it should not be difficult to make that the ultimate operational limit.

2. Monitoring

A. Project Operation, Monitoring, and Reporting Plan

FRCOG recommends that the language about the Project Operation, Monitoring, and Reporting Plan as contemplated in A200 of the FFP Settlement Agreement be modified to include the following TFI statistics in the annual compliance reports until the end of the license: for each month of the year, the average TFI elevation as measured at the Turners Falls Dam, the average daily elevation change (maximum elevation minus the minimum daily elevation, averaged over the month), the highest elevation of the month, and the lowest elevation of the month. This report will also demonstrate compliance with any TFI target ranges that are developed. These same statistics should be included for the USGS gage site in Northfield.

B. Transect Surveys

FirstLight is currently required to conduct annual transect surveys. FRCOG recommends that this requirement continue into the next license. Based on our experience reviewing previous cross-sectional charts provided by FirstLight, we have the following recommendations. Cross-sectional surveys will be conducted by a Licensed Surveyor at the 22 historical transect locations and 9 new locations established for relicensing studies 3.1.1 and 3.1.2 locations. Annual reports will be submitted to FERC, showing a cross-sectional view with consistent vertical and horizontal scales that do not obscure the horizontal bank changes. The previous 10 years' worth of cross-section survey lines should be provided on each graph in a line color or pattern that is easy to see from one survey-year to another. The maximum and minimum water surface elevations (for flows less than 18,000 cfs) for each transect location should be provided on each cross-section chart. Right and left bank (looking downstream) should be clearly identified. Each transect chart in the report shall have the licensed surveyor's business name on the chart. The raw data from the transect surveys shall be made available if requested by the public. Each year, FirstLight shall calculate and report on the amount of erosion or accretion at each site, reported in square feet or square meters. This information shall be reported for three zones: 1) the cross-section area below the typical water line, 2) the elevation range for 90% of conditions when flows are below 18,000 cfs (operation range), and 3) bank above the ordinary high water line.

C. Full River Reconnaissance

The Full River Reconnaissance should continue to be required. The methods of the FRR should be determined by an independent consultant hired and managed by an outside agency that is not the licensee. Methods that are less subjective and more objective, such as LiDAR surveys or side-scanning sonar, should be employed (methodology changes made during previous FRR efforts led to various problems with comparing results).¹⁶ Ideally, a survey should be done once per year, with the TFI level held at the same level each survey – the elevation should be relatively low so that the banks can be exposed and surveyed. The methodology of the FRR should be written and viewable by the public, and there should be a Quality Assurance Project Plan reviewed and approved by MassDEP and the U.S. Environmental Protection Agency. The first FRR should be completed in the first year of the new license to establish baseline conditions for the new license.

D. Photo Documentation

For each detail study site from Study 3.1.2, there shall be a set of photos made at license issuance and every 5 years after that. Photo documentation methodology should be established in an approved photo documentation QAPP. These should be made available to the public on a map-based website, similar to what was made available as Appendix K to the 2013 FRR as Study 3.1.1 (<https://gsegis.maps.arcgis.com/apps/Viewer/index.html?appid=7e9cf7b8e4de45dd82948e5d393f44cd>) before the links were broken and never re-established.

E. Contribution to USGS gage at Route 10 bridge

FirstLight should fund annual operational costs to continue the USGS gage (gage level data only) near the Route 10 bridge, separate from other funding. This is gage 01161280. The estimated cost to operate is \$25,000 in 2020 dollars based on personal contact with MassDEP. The funding contribution should continue for the duration of the license and data will be publicly available in real-time via the USGS. This is consistent with [Standard License Article 8 under FERC's L-3: Terms and Conditions of License for Constructed Major Projects on Navigable Waters of the United States](#).

3. License Articles

Articles 19 and 20 from the existing Turners Falls and Northfield Mountain Project licenses should be updated based on new conditions set in the 401 Water Quality Certificate and FERC license.

4. Maintenance of Previously Repaired Sites

FirstLight should continue to be responsible for maintenance and repair of all bank restoration projects started and/or completed under the prior/currently existing license.

¹⁶ Massachusetts has partnered with the U.S. Geological Survey to map and track coastal erosion. See Massachusetts Shoreline Change Mapping and Analysis Project, 2013 Update, available online at <https://pubs.usgs.gov/publication/ofr20121189>.

5. Shoreline Management and Erosion Control

An update to the 1999 Erosion Control Plan is needed. The Plan should be modified to indicate a more holistic approach to managing the riverbank and riparian area, and could be called a Shoreline Erosion Control Management Plan. FRCOG would not be opposed if a single plan was developed for all five projects Connecticut River projects undergoing relicensing, which would potentially recognize cumulative effects of the projects, setting wider management goals, and an agreement for many parties to work collaboratively. However, the MA projects will be geared towards restoring conditions to meet MA State Surface Water Quality Standards. The new plan should have the following elements:

- A. Interested party involvement. It took more than 20 years for the formation and recognition of the Connecticut River Streambank Erosion Committee (CRSEC), which was then recognized as an ad-hoc group by FERC and MassDEP. The licensee should continue to meet and consult with CRSEC into the next license.
- B. Full River Reconnaissance. The licensee should continue to be responsible for conducting a reconnaissance survey of bank erosion at regular intervals throughout the license term. See previous recommendation details in #2C.
- C. Mitigation Projects. FirstLight will work with the CRSEC, town Historical Commissions, and indigenous groups to commit to riverbank and riparian projects to reduce and mitigate project effects. Particular attention must be given to preserving farmland, infrastructure, and historical and cultural artifacts.
- D. Invasive Species Management. See our comments below regarding FirstLight's responsibilities as steward of riparian lands. These recommendations are very much tied to erosion concerns. Additional comments are provided that address impairments in Barton Cove.
- E. Riparian Buffer Establishment. For the shoreline lands that FirstLight owns, FirstLight should establish, at a minimum, a 50-foot vegetated buffer between the river and any development or land use that prevents the maintenance of natural vegetation. MassDEP should specify how the width of the buffer is to be measured. For the flowage rights that FirstLight owns, FirstLight should work with landowners to establish the same vegetated buffer, potentially paying them to not till this area along the river. For shoreline lands that FirstLight neither owns nor has flowage rights for, FirstLight should work with area organizations like the Franklin Conservation District to conduct landowner outreach to encourage the preservation of a riparian buffer.

Invasive Species Management

FRCOG recommends that FirstLight be required to prepare a revised Invasive Plant Species Management Plan that spans both projects and involves a public comment period. A draft should be distributed to all relevant federal and state agencies, including consortiums that are involved in invasive plant identification and removal, as well as parties intervening in the relicensing effort.

The format of a revised Plan should be closer to that developed by another land conservation organization, The Trustees of Reservations, or from Army Corps of Engineers guidance.^{17, 18} The revised plan should commit FirstLight to early detection and response, in partnership with volunteers, agencies, and nonprofits. Management guidelines and a guide for prioritization should be developed. The Plans should be geared towards meeting water quality standards.

FirstLight should commit to the following, at a minimum:

1. Early detection and removal of new invasive species in the project area, both aquatic and upland, in coordination with relevant agencies and organizations. This commitment may include species beyond plants.
2. Continued participation, which includes staff assistance and expenses, in managing and removing aquatic invasive plants in the entire project area. FL could help fund staffing and/or signage to reduce the spread of invasive aquatic plants through boats, motors, trailers, and fishing gear.
3. A priority set of upland invasive plants should be monitored in the project area at regular intervals throughout the term of the license (once every 5 or so years).
4. FirstLight should commit to controlling and reducing the further increase of established priority invasive plants in priority areas that are identified in coordination with interested parties.
5. FirstLight should coordinate with agencies on any non-plant invasive species, when they become an active threat.
6. FirstLight should host a meeting with agencies and other interested parties once every 5 years, after the results of the surveys are completed. These meetings should include a summary of the current state of invasive species, management techniques, and input on the upcoming efforts of the next five years in coordination with parties attending. Such meetings will allow the licensee and interested parties to adjust to any unanticipated issues over the term of the license.

Managing Sediment Releases During Northfield Mountain Maintenance Activities

- MassDEP should establish whether or not FirstLight followed their own Dewatering Protocol during the dewatering event that took place between September and the end of December, 2023.
- MassDEP should request a copy of FirstLight's suspended sediment monitoring data from the 2023 upper reservoir dewatering event.
- In the 401 WQC, MassDEP should set notification and monitoring protocol for future dewatering events. As a part of this, MassDEP should require that the 2012 Quality Assurance Project Plan (QAPP) (mentioned in a footnote on page 1-1 of the Dewatering Protocol Document) be revised and approved for the monitoring protocol.

¹⁷ <https://thetrustees.org/wp-content/uploads/2020/07/Invasive-Plant-Management-GUIDELINES-AND-BEST-PRACTICES.pdf>

¹⁸ <https://www.nae.usace.army.mil/portals/74/docs/regulatory/invasivespecies/ispcguidance.pdf>

- MassDEP should establish turbidity limits and disposal requirements for dewatering and dredging events, as appropriate.

Recommended 401 Water Quality Certification Conditions

MODIFIED FFP Article A190. Turners Falls Impoundment Water Level Management (grey shading is where the FRCOG proposes changes to the article in the Flows and Fish Passage (FFP) Settlement Agreement)

Upon license issuance, the Licensee shall operate the Turners Falls Impoundment, as measured at the Turners Falls Dam, as follows:

- (a) Target elevation: The Turners Falls impoundment shall be held at a target average elevation of 181.5 ft. "Average" is defined as the arithmetic average of all hours of a given year.
- (b) Target bandwidth: The TFI elevation shall be maintained between the following target bandwidths: for 50% of the hours per year, the daily elevation change shall be less than 1.2 ft., for 75% of hours per year the daily elevation change shall be less than 1.5 ft, and for 90% of hours per year, the daily elevation change shall be less than 2.1 ft. Daily elevation change is defined as the maximum elevation minus the minimum elevation of a calendar day.
- (c) For the remaining 10% of hours, water surface elevations shall be between 179 and 184 ft. msl. These deviations will be necessary only during certain prescribed circumstances, such as during ISO-NE grid emergencies, flood events, disaster declarations, and/or rare instances during which flow management of Cabot Station dictated by the FFP Cabot requires more flexibility as agreed-to by federal and state resource agencies.
- (d) Limit the rate of rise of the Turners Falls Impoundment water level to be less than 0.9 feet/hour from May 15 to August 15 from 8:00 am to 2:00 pm. However, if the NRF is greater than the sum of the hydraulic capacity of Cabot Station and Station No. 1 and the Minimum Flow below Turners Falls Dam in effect at the time, the Turners Falls Impoundment rate of rise requirement will not apply.
- (e) The rate of rise of the Turners Falls Impoundment may be temporarily modified if required by equipment malfunction or operating emergencies reasonably beyond the control of the Licensee. If the rate of rise of the Turners Falls Impoundment is so modified, the Licensee shall notify the Commission, MDEP, MDFW, NMFS, and USFWS as soon as possible, but no later than 10 days after such incident. The rate of rise of the Turners Falls Impoundment may also be temporarily modified for short periods upon mutual agreement with the Licensee for the Northfield Mountain Pumped Storage Project (FERC No. 2485), MDEP, MDFW, NMFS, and USFWS, and upon 5 days' notice to the Commission.
- (f) The Licensee may increase the allowable NRF deviation from $\pm 10\%$ to $\pm 20\%$ to better manage Turners Falls Impoundment water levels. The increased flow deviation is limited by the number of hours shown in the first table of Article A160. This allowance for an increased flow deviation is in addition to the exceptions outlined in paragraphs (a) and (b) of Article A160. As such, the increased flow allowable deviations outlined in this paragraph will not count against any time allotment for exceptions outlined in paragraphs (a) and (b) of Article A160.

Similarly, operations meeting the exception criteria outlined in paragraphs (a) and (b) of Article A160 will not count against any time allotment for allowable deviations outlined in this paragraph. Allowable flow deviations in excess of A-11 $\pm 10\%$ of NRF resulting from conflicting operational requirements will not count against any time allotment for allowable deviations outlined in this paragraph.

Condition FRCOG1. Turners Falls Impoundment Water Level Management, Northfield Gage

Upon license issuance, the Licensee shall operate the Turners Falls Impoundment, as measured at the USGS Gage at Northfield (01161280), as follows:

- (a) Target elevation: The river level shall be held at a target average elevation of 182 ft. "Average" is defined as the arithmetic average of all hours of a given month.
- (b) Target bandwidth: The TFI elevation shall be maintained between the following target bandwidths: for 50% of the hours per year, the daily elevation change shall be less than 1.5 ft, for 75% of hours per year the daily elevation change shall be less than 2.1 ft, and for 90% of hours per year, the daily elevation change shall be less than 2.7 ft. Daily elevation change is defined as the maximum elevation minus the minimum elevation of a calendar day.
- (c) When naturally-routed flow exceeds 30,000 cubic feet per second (cfs), operating Northfield Mountain Pumped Storage shall not cause any increase in river elevation as measured at the gage. (Flow rate chosen based on page 5-71 of Volume II of Study 3.1.2, where it says that "measurable erosion processes do not begin at the vast majority of sites until flows exceed 25,000 to 30,000 cfs).
- (d) To protect state-listed odonates, limit the rate of rise of the Turners Falls Impoundment water level to be less than 0.9 feet/hour from May 15 to August 15 from 8:00 am to 2:00 pm, as measured at the USGS gage. However, if the NRF is greater than 20,000 cfs (when French King Gorge becomes a hydraulic control), the restriction will not apply.
- (e) The rate of rise of the Turners Falls Impoundment may be temporarily modified if required by equipment malfunction or operating emergencies reasonably beyond the control of the Licensee. If the rate of rise of the Turners Falls Impoundment is so modified, the Licensee shall notify the Commission, MDEP, MDFW, NMFS, and USFWS as soon as possible, but no later than 10 days after such incident. The rate of rise of the Turners Falls Impoundment may also be temporarily modified

Modifications to FFP License Article A200.

The Project Operation, Monitoring and Reporting Plan shall be modified to include the following TFI statistics in the annual compliance reports until the end of the license: for each month of the year, the average TFI elevation as measured at the Turners Falls Dam, the average daily elevation change (maximum elevation minus the minimum daily elevation, averaged over the month), the highest elevation of the month, and the lowest elevation of the month. Similar statistics will be supplied for the USGS Gage at Northfield. This report will also demonstrate compliance with TFI target ranges as described in Modified FFP License Article A190 and FRCOG1.

Condition FRCOG 2. Riparian Buffer Management

On lands abutting the Connecticut River that the licensee owns, the Licensee shall establish a 50 foot vegetated buffer. Within this buffer, the licensee shall make efforts to remove and reduce the spread of invasive plants that threaten bank stability and plant diversity, such as Oriental bittersweet.

Condition FRCOG 3. Shoreline Management and Erosion Control

Upon license issuance, the licensee shall be responsible for the following activities in the TFI:

- (a) In order to minimize notching and undercutting of the riverbanks, which leads to cycles of bank instability and erosion, anywhere the typical operation range of the bank is not composed of bedrock or hardened from previous bank stability work (rip-rap, tires, coir logs, etc.), the Licensee shall re-inforce the bank along a 2.5 to 3-ft-wide band at the average water elevation for that location. The protected band should be wide enough to cover typical operations for more than 50% of the time and to allow for wave action from boat wakes on the upper end of the band (Figure 4.2.8.5-7 in Volume II of Study 3.1.2 shows wave height distributions; 0.3 ft. would cover most boat wakes). Such installations shall use a variety of nature-based techniques or modern techniques that are more conducive to healthy aquatic habitat (i.e., avoiding rip rap), in consultation with the MA Natural Heritage and Endangered Species Program, MassDEP, and the local Conservation Commission. The Licensee shall be responsible for maintenance and repair of these installations for the life of the license.
- (b) The above-said toe protection should be fully installed within all erodible areas of the TFI that have not previously been restored within 5 years of license issuance.
- (c) The Licensee shall conduct the following monitoring activities for the duration of the license:
 - a. Transect surveys completed by a licensed surveyor at each of the 22 historical transect locations and 9 new locations established for relicensing Studies 3.1.1 and 3.1.2. These shall be completed annually and after each flow event higher than 60,000 cfs.
Annual reports will be submitted to FERC, showing a cross-sectional view with consistent vertical and horizontal scales that do not obscure the horizontal bank changes. The previous 10 years' worth of cross-section survey lines should be provided on each graph in a line color or pattern that is easy to see from one survey-year to another. The maximum and minimum water surface elevations (for flows less than 18,000 cfs) for each transect location should be provided on each cross-section chart. Right and left bank (looking downstream) should be clearly identified. Each transect chart in the report shall have the licensed surveyor's business name on the chart. The raw data from the transect surveys shall be made available if requested by the public. Each year, FirstLight shall calculate and report on the amount of erosion or accretion at each site, reported in square feet or square meters. This information shall be reported for three zones: 1) the cross-section area below the typical water line, 2) the cross section area within the elevation range for 90% of

conditions when flows are below 18,000 cfs (operation range), and 3) the cross-section area of the bank above the ordinary high water line.

- b. Full river reconnaissance (FRR) surveys conducted according to a MassDEP-approved Quality Assurance Project Plan (QAPP). The surveys will include methods such as LiDAR or side-scanning sonar that are replicable and comparable year to year in order to monitor bank stability and efficacy of shoreline erosion control and riparian buffer mitigation work. Surveys should be completed annually at a consistent water surface elevation and during leaf-off. The FRR should include sufficient data to identify the type and stages of erosion in the TFI, priority sites for stabilization and the types of nature-based solutions to be used to stabilize the banks and mitigate sedimentation of the river. If, after a period of time (no earlier than 15 years from the date of full toe protection of the shoreline), the Licensee is able to justify a reduced frequency of surveys, the Licensee shall continue to monitor once every 5 years. The FRR reports should present calculations on volume of bank material lost or gained within a statistically significant set of locations chosen by MassDEP, CRSEC, and a third-party reviewer.
- c. Photo-documentation. The licensee shall conduct photo surveys following an approved QAPP upon license issuance and every five years thereafter. The survey locations shall be the detail study sites from the relicensing studies 3.1.1 and 3.1.2. Photos shall include scales and reference points.
- (d) The Licensee will work with the Connecticut River Streambank Erosion Committee, town Historical Commissions, municipalities, indigenous groups, and MassAudubon to identify and implement riparian projects to reduce and mitigate project effects. Particular attention will be given to preserving farmland, infrastructure, and historical and cultural artifacts. Allowing some sites to erode will be an essential element to this work which will, among other things, provide habitat for bank-nesting birds. The FRR will identify these sites. The Licensee will be responsible for repair of sites stabilized under the previous license, if desired by the landowner or interested parties.

Condition FRCOG 4. Suspended Sediment Management during Maintenance Activities

To ensure that maintenance activities do not result in water quality violations, the licensee shall do the following:

- (a) FirstLight shall update their 2012 QAPP for Dewatering Events and every five years following.
- (b) Three months prior to the maintenance event, FirstLight shall send a letter to MassDEP, USEPA, and FERC describing the schedule for maintenance, the best management practices that are planned, the monitoring that will be done, and the disposal plan for dredged sediment.
- (c) Dewatering and dredging of the upper reservoir shall cause no water quality violations in the Connecticut River.

Condition FRCOG5. Barton Cove aquatic invasive species control

Upon license issuance, the licensee shall:

1. Continue to monitor and help remove all invasive aquatic plants in the TFI and canal system.
2. Staff or help fund staffing to reduce the spread of aquatic invasive plants through boats and fishing equipment in the TFI.

Documents to be submitted to MassDEP as part of FRCOG's comments

FRCOG is submitting the following documents to be part of the public record for MassDEP's preparation of a 401 Water Quality Certificate. They are listed oldest to most recent.

FirstLight Document	Description	Submission Date	Reason for Including
Full River Reconnaissance Quality Assurance Project Plan (QAPP)	CRSEC Comments on 2 nd Draft of QAPP	January 25, 2013	Represents FRCOG's concerns about the QAPP
Pre-Application Document (PAD)	FRCOG Comments on PAD and Study Requests	March 1, 2013	Represent FRCOG's study needs at the beginning of relicensing
	BSTEM-Dynamic User Manual	April, 2013	Cited in this FRCOG letter related to BSTEM modeling.
Revised Phase IV site list under the Erosion Control Plan	CRSEC Comments on bank stabilization projects under Phase IV	May 13, 2013	Represents FRCOG's concerns about the list of stabilization projects
Updated Proposed Study Plan (PSP)	FRCOG Comments on Updated PSP	July 15, 2013	Represent FRCOG's study needs at the beginning of relicensing
Revised Study Plan (RSP)	FRCOG Comments on RSP	August 28, 2013	Represent FRCOG's study needs at the beginning of relicensing
Study 3.1.1 Full River Reconnaissance	CRSEC Comments on Study Report	November 14, 2014	FRCOG's technical comments on the study report.

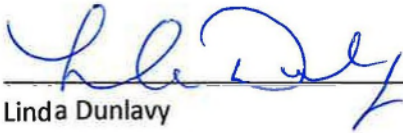
FirstLight Document	Description	Submission Date	Reason for Including
Study 3.1.2 Causation Study	CRSEC Comments on Interim Study Report	November 14, 2014	Technical comments on the study that is at the basis of FirstLight's proposal. Contains peer review of study plan by University of Illinois at Urbana-Champaign.
	CRSEC Request for Transect Report	January 9, 2015	Relates to 401 Application Section 5.5.1.
Study 3.1.1 Full River Reconnaissance	CRSEC Memo to John Howard re: FRR Prioritized Site List	March 3, 2015	FRCOG's concerns about the site list
	U.S. Army Corps HEC-RAS USDA-ARS Bank Stability & Toe Erosion Model (BSTEM) Technical Reference and User's Manual	March 2015	Referred to in this FRCOG comment letter, but is difficult to link to a website.
Study 3.1.1 Full River Reconnaissance Addendum	CRSEC Comments on FRR Addendum	April 2, 2015	FRCOG's technical comments on the addendum
Study 3.1.2 Causation Study	CRSEC Comments on Updated Study Report	November 10, 2015	Technical comments on the study that is at the basis of FirstLight's proposal
Study 3.1.2 Causation Study	FRCOG Comments on Final Study Report	December 15, 2016	Technical comments on the study that is at the basis of FirstLight's proposal
Study 3.1.2 Causation Study	Connecticut River Watershed Council's comments on Final Study Report	December 15, 2016	Technical comments on the study report. Contains Princeton Hydro peer review.
Amended Final License Application (AFLA) 2020 and FERC Ready for Environmental Analysis (2024)	FRCOG Motion to Intervene	April 16, 2024	History of FRCOG and CRSEC involvement; interests of FRCOG
Amended Final License Application (AFLA) 2020 and FERC Ready for Environmental Analysis (2024)	FRCOG Comments and Recommended Terms of the License	May 22, 2024	Technical comments on erosion concerns. Contains review by Dr. Evan Dethier

Conclusion

FRCOG urges MassDEP to address the water quality impairments in the Connecticut River upstream of the Turners Falls Dam. This section of river has undergone a large experiment for the last 50 years. The impacts have been significant, and this is the only opportunity to course correct and set appropriate conditions for the next 30-50 year.

Thank you for this opportunity to review and provide comments on this Notice. If you have any questions, please do not hesitate to contact myself (lindad@frcog.org) or Kimberly Noake MacPhee (kmacphee@frcog.org).

Sincerely,



Linda Dunlavy
Executive Director

Review of Erosion in the Turners Falls Impoundment

Prepared 19 May 2024 by Dr. Evan Dethier for the Connecticut River Conservancy and Franklin Regional Council of Governments

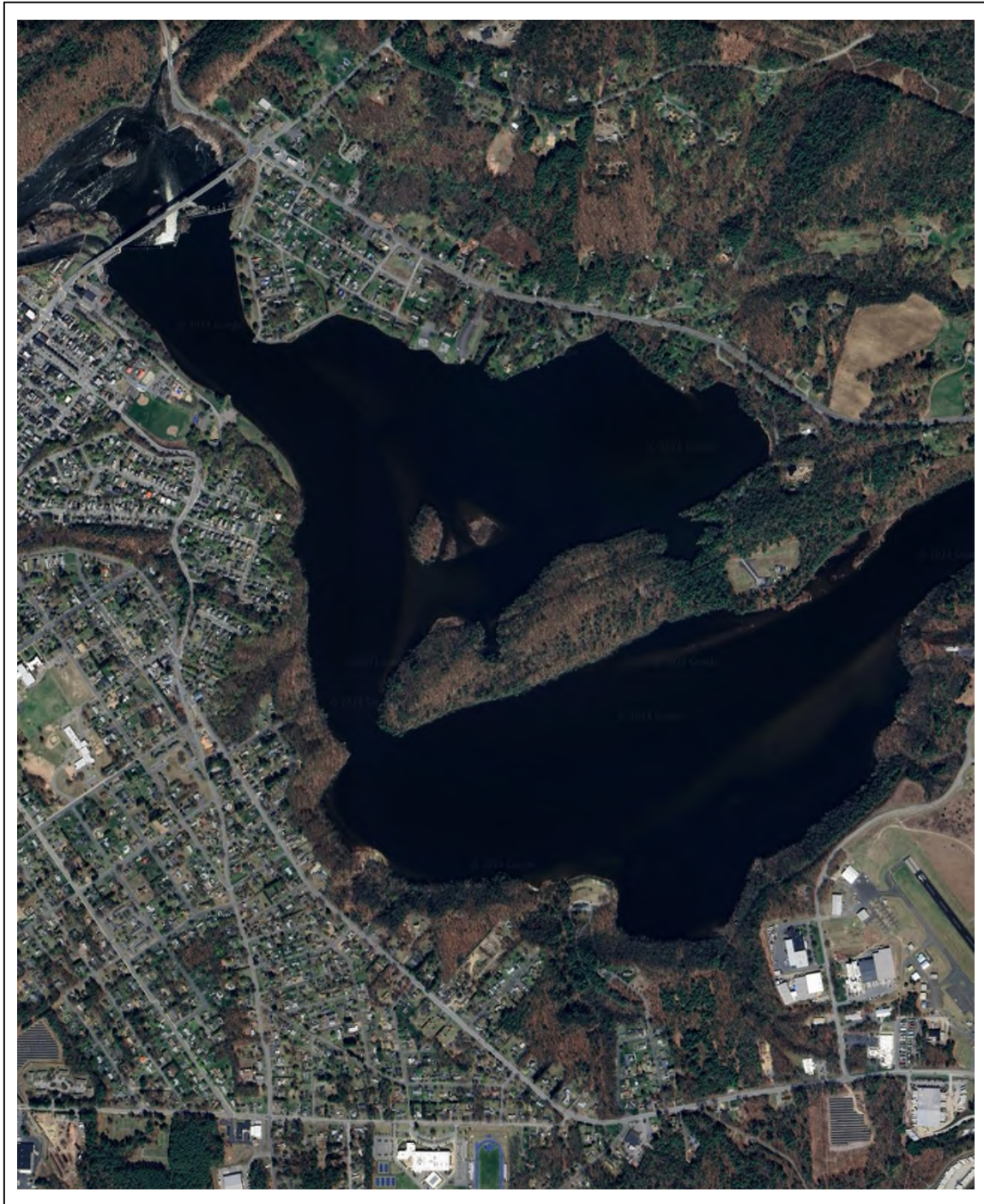


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Short Biography

Evan Dethier holds a Masters and PhD in Earth Science from Dartmouth College. He is an assistant professor of Geology at Colby College in Waterville, Maine. Evan is a fluvial geomorphologist who has studied erosion in New England rivers for the past decade. He uses field and remote-sensing methods to monitor and improve understanding of natural and anthropogenic disturbance to these rivers and those around the world, including by floods, landslides, mining, and dams.

Dr. Dethier's CV is attached at the end of this report for reference.

i. Executive Summary

Erosion in the Turners Falls Impoundment

There is substantial evidence of erosion in the Turners Falls Impoundment (TFI), much of it consistent with fluctuations in water level due to dam operations. Several reports and memos, including by the US Army Corps of Engineers, Field Geology Services, and Princeton Hydro, have already established that water level fluctuations in the TFI can, and likely do, enhance erosion in the reservoir.

Reports by FirstLight have repeatedly denied the connection between fluctuating water level and erosion. These denials defy direct observations, including those presented by FirstLight, showing the likely links between FirstLight operations and erosion in the TFI.

- Water fluctuations in the TFI result from a combination of natural flows, which are regulated to some extent by upstream dams, and approximately daily fluctuations that a) move water between the River as lower reservoir and Northfield Mountain's upper reservoir (pumping withdraws water from the river and generation returns water to the river) and b) regulate flow through the Turners Falls Dam and power canal for conventional hydropower. The combination of a) and b) are termed "Project operations" in this report.
- Erosion is clearly documented in both data and images produced by FirstLight.
- Erosion occurs with very few signs of deposition. In its pre-dam state much of the TFI may have been a net-depositional zone, given that the TFI is in a mostly alluvial reach of the Connecticut River, with limited bedrock, a well-developed floodplain, and decreasing stream power.
- River flows have rarely inundated floodplains since flood control dams were established in the mid-20th century, eliminating the possibility of replenishing overbank sediment.
- Observations and measurements included in the FirstLight Full River Reconnaissance and Erosion Causation Study point to numerous mechanisms that could enhance erosion in the TFI due to Project operations.
- FirstLight has not presented credible, reproducible evidence that their operations do not increase erosion in the TFI. Absent targeted mitigation, increase in the water-level range of typical Project operations may increase erosion in the impoundment.

Flaws in FirstLights Erosion Attribution Analyses

FirstLight's two relicensing studies, Study 3.1.1, the Full River Reconnaissance (FRR), and Study 3.1.2, Northfield Mountain/Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report (commonly called the Erosion Causation Study) have numerous methodological flaws and gaps in reporting. These studies document widespread erosion in the TFI, but downplay this erosion in the text and summaries. Other studies and reviews prepared by scientists, including the 2007 and 2013 reports by Field Geology Services

and the Princeton Hydro peer review, point out flaws in FirstLight’s analyses and highlight the likelihood that FirstLight operations contribute to erosion.

- FirstLight documents substantial evidence of erosion, even attributing some of it to changing water levels due to dam operations. However, this finding is discounted in their text, conclusions, and executive summary.
- There is no mention of the inability of vegetation to colonize lower banks because of water level fluctuations, leaving them prone to erosion.
- There is no mention of freeze-thaw effects causing erosion on unvegetated, steep banks created and maintained (in their unvegetated state) by frequent inundation and erosion. Freeze-thaw erosion does not require ice floes, which FirstLight does address, but can occur from frost wedging and liquefaction on steep banks. In addition, FirstLight’s dismissal of erosion by ice jams is not evidence-based.
- The BSTEM model used by the consultants was developed by them. The report has a lack of transparency in model inputs that makes it impossible to judge its appropriateness.
- The version of the BSTEM model used in the Erosion Causation Study is not publicly available and thus the results cannot be understood or replicated.
- Despite high-resolution cross sections available to the model, only a simple parameterization is used (as far as can be understood from the summary). Average slopes for upper and lower banks are used, potentially diminishing estimates of erosion except during floods.
- Groundwater saturation is integral to the model, but almost no data was collected to inform its parameterization.
- Root cohesion data was only collected for large trees. There is no information on grasses and smaller vegetation that does much of the work of bank stability and velocity reduction. Cohesion does not vary through the model run, despite likely lower cohesion during late winter and spring, when soils are saturated and vegetation has not taken root for the season.

Erosion along the banks of the Turners Falls Impoundment has been documented since the construction of the reservoir. A series of independent, expert scientists have attributed at least part of this erosion to Project operations, which raise and lower the water level in the TFI or Connecticut River, exposing different parts of the bank to erosion.

The results of expert analysis—that erosion in the Turners Falls Impoundment is increased by Project operations—conform with the general scientific consensus about shoreline erosion in human-controlled impoundments, particularly in those with fluctuating water levels.

1. Background

1.1 Summary

Erosion is a natural process along any shoreline. Human activities can accelerate erosion processes, causing erosion to occur in excess of natural rates or at different seasons than is normal. Because natural processes generally continue, at least to some extent, after human intervention, and natural and human processes interact with each other, quantifying the precise contribution of natural and human processes to erosion is a difficult task. Over the past several decades, various analyses have attempted to do so. However, as Field Geology Services noted in 2007 (working as a consultant for FirstLight's predecessor), accurately separating human and natural contributions to the erosion in the Turners Falls Impoundment is not possible without more detailed and accurate monitoring than has yet been undertaken¹. This remains true.

Monitoring recommended by Field Geology Services in 2007 and 2012 (working as a consultant to a landowner group), such as annual lidar surveys^{2,3}, would address inconsistencies and gaps in historical monitoring efforts, but have not yet been undertaken. Stymied by this lack of certainty, the Field Geology Services Report from 2007 detailed the many potential sources of human and natural erosion and the challenge of separating them, given the interconnected natural and human processes in the TFI⁴. In this report, I summarize peer-reviewed literature about the TFI and similar reservoirs, as well as non-peer-reviewed reports and observations. I also discuss shortcomings in FirstLight's recent analyses of erosion in the reservoir: Study 3.1.1 (the Full River Reconnaissance), Study 3.1.2 (aka the Erosion Causation Study), and several other FirstLight publications. This review should provide insight into the likely contribution of FirstLight operations to erosion on the TFI shorelines, while making clear that FirstLight claims that they are not contributing to erosion are much more certain than is scientifically supported.

1.2 Erosion on reservoir shorelines

1.2.1 Overview

For decades, the technical and scientific community has measured anomalous erosion on the banks of impounded reservoirs. Several studies have shown that erosion occurs or is increased due to reservoir construction and operation. Numerous scientists have found that such erosion can persist well into the lifespan of the dam.

¹ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. p. 42 ("Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.")

² Kaczmarek, H., Tyszkowski, S., Bartczak, A., Kramkowski, M., & Wasak, K. (2019). The role of freeze-thaw action in dam reservoir cliff degradation assessed by terrestrial laser scanning: A case study of Jezioro Reservoir (central Poland). *Science of the total environment*, 690, 1140-1150.

³ Field (Field Geology Services), 2012, Rebuttal of FirstLight's Response to Landowner Filing: Unpublished report prepared for Landowners and Concerned Citizens for License Compliance Turners Falls Pool, 12 p. p. 10 ("Given that both Landowners and Simons (2012) agree that the FRR methodology cannot be used to make comparisons of erosion from year to year, FERC should insist that FirstLight and its agents make no further representations that the 2008 FRR demonstrates a decline in erosion levels between 2004 and 2008. Since FirstLight (2012) makes clear that the objective of the 2013 FRR is, in part, to "analyze any change in the condition of the riverbank since the last FRR" (FirstLight, 2012, Appendix 1, p. 2), FERC should further insist that future FRRs be designed in a manner that allows for detailed site-by-site comparisons from year to year.")

⁴ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. p. 42 ("Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.")

The Turners Falls Impoundment is relatively long and narrow, resembling both a river and a typical ponded reservoir. Nonetheless, it does not appear to be an exception to this general pattern of increased erosion, because it experiences many of the same processes that enhance erosion in wider reservoirs. Indeed, its non-cohesive sediment banks, location in a freeze/thaw climate, and fluctuations from pump-storage operations increase its likelihood of increased erosion due to Project operations.

1.2.2 Why is there erosion along reservoir shorelines?

The area along a reservoir shoreline that is exposed to changing water level has been termed the “reservoir disturbance zone” due to “the cyclic submergence and exposure caused by the reservoir operation”⁵. Prior to reservoir construction, these elevations usually remain well above the high-water line. They would generally be inundated only during floods, if at all. After the reservoir is completed, frequent water inundation occurs in the reservoir disturbance zone, between the base and peak of normal dam operations. This inundation in the reservoir disturbance zone disrupts soils, vegetation, and fauna. In many cases, these disruptions contribute to erosion⁶.

A US Army Corps of Engineers review of ten reservoirs found wind-wave erosion, groundwater-induced sliding, freeze-thaw effects, and landsliding to be the dominant processes after the period of initial reservoir filling⁷. Each of these processes occurs in the reservoir disturbance zone and is caused or accentuated by the inundation of shoreline sediments. Consistent or intense wave action from wind and waves⁸ subjects the previously high-and-dry banks to the erosive action of water, leading to sediment removal. Flooding can increase flow velocity and increase erosion. In some cases, previous erosion at the “toe” (base) of steep banks can undercut the bank slope or soil saturation can reduce soil strength during to high-water fluctuations. These events can lead to mass sediment failure farther up the bank and above the disturbance zone⁹, as has been found in the Wilder Dam reservoir farther upstream on the Connecticut River¹⁰.

⁵ Bao, Y., Gao, P., & He, X. (2015). The water-level fluctuation zone of Three Gorges Reservoir—A unique geomorphological unit. *Earth-Science Reviews*, 150, 14-24. p. 15.

⁶ Bao, Y., He, X., Wen, A., Gao, P., Tang, Q., Yan, D., & Long, Y. (2018). Dynamic changes of soil erosion in a typical disturbance zone of China's Three Gorges Reservoir. *Catena*, 169, 128-139. p. 136 (“Influenced by this new hydrological regime, the abundance of the original plant species within the [Disturbance Zone] has been drastically reduced”).

⁷ Gatto, L. W., & Doe III, W. W. (1987). Bank conditions and erosion along selected reservoirs. *Environmental Geology and Water Sciences*, 9(3), 143-154. p. 143 “However, freezing can disrupt soil structure and draw pore water to the freezing zone, which may make bank sediment more susceptible to erosion after thaw.”

⁸ Vilmundardóttir, O. K., Magnússon, B., Gísladóttir, G., & Thorsteinsson, T. (2010). Shoreline erosion and aeolian deposition along a recently formed hydro-electric reservoir, Blöndulón, Iceland. *Geomorphology*, 114(4), 542-555. p. 550 (“After the formation of the Blöndulón Reservoir the most rapid initial erosion rate occurred on bluffs on the northern and western shores, comprising about one third of the shoreline of the reservoir, where the available wave energy was high. This is evident from the high cumulative wave power at those sites due to the long fetch towards the south and east and frequent south to south-easterly storms occurring during high water levels.”)

⁹ Kaczmarek, H., Mazaeva, O. A., Kozyreva, E. A., Babicheva, V. A., Tyszkowski, S., Rybchenko, A. A., ... & Słowiński, M. (2016). Impact of large water level fluctuations on geomorphological processes and their interactions in the shore zone of a dam reservoir. *Journal of Great Lakes Research*, 42(5), 926-941. p. 933 (“Landslide activation took place in 2004, 2006, and 2009, in periods of high water level in the reservoir, reaching 400 m a. s. l. or more”).

¹⁰ https://www.lymenh.gov/sites/g/files/vyhlf4636f/uploads/lyme_hmp_finalforadopt_apr3_17.pdf

Inundation also increases the susceptibility of the reservoir banks to erosion. Devegetation due to inundation and erosion¹¹ reduces bank sediment cohesion, especially in silty and sandy soils like those present in the TFI¹², leading to easier removal by reservoir waters. Freeze-thaw erosive processes can physically separate blocks of soil from the bank¹³. Increased water saturation due to reservoir inundation can enhance these processes. Each of these erosion-increasing processes occurs in the Turners Falls Impoundment.

1.2.3 Where does erosion occur in reservoirs?

Despite investigating 32 causes of erosion in reservoirs, the US Army Corps of Engineers study makes virtually no mention of river flooding as an important factor¹⁴, nor do most of the other peer reviewed studies of reservoir erosion. Instead they find the importance of water fluctuations, combined with processes that occur consistently at the reservoir shoreline, facilitated by inundation and wave action¹⁵. The riverine geometry and flow characteristics of the TFI, especially its upper reaches, makes it susceptible to erosion by flooding, which is most likely a cause and perpetuator of erosion along the shoreline¹⁶. However, as these studies show, many processes contribute to erosion in a reservoir, and rarely can erosion be distilled to a single cause.

Which of the above processes is dominant in a given reservoir depends on the make-up, orientation, and slope of the reservoir banks, slope and vegetation, dam operations, the prevailing hydrology and climatology, and reservoir activity¹⁷. The primary cause of erosion may vary within a reservoir due to variations in current, exposure, or bank material. However, in each case erosion mostly occurs in the reservoir disturbance zone, which is largely determined by the dam or project operations^{18,19}.

In a given moment, erosion primarily occurs within a few vertical meters of the waterline²⁰, usually when waves or currents transport sediment away from banks^{21,22}. Because reservoir levels change with seasons, natural floods, and dam operations, the erosion band moves up and

¹¹ Bao, Y. et al. (2018). p. 136 (“Influenced by this new hydrological regime, the abundance of the original plant species within the [Disturbance Zone] has been drastically reduced”); Fig. 7.

¹² Kaczmarek et al. (2016) p. 927 (“Depending on rock resistance, the mean width of eroded shore varies from 80 m in sandstones to 140–200 m in silty deposits”)

¹³ Gatto, L. W., & Doe III, W. W. (1987). Bank conditions and erosion along selected reservoirs. *Environmental Geology and Water Sciences*, 9(3), 143-154. p. 143 “However, freezing can disrupt soil structure and draw pore water to the freezing zone, which may make bank sediment more susceptible to erosion after thaw.”

¹⁴ *Id.* at p. 147 Table 2 (“Summary of historical recession”).

¹⁵ Vilmundardóttir et al. (2010) p. 554 (“Bluff erosion and aeolian reworking of sediments at the Blöndulón Reservoir are closely linked to water level fluctuations.”)

¹⁶ U.S. Army Corps of Engineers, 1979, Report on Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire and Vermont: Department of the Army New England Division Corps of Engineers: Waltham, MA, 185 p.

¹⁷ Gatto and Doe III (1987) p. 143 (“The importance of a process or a set of processes or factors will vary at different sites and different times”).

¹⁸ Bao, Y. et al.(2018). p. 135 (“the fluctuation pattern of soil erosion rates in the DZ was consistent with that of the specific water level residence time. The residence times around the minimum and maximum levels were significantly longer than those at the other levels.”)

¹⁹ Newbury, R. W., & McCullough, G. K. (1984). Shoreline erosion and restabilization in the Southern Indian Lake reservoir. *Canadian Journal of Fisheries and Aquatic Sciences*, 41(4), 558-566. p. 561 (“melting occurs below and slightly above the water surface.”)

Gatto and Doe III (1987) p. 143 (“The importance of a process or a set of processes or factors will vary at different sites and different times”). p. 152 (“much of the bank erosion along most of the” reservoirs is caused by water action at the bank toe”)

²¹ Bao, Y. et al.(2018). p. 128.

²² Vilmundardóttir et al. (2010) p. 552 Fig. 11.

down throughout the year. The wider the band of water-level variation, the more area that is subject to inundation, scour, devegetation, and thus erosion, and the wider the reservoir disturbance zone.

The physical properties of the reservoir bank sediments are another important control on their erodibility. Where banks are comprised of sandy or silty sediments, they are less likely to be stable than banks made of coarser material or bedrock. Several studies of reservoir erosion have found that, within a reservoir, bank sediment is the most important spatial control on erosion rate. Where sediments are sandy or silty, similar to those in the TFI^{23,24}, banks are most susceptible to erosion during reservoir water fluctuations since they “lack cohesion and grains of boulder and cobble size”²⁵.

High slopes at or near the waterline are correlated with higher erosion rates²⁶. Although some studies have found elevated erosion even at low slope²⁷, in general steep banks like those found in glacial and floodplain sediments along much of the TFI are thought to be most susceptible to water-fluctuation erosion (and erosion in general).

Project operations in the TFI frequently raise and lower the water level. Thus, the local area of possible erosion is a dynamically changing band that spans normal pump-storage operations and moves up and down with natural variations in river flow (Figure 1). As opposed to other reservoirs where fluctuations might occur on a seasonal basis and/or with occasional flood events, fluctuations in the TFI occur daily or even multiple times in a day. Rapid erosion throughout the reservoir has occurred in and above this erosion band. FirstLight itself has documented this erosion, including wave-cut banks and bars, bank undercutting and failure, bank retreat, and rotational landslides and slumps²⁸. Erosion has encroached on land surrounding the reservoir, removing soil and acreage and threatening roads and infrastructure.

²³ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. p. 50 (“Most of the riverbank sediments in the Turners Falls Pool are naturally susceptible to erosion given their noncohesiveness and fine-grained texture”)

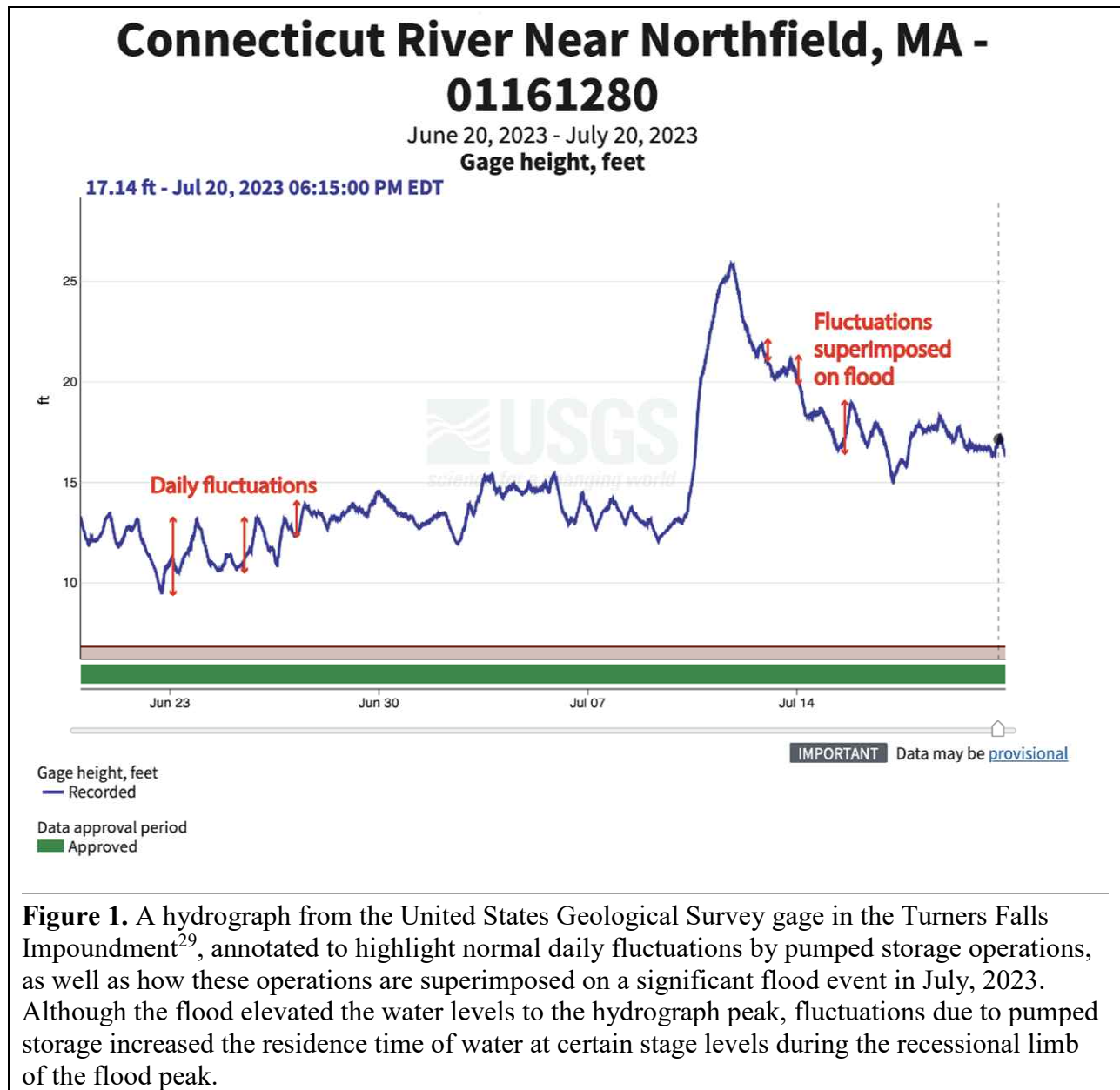
²⁴ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Table 4.2.6.3-4: Particle-size Data of the Bank Materials along the Turners Falls Impoundment

²⁵ Vilmundardóttir et al. (2010) p. 552 (“The current erosion rate is due to loose fluvioglacial substrate material; the texture of the fluvioglacial sediments did not create stable bluffs since it lacked cohesion and grains of boulder and cobble size. We suggest that the nature of the substrate material is the most important environmental factor affecting the development of bluffs towards equilibrium.”).

²⁶ Bao, Y. et al. (2018). p. 136 (“that the soil erosion rate was positively correlated with the slope gradient”); Fig. 6.

²⁷ Vilmundardóttir et al. (2010)

²⁸ FirstLight Relicensing Study 3.1.2 2017 Erosion Causation, Appendix M – 2013 Full River Reconnaissance Riverbank Segments With Causes Of Erosion



1.2.4 Are there close analogues for the Turners Falls Impoundment?

As discussed above, the Turners Falls Impoundment is a narrow, riverine reservoir, especially in its upper reaches. Thus, it is somewhat different from many of the reservoirs that have been studied for erosion, which tend to be broader. River currents are likely higher, especially in the upper sections of the reservoir, than is typical in large, ponded reservoirs.

Nonetheless, it is a reservoir with sub-daily water-level fluctuations, and with banks that are steep, sandy and silty. Reservoirs with these characteristics are highly prone to erosion from

²⁹ <https://waterdata.usgs.gov/monitoring-location/01161280/#parameterCode=00065&period=P7D&showMedian=false>

water fluctuations.³⁰ Its lower section near Bartons Cove, also much more resembles a ponded reservoir, with a maximum width of more than 4,000 feet. Flow velocities there must thus be much lower, even during floods. Despite the lower flow velocities, this section of the reservoir generally experiences comparable erosion rates to the upstream reaches³¹, suggesting that water fluctuations may play a larger role in erosion.

In Quebec, erosion rates of 10–30 meters over 20 years were found in similar sediments to those at TFI³². The erosion processes are very similar to those in the Turners Falls Impoundment, consistent with understand of geomorphology along sandy shorelines. They are described by Saint-Laurent et al., 2001:

“The mechanism of bank recession is ruled by shore dynamics and slope rheology (Whalen et al. 1995). The breaking waves dissipate energy and disperse weathering fine particles such as sand and silt towards deep water. The shore is thus depleted and further exposes the foot of the slope to the action of the waves. The sapping of the waves at the foot of the slope progressively removes material at the base until the breakpoint of the slope. The debris join the bottom part of the shore and form a sort of rampart against the effect of the waves. The erosion process thus continues and starts up again year after year (mobilization of shore material by the waves, sapping, and collapse, etc.).” (p. 491)

Photographs and descriptions from Saint-Laurent et al. document similar landforms and erosional features as are present in the TFI (Figure 2), suggesting similar and/or identical processes are at work in the TFI. Saint-Laurent et al., 2001 noted that fluctuations accentuated this erosion: “the equilibrium obtained at a relatively constant level is somehow lost with fluctuations in reservoir water levels.”

³⁰ *e.g.*, Saint-Laurent, D., Touileb, B. N., Saucet, J. P., Whalen, A., Gagnon, B., & Nzakimuena, T. (2001). Effects of simulated water level management on shore erosion rates. Case study: Baskatong Reservoir, Québec, Canada. *Canadian Journal of Civil Engineering*, 28(3), 482–495. p. 490 (“Proglacial sandy deposits, such as those observed around the Bras Nord and Du Diable Bay, are particularly prone to erosion, especially when exposed to wave action.”).

³¹ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. Table 5; Table 6.

³² *Id.* at p. 492 (“Windigo Bay (20–30 m over 20 years) and Du Diable Bay (10–15 m over 20 years)”)



Figure 2. Figure 6a. from Saint-Laurent et al., 2001 shows a shoreline bank failure that strongly resembles failures along the TFI shorelines.

In a study in Poland, silty glacial sediments similar to those at the TFI experienced 1.4–3 m of erosion per year³³. Another reservoir in Iceland with glacial sediments along its shoreline experienced erosion along its banks of 0–1.7 m per year³⁴. Erosion in the TFI is similar to these rates for some banks, with bank losses of >1 ft/yr at some cross sections³⁵.

The primary mechanism for erosion in each of these reservoirs is likely wave or frost action, as opposed to in the Turners Falls Impoundment, where it may be flood flows. Yet where the erosion occurs and, at least to some degree how much erosion occurs, is set by the reservoir water level. Erosion is highest in the reservoir disturbance zone, where the banks are subject to wave action, inundated or saturated, devegetated; because the reservoir exists, erosion likely occurs at higher rates than if it did not.

³³ Kaczmarek et al. (2016) p. 930 (“The rate of bluff recession was the highest in the initial period of reservoir use: on average 3 m/year in 1969–1980, compared to 1.4 m/year in 1980–2013.”)

³⁴ Vilmundardóttir et al. (2010) p. 547 (“The bluff retreat measured 1.3 m in 1997, while no erosion was measured in 1998 and 1999 (Table 3) when the water level was low and did not reach overflow level (Fig. 3). Erosion of 0.4 m was measured in 2000 but in 2001 again there was no erosion measured. The most rapid erosion period occurred in 2002 when the bluff receded 1.7 m. Since 2003 the erosion rate has greatly decreased to < 0.2 m yr⁻¹.”)

³⁵ Field (Field Geology Services), 2007, Fluvial geomorphology study of the Turners Falls Pool on the Connecticut River between Turners Falls, MA and Vernon, VT: Unpublished report prepared for Northfield Mountain Pumped Storage Project, 131 p. Table 5; Table 6.

1.2.5 Will erosion naturally slow in the TFI, or has it already?

The Turners Falls Impoundment is an old reservoir, with operations at the present levels initiated in 1970 (the dam was raised first, before Project operations began in 1972). Reservoir shoreline erosion documented in some studies is rapid after initial inundation, then dramatically slows as erodible material is removed. Given the rapid initial erosion in the TFI after reservoir levels were raised in 1970 and the possible slowdown in the 1990s and early 2000s³⁶, it is reasonable to wonder whether this initial adjustment period has ended and erosion is no longer an issue. However, cessation of shoreline erosion principally occurs when shorelines are eroded to bedrock³⁷ or beaches can be established³⁸, protecting against wave action and inundation³⁹. Once easily eroded sediments are removed or protected, erosion rates plummet. However, these conditions are generally not present in the TFI. There is limited bedrock that might stabilize the channel, and beaches that might provide a buffer against bank erosion may be destroyed by high flows, limiting bank protection⁴⁰ (see below, Figures 6–8).

Reservoirs like the TFI, with shorelines primarily comprised of unconsolidated sediments, tend to maintain higher erosion rates for the reservoir lifespan⁴¹. Although some slowing usually occurs, as may be the case in the TFI, its sandy and silty banks and general lack of bedrock shoreline means that erosion can essentially continue unchecked⁴². This is particularly true if water level fluctuations remain the same or are increased.⁴³ In the TFI, if Project operations use a wider range than has been typical during the past 50 years, it is possible that a new wave of erosion will occur, as slopes on the upper bank are inundated for longer periods of the year⁴⁴, similar to the initial cycle of erosion that occurred when the reservoir levels were raised in the 1970s.

1.3 Past studies of erosion in the Turners Falls Impoundment

While the existing peer-reviewed literature on reservoir erosion clearly shows that water level fluctuations can cause or contribute to erosion, there is also a decades-long history of studies making a similar conclusion for the TFI specifically. In 1979 and 1991, the US Army Corps of

³⁶ Field (2007). p. 27 (“South of the Massachusetts state line, the data reveal an 18 percent increase in the amount of mapped erosion between 1978 and 1990, a 6 percent decline between 1990 and 2001, and a 3 percent decline between 2001 and 2004”); Figure 28a.

³⁷ Newbury, R. W., & McCullough, G. K. (1984). Shoreline erosion and restabilization in the Southern Indian Lake reservoir. *Canadian Journal of Fisheries and Aquatic Sciences*, 41(4), 558-566. p. 561 (“If bedrock is encountered at the eroding face, erosion at the water level ceases. In the wave-washed zone overlying the bedrock, erosion continues until a bedrock backshore zone is exposed up to the maximum wave upwash elevation.”).

³⁸ Field (2007)

³⁹ Vilmundardóttir et al. (2010)

⁴⁰ Field (2007). p. 43 (“The presence of higher beach deposits preserved at the base of the bank, particularly in protected areas, suggest prior beaches have been removed by scour”)

⁴¹ *Id.* at p. 551 (“Despite the low energy at the south-east shore (R13 and R15) the erosive substrate has prevented the shore from reaching even close to equilibrium.”).

⁴² Kaczmarek et al. (2016) p. 940 (“Although the reservoir has been operated for several dozen years, the activity of geomorphological processes in its shore zone, initiated or intensified by its creation, is still high.”); p. 940 (“Their activity has not decreased after several decades and the affected area is often gradually extended.”).

⁴³ *Id.* at p. 940 (“The course of geomorphological evolution is closely linked to large water level fluctuations. The intensity of their development is characterized by remarkable variation between years and within years, conditioned by high water level fluctuations... In periods of high water levels, which reach the base of the bluff, as a result of subaqueous coastal processes result and intensive bluff recession is observed.”).

⁴⁴ Bao, Y. et al. (2018). p. 135 (“the fluctuation pattern of soil erosion rates in the DZ was consistent with that of the specific water level residence time. The residence times around the minimum and maximum levels were significantly longer than those at the other levels.”)

Engineers identified flooding, seepage, project-caused water fluctuations, and boat wakes as possible causes of erosion^{45,46}. In 2007, Field Geology Services was hired by FirstLight to study erosion in the reservoir, and provided the most comprehensive summary of erosional processes in the TFI. They found that a combination of erosional processes, contingent on one another, most likely collectively cause erosion in the reservoir⁴⁷.

The 2007 Field Geology Services report, summarizing likely erosion processes occurring in the TFI, included natural erosion processes that may occur regardless of Project operations, including flood flows, undercutting and seepage, boat waves, freeze-thaw processes, and landsliding and slumping. However, it also discusses how pool fluctuations due to Project operations likely cause erosion themselves while also potentially initiating or perpetuating the “erosion sequence”. Field Geology Services added that “erosion is likely to persist as flood flows rework beach deposits and inundate the beach face, enabling boat waves, *pool fluctuations*, and natural river currents to remain active at the base of the banks” (emphasis added).

Since then, in FirstLight’s Full River Reconnaissance in 2008, Full River Reconnaissance in 2013, the Erosion Causation Study in 2017, and several other documents and rebuttals, FirstLight has scrupulously denied taking responsibility for almost any erosion in the reservoir, despite repeated reports and letters by independent scientists and community groups. Field Geology Services, who was considered a sufficiently reputable scientist to be hired by FirstLight in 2007, summarized this avoidance of responsibility and deflection in their 2012 critique of FirstLight’s approach⁴⁸:

“However, as detailed below, the supporting evidence for making such a strong charge is found wanting in accuracy, relevance, and evenhandedness in application. Simons (2012) uses six oft-repeated strategies to give the appearance of refuting Field’s (2011) claims without providing sufficiently compelling evidence to do so: 1) providing information that in fact contradicts the assertion being made, 2) presenting information that is inaccurate, misleading, or misrepresents the work of others, 3) presenting information that is factually correct but irrelevant in regards to changing erosion levels in the Pool, 4) presenting information that is not readily verifiable, 5) presenting new information that further calls into question findings of the 2008 [Full River Reconnaissance (FRR)], and 6) making assertions that if applied evenly would discredit Simons’ (2009) conclusion that erosion levels decreased between the 2004 FRR and 2008 FRR.” (p. 5)

These are strong rebukes from a respected scientist, and call into question the claims made by FirstLight. Nonetheless, in subsequent reports, FirstLight has persisted in this pattern of denial, rejecting even the possibility that Project operations are meaningfully contributing to erosion in the TFI.

The erosion sequence as proposed by Field (2007) (similar to the stages of erosion discussed in this report), describes processes and feedbacks potentially caused by Project operations that

⁴⁵ U.S. Army Corps of Engineers, 1979, Report on Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire and Vermont: Department of the Army New England Division Corps of Engineers: Waltham, MA, 185 p.

⁴⁶ Field (2007)

⁴⁷ *Id.* at p. 42 (“Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.”)

⁴⁸ Field (2012)

accentuate natural erosion processes and perpetuate a cycle of erosion in the reservoir⁴⁹. The original Field Geology Services report is still valid, and the processes it details refute the FirstLight claim that erosion cannot be attributed to Project operations. Field Geology Services provides numerous illustrations and photographs showing erosional landforms that could be caused or accentuated by Project operations (e.g., Figure 3, 4). In their reports, FirstLight provides many images showing the same erosional features, yet denies that Project operations could contribute to their formation.



Figure 8: a) Active beach face and b) remnants of a higher beach.

Figure 3. Figure 8 from Field Geology Services’ 2007 Fluvial Geomorphology Study of Connecticut River⁵⁰ shows erosion that is consistent with changing water levels forming and eroding beaches along a sandy bank of the TFI. Each “step” in the beach is consistent with water levels being at that height, possibly due to water level fluctuations, with wave-cut faces and ripples showing evidence of sediment transport away from each face.

⁴⁹ *Id.* at p. 42 (“boat waves and pool fluctuations play a role in the creation of undercuts that begin the erosion sequence”)

⁵⁰ Field (2007)



Figure 43: Seepage channels forming across a beach face.

Figure 4. Figure 43 from Field Geology Services’s 2007 Fluvial Geomorphology Study of Connecticut River⁵¹ shows erosion that is consistent with changing water levels forming and eroding beaches along a sandy bank of the TFI. In this case, Field Geology Service identified seepage channels, clearly transporting sediment away from the beach. FirstLight has denied the importance of this process and not included it in BSTEM modeling. However, its documentation has not been thorough in the reservoir.

Despite the well-reasoned and reasonable conclusions by these scientists, FirstLight has consistently contradicted independent, expert conclusions and does not acknowledge that dam operations most likely contribute to erosion in the reservoir. Instead, FirstLight has repeatedly attributed erosion to other factors and downplayed the amount of erosion occurring.

Most recently, the Erosion Causation Study is the latest report by FirstLight that selectively interprets or overinterprets results that downplay erosion in the TFI in general, and erosion attributable to Project operations specifically. FirstLight has used a proprietary software to claim that erosion is primarily due to natural flood flows through the reservoir. This computer software, BSTEM, attempts to model the erosion conditions in the reservoir. Although modeling of such dynamic systems is well known to be highly uncertain, particularly absent rigorous site-specific calibration and testing⁵², FirstLight claims a certainty from the model that is not

⁵¹ Field (2007)

⁵² Klavon, K., Fox, G., Guertault, L., Langendoen, E., Enlow, H., Miller, R., & Khanal, A. (2017). Evaluating a process-based model for use in streambank stabilization: insights on the Bank Stability and Toe Erosion Model (BSTEM). *Earth Surface*

credible. There are large uncertainties in its inputs and many “dial settings” that allow the model to be adjusted to achieve a range of results. The results do not sufficiently rule out the possibility of erosion due to water level fluctuations, which has been raised by many scientists, documented by landowners⁵³, and is supported by field observations from decades of monitoring in the reservoir.

More recently, Princeton Hydro⁵⁴ provided a systematic critique of the FirstLight Erosion Causation Study, particularly its reliance on BSTEM, which FirstLight has used to deny responsibility of erosion. The parameterization of BSTEM, and thus its results, has been similarly critiqued by an independent scientist for the US Department of Agriculture⁵⁵ and several peer-reviewed scientific papers, summarized by Klavon (2017)⁵⁶. Each of these independent experts find serious problems with the methods and results produced by BSTEM, which calls into question any interpretations by FirstLight.

1.4 Report objectives

In the remainder of this report, I summarize the ongoing erosion that is likely at least partly attributable to Project operations in the Turners Falls Impoundment (section 1). Much of this erosion analysis builds on past work by scientific experts and peer-reviewed literature about reservoir shoreline erosion. It also relies heavily on observations made by FirstLight and its consultants. For decades, scientists have presented such evidence, showing that FirstLight operations are most likely contributing to excess erosion in the TFI while acknowledging that the complexities in the reservoir prevent detailed, specific attribution to FirstLight, recreational, and natural process.

In contrast, FirstLight and its consultants have claimed to be *certain* that Project operations are not meaningfully contributing to erosion in the TFI. As a result, in Section 3 I also address the failings of the BSTEM model, which FirstLight claims shows they are not the “dominant, primary cause of erosion”⁵⁷ anywhere in the impoundment and only a “contributing cause of erosion” along 1.5 miles of shoreline (out of 44 miles)⁵⁸. Absent accurate, repeatable *documentation* of the erosional processes they favor, this modeling is not credible.

Processes and Landforms, 42(1), 191-213. p. 191 (“The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.”)

⁵³ Landowners and Concerned Citizens for License Compliance Connecticut River, Turners Falls Pool, Massachusetts. August 2nd, 2012.

⁵⁴ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

⁵⁵ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p.

⁵⁶ Klavon, K., Fox, G., Guertault, L., Langendoen, E., Enlow, H., Miller, R., & Khanal, A. (2017). Evaluating a process-based model for use in streambank stabilization: insights on the Bank Stability and Toe Erosion Model (BSTEM). *Earth Surface Processes and Landforms*, 42(1), 191-213. p. 191 (“The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.”)

⁵⁷ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume I – Executive Summary and Summary. p. vii.

⁵⁸ *Id.* p. viii

2. Evidence of erosion in the Turners Falls Impoundment

2.1 Summary

Evidence from the Turners Falls Impoundment (TFI) indicates that FirstLight operations likely contribute to erosion in the TFI. Project operations set the likely height of erosional impacts, contribute to processes that directly cause erosion on banks in the impoundment, and most likely prevent natural recovery and re-stabilization from occurring.

This evidence, summarized both here and in past studies^{59,60}, consistently points toward FirstLight operations contributing to anomalously high erosion rates throughout the impoundment. These erosional processes occur in five primary ways, which are all interrelated and very likely attributable to FirstLight operations, as supported by direct observations in the TFI, past reports from various stakeholders, and decades of peer-reviewed research on erosion.

One note: these erosion mechanisms resemble closely the proposed ‘sequence of erosion’ proposed by Field (2007)⁶¹. They align with clearly established geomorphic processes on shorelines, specifically of reservoirs with fluctuating water levels.

2.1.1 Overview of likely erosion mechanisms or “sequence of erosion” in the Turners Falls Impoundment

1. Operations of the TFI reservoir (pumped storage and conventional hydro) cause water level in the impoundment to be repeatedly raised and lowered. Water levels are also subject to natural variability and upstream projects, including Vernon Dam immediately upstream. The year-round undercutting of the bank from sub-daily river fluctuations may decrease upper slope stability. Trees are undermined throughout the reservoir, indicating further reduced stability in a feedback loop.
2. Vegetation likely cannot colonize because of repeated inundation by fluctuating water in the impoundment during the growing season.
3. Daily FirstLight fluctuations likely saturate banks and toe slopes, reducing internal strength and accelerating erosion.
4. Moderate and flood flows transport eroded sediment away from toeslopes and bars, destroying beaches that might stabilize bank erosion.
5. Overbank and bank deposition is limited, so net change *on both banks* is erosional. In a river in equilibrium, erosion occurs but is approximately balanced by deposition on the opposite bank. In the TFI, upstream flood control and sediment trapping (not by FirstLight), sediment settling in the reservoir, and loss of vegetation due to FirstLight operations likely limit such balancing deposition.

Each of these erosion mechanisms is likely directly caused or accentuated by FirstLight operations. There is no doubt that flood flows contribute to erosion in the Turners Falls Impoundment, as they do in all natural rivers. However, FirstLight operations likely also

⁵⁹ Field (2007)

⁶⁰ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

⁶¹ Field (2007) p. 11 (“FRR methodology cannot be used to make comparisons of erosion from year to year”)

contribute to erosion and allow flood flows to be more erosional than they would be in a natural river.

Rather than taking steps to mitigate ongoing erosion in the TFI, FirstLight claims that it will continue similar fluctuation of water levels and has left open the possibility of increasing fluctuations.

FirstLight justifies this potential change by claiming⁶²:

“FirstLight’s proposed changes in operations under the Agreement do not change the basic finding that FirstLight’s operations are an insignificant cause of bank erosion in the TFI. Because FirstLight’s operations under the Agreement will not be a significant cause of erosion, it is not within FirstLight’s control to prevent it; and neither should FirstLight be responsible for remediating it.” (p. 14)

The magnitude of erosion attributable FirstLight operations (“significant” vs. “insignificant”) cannot be credibly quantified due to the lack of rigor in FirstLight monitoring^{63,64,65} and unacknowledged uncertainties in the BSTEM model approach⁶⁶. However, FirstLight studies *do* document numerous field instances of bank erosion that is likely ongoing due to, and/or accentuated by, FirstLight operations. Much of the erosion documented in each study commissioned by FirstLight is consistent with regular, repeated cycles of inundation and exposure of river bars and banks that occurs at least partly as a result of Project operations. An increase in the frequent range of this inundation would likely increase erosion in the TFI. FirstLight’s arguments that it will not shows an unscientific and unsupported degree of certainty about uncertain processes, while also defying evidence in its own reports and decades of geomorphology and reservoir study.

Below, each point is explained and evidence for project operation contribution to these erosional processes is presented. In each case, the findings show that the BSTEM model is not modeling the full suite of erosional processes occurring in the Turners Falls Impoundment. The BSTEM model and FirstLight reports consistently discount or ignore erosional processes that can be attributed to FirstLight operations. BSTEM is not adequately capturing erosion processes in the TFI, nor is uncertainty reported in its presentation; accordingly, its results cannot be treated as definitive.

Several scientists have described these erosion processes and demonstrated critical failings in scientific methods and inference made by FirstLight consultants, including the most recent

⁶² Response of Firstlight MA Hydro LLC And Northfield Mountain LLC to Comments on Flows and Fish Passage Settlement Agreement. June 12, 2023. 49 p. p. 14.

⁶³ Field (2007) p. 7 (“Many areas of additional study are necessary including surveys of erosion using a systematic and explicit method for mapping the types of erosion present in order to eliminate artifacts in the mapping process.”)

⁶⁴ Field (2012) p. 11 (“FRR methodology cannot be used to make comparisons of erosion from year to year”)

⁶⁵ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. p. 5 (“Large Portions of the Turners Falls Impoundment Remain Unassessed”)

⁶⁶ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

BSTEM Model. These include two reviews since 2010^{67,68}, which are both rigorous and document failings in erosion attribution by FirstLight.

2.2 Repeated undercutting of the bank decreases upper slope stability. Trees are undermined, further reducing stability in a feedback loop

FirstLight claims several times that the upper slopes of river banks are not wetted by their operations, and only experience erosional flows during floods. However, it is clear from FirstLight's reports that Project operations regularly inundate steep banks along the TFI reservoir shoreline. Plots of water surface elevation show as much as 6 ft of daily water surface elevation changes during just one example period⁶⁹. In addition, pumping and release occurs during high-flow events. Fluctuations are thus superimposed on larger fluctuations in the hydrograph, potentially amplifying the erosional effects of those events (Figure 1, Figure 5).

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)
STUDY 3.1.2 NORTHFIELD MOUNTAIN / TURNERS FALLS OPERATIONS IMPACTS ON EXISTING EROSION AND POTENTIAL BANK INSTABILITY

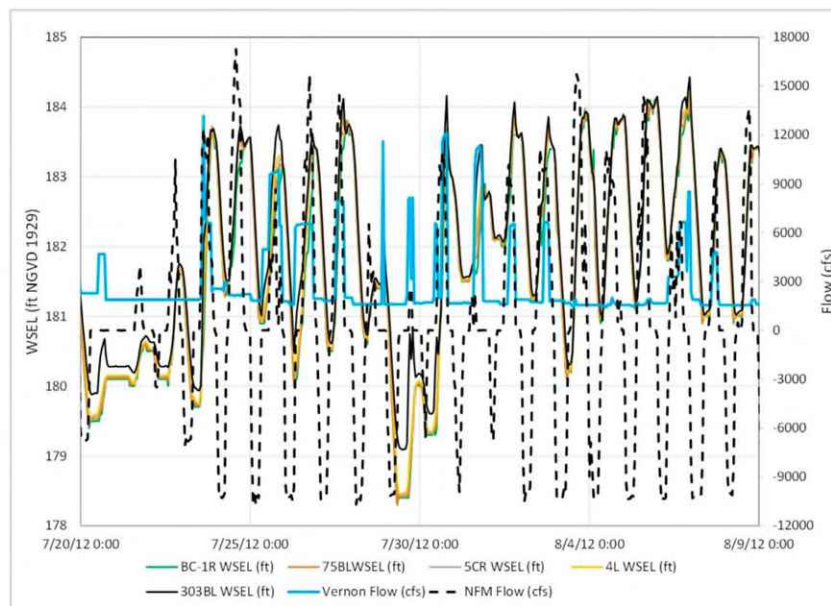


Figure 5.1.3.1-3: Turners Falls Impoundment Modeled Water Surface Elevations – July 20 – August 8, 2012

Figure 5. A plot of modeled water surface elevation from Study 3.1.2⁷⁰ shows up to 6 feet of elevation variation in an approximately weeklong stretch, with similar elevation differences at several cross-section locations in the reservoir.

⁶⁷ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

⁶⁸ Field (Field Geology Services), 2012, Rebuttal of FirstLight's Response to Landowner Filing: Unpublished report prepared for Landowners and Concerned Citizens for License Compliance Turners Falls Pool, 12 p.

⁶⁹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Figure 5.1.3.1-3: Turners Falls Impoundment Modeled Water Surface Elevations – July 20 – August 8, 2012

⁷⁰ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Figure 5.1.3.1-3: Turners Falls Impoundment Modeled Water Surface Elevations – July 20 – August 8, 2012

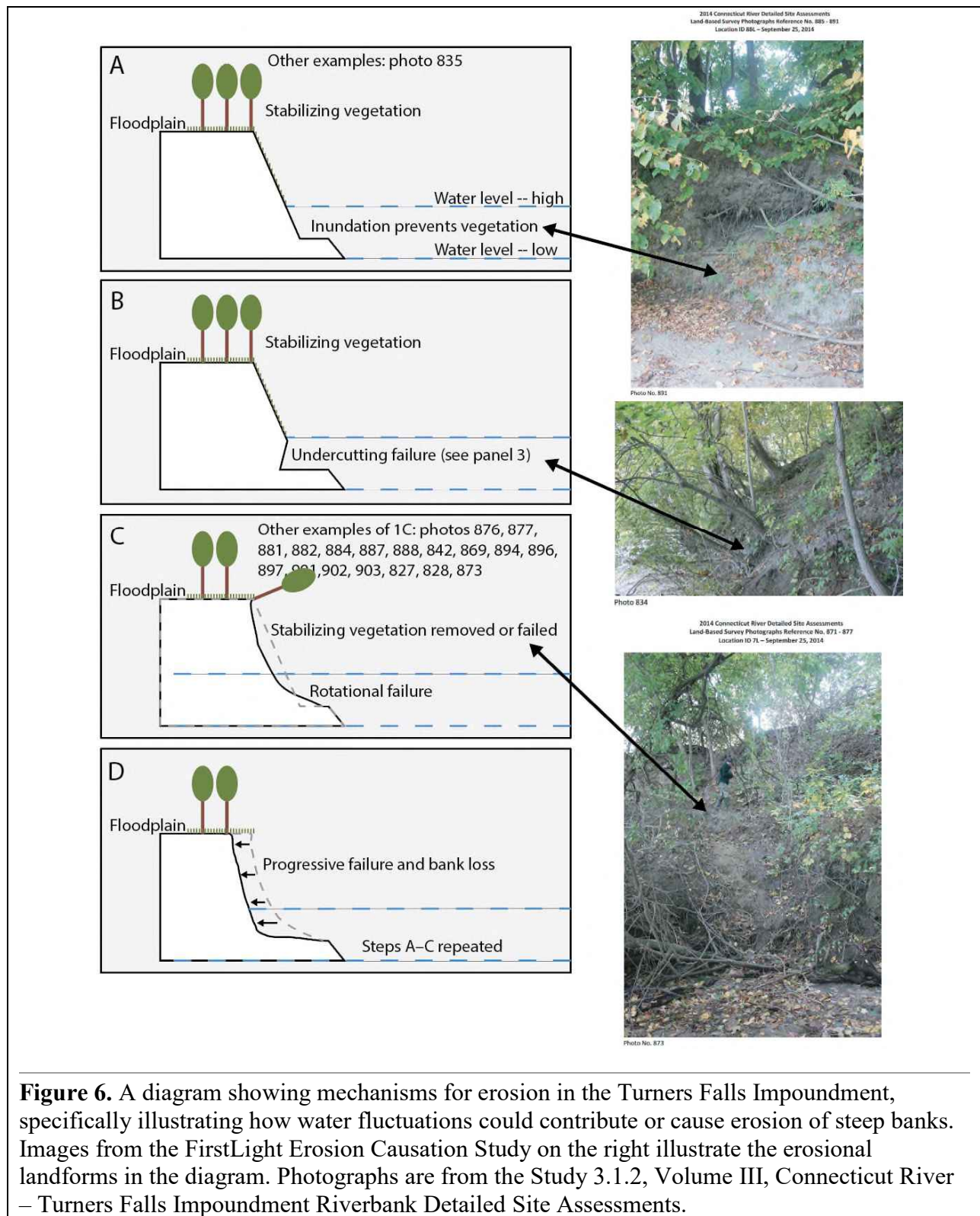


Figure 6 illustrates a sequence of bank undercutting that is likely accentuated by Project operations continually fluctuating water levels up and down, saturating the bank sediments and exposing them to currents and wave action (Figure 6, A). Sediment is eroded when water levels are high, transported away from river banks, tree roots, and beaches. When the reservoir level drops, the undercut sediment may also fail as the water's confining pressure is removed. It is also more susceptible to wave and current erosion because it has been saturated. In each case, because sediment buttresses the banks, its removal destabilizes those banks (Figure 6, B). Community members have observed these processes occurring in the reservoir⁷¹:

“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.*” (p. 2) (emphasis added)

As the community members have observed, this process may occur almost daily in some places on the TFI shoreline during reservoir storage and release. Vegetation is sporadic in the lower banks, where undercutting is very common, limiting the cohesive strength of bank sediments (see Section 2, below). Undercutting of the banks can lead to failure during rain events and snowmelt periods, as has been observed by landowners⁷²:

“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.” (p. 2)

Erosion of this nature has been documented at other reservoirs, including in similar temperate climates where reservoir bank substrate is glacial sediment. Reid (1985)⁷³ found that:

“During high pool levels, waves pound that area, exposing this sand unit, resulting in rapid undercutting of the overlying till. Upon lowering of the pool level, the undercut till quickly fails”. (p. 783)

Field evidence presented in the Erosion Causation Study⁷⁴ shows similar processes are active in TFI. The combination of fluctuating reservoirs and wave and current erosion (driven by flow, wind, and/or boat wakes) leads to undercutting of steep, unvegetated banks. Upper slope destabilization consistent with consistent lower bank erosion and undercutting is documented in numerous photographs in the Full River Reconnaissance⁷⁵ (see photos 876, 877, 881, 882, 884, 887, 888, 842, 869, 894, 896, 897, 901, 902, 903, 827, 828, 873) (Figures 6–9). Three examples are provided here, showing undercutting and undermining of bank-stabilizing tree roots (Figure 7), and high bank failures above evidence of lower bank undercutting (Figure 8 and Figure 9).

⁷¹ Landowners and Concerned Citizens for License Compliance Connecticut River, Turners Falls Pool, Massachusetts. August 2nd, 2012. p. 2

⁷² *Id.*

⁷³ Reid Jr., J. R. (1985). Bank-erosion processes in a cool-temperate environment, Orwell Lake, Minnesota. Geological Society of America Bulletin, 96(6), 781-792.

⁷⁴ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

⁷⁵ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.



Photo No. 887

Figure 7. An image from the FirstLight Study 3.1.2, Volume III Appendix D (pdf page 200) shows undercutting of a lower bank has stripped vegetation, removed vegetation under tree roots, and undermined sediments on the upper bank.

2014 Photo: Montague



Observations: Erosion has been ongoing at this site for quite some time and has been recommended for preventative maintenance and/or bank stabilization work in the 2013 FRR report.

Figure 8. An image from the FirstLight Causation Study Volume II shows minimal protection by a beach of a slope failure in the reservoir disturbance zone.



Observations: This site has been eroded for some time and was recommended for preventative maintenance and/or bank stabilization work in the 2013 FRR report.

Figure 9. An image from the FirstLight Causation Study Volume II shows that undercutting erosion can occur on steep banks even when there is a well-developed beach protecting them.



FIG. 2. Erosion in frozen lacustrine clay at site 1.

Figure 10. An image from Southern Indian Lake in Manitoba, Canada shows erosion that strongly resembles erosion depicted in images of the shoreline of the Turners Falls Impoundment.⁷⁶ Researchers attributed Southern Indian Lake erosion partly to inundation and devegetation of the banks, which combined to reduce sediment cohesion.

Other researchers have reported on reservoir shoreline erosion attributable to lack of bank cohesion that strongly resembles erosion at TFI (Figure 10). At Southern Indian Lake, a dam-regulated reservoir in Manitoba, shoreline substrate, although frozen, is unconsolidated glacial sediment similar to that in the TFI, with grassy vegetation and trees providing some strength⁷⁷. Researchers found that wave energy and inundation were found to cause an erosional feedback loop, with an anticipated 35 meters of horizontal erosion forecast before bedrock would be encountered. The researchers observed the inundation of frozen sediments, after which “bank materials become oversaturated with water and form a slurry-like mixture. The partially thawed materials flow out” and are subsequently “completely removed during storms”⁷⁸. The processes and feedback loop described here are very similar to the “sequence of erosion” described by Field Geology Services (2007)⁷⁹ and here in the five-step erosion feedback loop.

⁷⁶ Newbury, R. W., & McCullough, G. K. (1984). Shoreline erosion and restabilization in the Southern Indian Lake reservoir. *Canadian Journal of Fisheries and Aquatic Sciences*, 41(4), 558-566. p. 561 Fig. 2.

⁷⁷ Newbury, R. W., & McCullough, G. K. (1984). p. 561 Fig. 2.

⁷⁸ Newbury, R. W., & McCullough, G. K. (1984). p. 561 (“melting occurs below and slightly above the water surface.”).

⁷⁹ Field (2007) p. 11 (“FRR methodology cannot be used to make comparisons of erosion from year to year”)

In addition, FirstLight downplays the magnitude of existing fluctuations in the TFI. For all of the days (other than May – November 2010) that were modeled, they report that 15% of the daily water surface elevation variations were less than 1.6 feet and about 95% were less than 4.0 feet. However, this means that 85% of days have > 1.6 feet of variation – constant rise and fall of water level consistent with erosion on beaches, bars, and steep banks that are not protected by beaches. The 5% of days with more than 4.0 feet of elevation change likely accentuated erosion further.

2.3 Vegetation cannot colonize because of repeated inundation during the growing season.

The second component of the erosion feedback loop is the removal of vegetation along beaches, benches, and steep banks of the reservoir shoreline by frequent inundation. In the Connecticut River watershed, erosion is generally low compared to other regions⁸⁰ despite abundant unconsolidated glacial sediments in the river valley. The general stability of riverbanks in the Connecticut River watershed, and New England generally, is mostly explained by the presence of abundant stabilizing vegetation in the region, which has approximately 80% forest cover and pervasive riparian vegetation.

Many plant species not suited to water are threatened by any inundation, and substantial loss of vegetation due to inundation in the reservoir disturbance zone has been documented along other reservoir shorelines⁸¹. FirstLight’s own HEC-RAS modeling shows that flows rest on the upper bank between 1–22% of the time for selected reaches—10–20% of the time is substantial and consistent with numerous images in the FirstLight Full River Reconnaissance, as well as the 2007 Field Report, showing bare tree root balls, devegetated banks and bars, and undercut slopes⁸² (Figure 11).

Figure 11 shows the cycle of devegetation that can occur from frequent inundation. As FirstLight stated in their Full River Reconnaissance in 2008⁸³:

“Vegetation plays a significant role in the stability of riverbanks. Vegetation colonizing and expanding onto a riverbank where vegetation did not exist or was sparse indicates that the riverbank is becoming more stable. As vegetation expands and matures, it offers greater protection against erosion.”

Vegetation is not able to colonize banks in the reservoir disturbance zone due to unsuitable conditions. Lack of vegetation prevents sediment trapping, leading to beach and bank instability and further erosion. The absence of root cohesion also limits shoreline resistance to erosion.

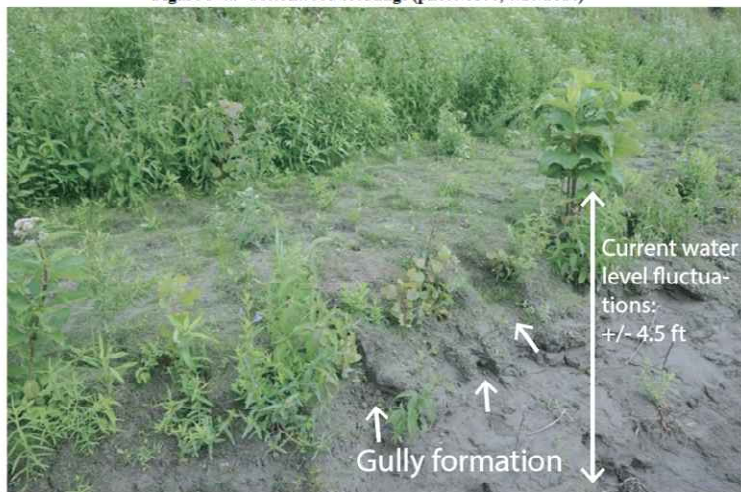
⁸⁰ Rainwater, F.H., Stream Composition of the Conterminous United States, USGS Atlas HA 61, Washington, D.C., 1962.

⁸¹ Bao, Y. et al.(2018). p. 136 (“Influenced by this new hydrological regime, the abundance of the original plant species within the [Disturbance Zone] has been drastically reduced”); Fig. 7.

⁸² FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

⁸³ FirstLight Full River Reconnaissance. 2008 TURNERS FALLS POOL, CONNECTICUT RIVER. p. 27.

Figure J-4.9 Cottonwood seedlings (photo 6576, 7/15/2014)



Inundation and erosion during hydropower water level fluctuations (see panel 3) and floods prevent stable conditions necessary for vegetation establishment. While these flows can contribute to seed dispersal, they also remove soil necessary for root establishment.

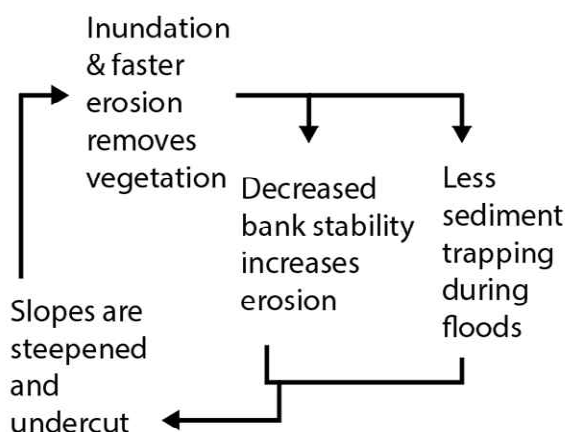


Photo 828

Progressive erosion has occurred during years of unreliable vegetation colonization. This erosion contributes to bank loss. Many images are similar to this one: overhanging trees with soils eroded from their roots. These trees were once part of stable riparian buffers, but have been steadily lost, likely reducing flood resilience.

Figure 11. A diagram showing the erosion feedback loop that occurs with devegetation. Inundation removes vegetation or prevents vegetation from successfully growing. Upper⁸⁴ and lower⁸⁵ images are from FirstLight surveys; annotations and text are from this report. Lack of vegetation lowers root-based cohesion of the banks and traps sediment less effectively, leading to further destabilization and heightened erosion. This diagram is illustrated by ongoing, linked erosional and devegetation processes in the Turners Falls Impoundment, each of which is consistent with erosion caused or aided by fluctuating water levels due to Project operations.

⁸⁴ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix J.

⁸⁵ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

Vegetation that does colonize steep reservoir banks during the summer may not persist through the late fall and winter, leaving slopes susceptible to erosion especially during those months. Even where trees have maintained root structure, frequent inundation likely limits understory growth, allow rapid erosion and progressive undermining of larger trees. Lack of understory was documented at least at two sites by FirstLight and reported in the Erosion Causation Study⁸⁶:

“It should be noted that although the tree cover is 95% and 70% at sites 75BL and BC-1R respectively, the understory data at these locations indicates a high percentage (80%) of the soil under the trees is bare. In these cases, although the trees are contributing to root-reinforcement within the banks themselves, there is less surface protection from hydraulic forces.” (p. 4-113)

However, in FirstLight’s response to the Princeton Hydro letter, they defend the BSTEM model inputs by directly contradicting their own field observations, saying “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*”⁸⁷ (emphasis added). The banks are only vegetated sporadically, and are mostly unvegetated in many of the critical erosion locations. The inputs to BSTEM are thus both flawed and incomplete, casting doubt on its results.

Revegetation is also a primary factor in the recovery of destabilized slopes. In the case of bank failure caused by flooding, undercutting, freeze-thaw processes, or other causes, revegetation can stop the sequence of erosion, preventing the erosion feedback loop from running unchecked. In its analysis of erosion sources, FirstLight does not account for how the lack of stabilizing vegetation prevents banks from recovering once they are perturbed. Similarly, BSTEM only uses a one-time vegetation parameter. Because it does not seem as though vegetation is allowed to vary or evolve during the model, BSTEM is not accounting for critical changes in bank cohesion and thus erodibility that may be attributable to FirstLight Project operations.

2.4 Daily FirstLight fluctuations likely saturate banks and toe slopes, reducing internal strength and accelerating erosion.

2.4.1 Fluctuations can cause sapping, rilling, and gulying in bank sediments

As water levels rise and fall over unconsolidated sediments, progressive erosion can occur on beaches, bars, and banks – even those that are not as steep as the undercut banks in (Section 1). Sapping occurs when confining pressure from surrounding water is removed from saturated sediments. Resulting flow through the sediments can “sap” the bank of its water and sediment, transporting eroded sediment toward the receding water. Rilling, gulying, and knickpoint propagation can also occur. These processes occur in natural circumstances by runoff over the ground during precipitation or melting events. The erosional power of this runoff is focused where the bank or beach slope is locally steep (Figure 12).

⁸⁶ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 4-113

⁸⁷ FirstLight Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary. January 17, 2017. p. 2

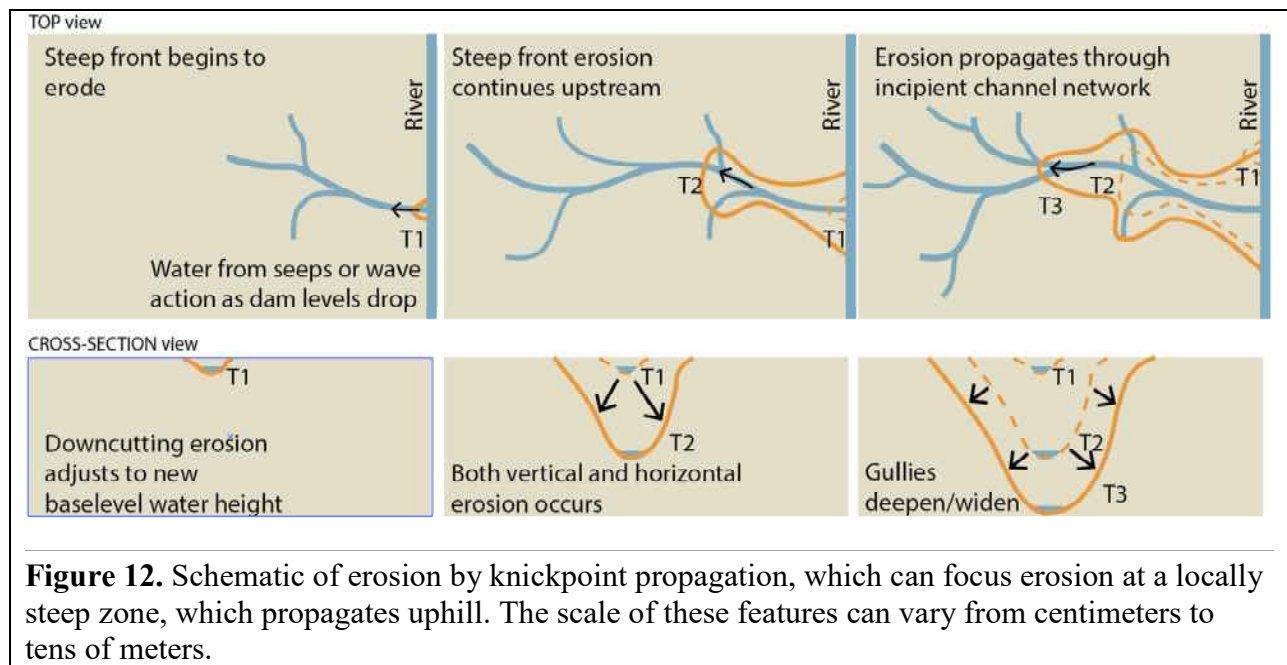


Figure 12. Schematic of erosion by knickpoint propagation, which can focus erosion at a locally steep zone, which propagates uphill. The scale of these features can vary from centimeters to tens of meters.

Sapping and local oversteepening of the bank can occur during rapid water level recession, which is often called “baselevel fall”. Kaczmarek et al., (2016) found evolution of gullies to be strongly related to reservoir water fluctuations⁸⁸:

“In periods of high water levels, due to coastal erosion of the bluff, the terminal, flattest parts of the gully were destroyed, which triggered their further development. In contrast, declining water level in the reservoir is a cause of intensified deep erosion in the gully bottom, which consequently initiates backward erosion at the bottom of these forms.” (p. 937)

Gullying, rilling, and knickpoint erosion are part of strong erosional feedback loops, as the locally oversteepened point progressively moves uphill, cutting farther into the bank. This process is illustrated in Figure 12 (diagram) and Figure 13 (annotated photograph), which show the process of gully development as it appears to occur along the shoreline of the TFI.

⁸⁸ Kaczmarek et al. (2016)



DETAIL

- a) Water level rising and falling prevents vegetation from colonizing in the inundation zone.
- b) As water level drops, outflow channels form and creating small gullies at the break-in-slope. Slopes are much higher in gullies than the average bank slope, increasing the likelihood of sediment transport and erosion.
- c) Knickpoints -- locally steep reaches in a channel -- propagate upstream in these new systems, progressively undermining the bank.
- d) Rainfall on these systems can heighten erosion, as can subsequent inundation.

NOTE: This process is similar to tidal fluctuations that form analogous sedimentary structures in beach environments.

Figure 13. An annotation of an image from the FirstLight Full River Reconnaissance Study 3.1.1 showing gully formation and likely knickpoint propagation. This appears to be occurring on a beach or low bench, where different water levels have allowed wave-cut vertical slopes to form. Notches in these slopes provide the initial node for knickpoint erosion (see Figure 12).

The “FL Response to Study Comments” states: “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.”

However, numerous photographs provided by FirstLight consultants in the Erosion Causation Study directly contradict this claim that there is minimal erosion in the flat, beach-like lower bank. This includes the photograph in Figure 13, as well as photos 583 (Figure 14), 638 (Figure 15), 698 (Figure 16), 709 (Figure 17), 833, 834, 882, 796⁸⁹, J-4.1 (Figure 18), and J-4.9⁹⁰ from

⁸⁹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix D – Detailed Site Assessments.

⁹⁰ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume III – Appendices, Appendix J -- Ice Data And Supplemental Information.

the 2017 FirstLight Erosion Causation Study. These photographs show significant erosion, including rilling, bank failure, devegetation, and winnowing of sediment in the lower bank zone. They also include successive benches on beaches, each showing gullying that was likely initiated by dropping water levels. As was noted by the Princeton Hydro review⁹¹, ***the fact that the BSTEM model failed to capture sediment transport or significant erosion in these lower bank zones indicates its failure to capture critical erosion dynamics in the TFI.***

These landforms and features are not all necessarily caused by Project water level fluctuations. However, they are clearly consistent with erosion by water level fluctuations and occur at elevations set by Project-determined water levels. Gullying has been consistently identified as a result of shoreline erosion related to changing water levels⁹². In Poland, erosion in glacial sediments similar to those in the TFI caused gullying on a variety of scales, with development strongly resembling gullies documented by FirstLight in the TFI⁹³:

“...gullies disturbed the stability of the bluff by developing in the easily degraded sandy-silty deposits, their dense network deeply indents the bluff and disrupts its continuity. Their development is cyclic and ***strongly related to water level fluctuations in the reservoir.***” (p. 932) (emphasis added)

This passage highlights the challenges with gully erosion if it is left unchecked. The local steepening of slopes continues to propagate into the bank and perpetuate the cycle of erosion being outlined here. Especially absent stabilizing vegetation (See Section 2) or the presence of bedrock⁹⁴, this propagation can also contribute to undercutting of steeper banks or undermining of upper banks (See Section 1), leading to mass failure.

Significant erosion at or near the low-flow water line is shown in the following photos and many others. In Figures 13–16, low, steep banks on several beaches show evidence of notching, which can be an initiation point for knickpoint erosion. In several instances, these steep banks have multiple wave-cut elevations, consistent with water levels fluctuating and thus focusing erosion at a certain beach elevation.

2.4.2 High water levels can exacerbate bank erosion during spring snowmelt

Saturation of sediments along the reservoir shoreline, especially given the lack of vegetation and root cohesion, also increases bank susceptibility to erosion during the spring snowmelt period. Freeze-thaw processes can physically wedge apart the banks, in processes similar to the ones that cause frost heaves in roads. Water that percolates into sediment pore space freezes and expands, wedging apart sediment. This can either cause erosion directly or make extra space for more

⁹¹ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. p. 13 (“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.”)

⁹² Kaczmarek et al. (2016) p. 937 (“In periods of high water levels, due to coastal erosion of the bluff, the terminal, flat- test parts of the gully were destroyed, which triggered their further development. In contrast, declining water level in the reservoir is a cause of intensified deep erosion in the gully bottom, which consequently initiates backward erosion at the bottom of these forms.”).

⁹³ Kaczmarek et al. (2016). p. 932 (“Gully development is also partly due to linear erosion, which is particularly important during summer rainstorms. Such forms appear frequently on primary pathways of surface runoff from local microcatchments.”).

⁹⁴ Newbury, R. W., & McCullough, G. K. (1984). p. 561 Fig. 2.

water to intrude, leading to more “frost wedging” and/or increasing the potential saturation of the banks during the spring. If the bank remains intact through the frost-wedging period, the extra water it retains can cause it to liquefy when the ice melts because of the loss of internal sediment grain contact and cohesion. Each of these well-known erosion processes may be increased by frequent saturation because of Project operations fluctuating water levels in the reservoir.

The FirstLight Erosion Causation Study does not account for freeze-thaw erosion of steep banks. The Causation Study and BSTEM also do not specifically model winter and spring snowmelt conditions, which, due to the processes described above, are both complex and lead to far higher erosion susceptibility than summer in the Connecticut River.

The Erosion Causation Study makes two admissions about freeze-thaw erosion. The first is that these processes have mostly been ignored by FirstLight studies of the reservoir, despite the importance of the snowmelt period in erosion in the Connecticut River watershed⁹⁵:

“No actual data exist that allows quantification of the effect of freeze-thaw cycles on riverbank stability in the TFI. Freeze-thaw is a natural process that is primarily influenced by weather and climatic cycles and is not considered a primary factor in riverbank erosion processes in the TFI, nonetheless it is likely to contribute to riverbank instability to some lesser degree.” (p. 5-271)

As this passage states, although FirstLight acknowledges the likely contribution of freeze-thaw to erosion processes, they have not collected any data about it. As a result, all of the claims about erosion in the TFI are at least partly based on conjecture.

The second admission is the possible importance of ice processes in killing vegetation in the reservoir⁹⁶:

“Ice both destroys riparian vegetation and limits its establishment and growth as demonstrated by various analyses and observations (and has been quantitatively demonstrated by vegetation demography studies, analysis and computer modeling that ice plays a “*significant, if not dominant*” role in removing and limiting riparian vegetation on the Platte River). As shown in the erosion causation study, riparian vegetation plays a significant role in riverbank stability” (p. 5-303)

Indeed, the contribution of freeze-thaw processes may be substantial. As noted in a similar geologic setting in Poland by a high-resolution study by Kaczmarek et al (2019)⁹⁷:

⁹⁵ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report.

⁹⁶ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report.

⁹⁷ Kaczmarek, H., Tyszkowski, S., Bartczak, A., Kramkowski, M., & Wasak, K. (2019). The role of freeze-thaw action in dam reservoir cliff degradation assessed by terrestrial laser scanning: A case study of Jeziorsko Reservoir (central Poland). *Science of the total environment*, 690, 1140-1150.

“As a result of the creation and operation of this water body, the formation of bare, nearly vertical cliff faces (which were absent in this location before the impoundment) facilitated the frost processes, and their course is specific, having no equivalent in natural conditions. When the water level is high, the periodical wave erosion at the bluff toe does not allow stabilization of the transformed cliff and long-term accumulation of talus slopes protecting the bluff toe. In such conditions, the whole cliff face is subject to frost processes.” (p. 1149)

In this reservoir in Poland, on years when water levels are high and wave action can contribute to erosion, frost action contributes approximately 20% of annual erosion. When water levels are low, frost action contributes approximately 70% of annual erosion.

FirstLight thus acknowledges that freeze-thaw erosion processes may be important contributors to reservoir erosion, that no data have been collected about them, and that riparian vegetation may be destroyed by ice processes related to Project operations. However, these are relegated to a section mostly devoted to abrasion and gouging by ice floes.

In their rebuttal to the Princeton Hydro memo, FirstLight states that “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.”⁹⁸ Yet its reports do not sufficiently measure or model erosion during this critical period: snowmelt in the winter and spring. Despite the importance of this period in cold climates, processes associated with snowmelt and freeze-thaw are discounted and/or not measured by FirstLight⁹⁹:

“it was noted that ice typically does not cause erosion if the ice simply melts in place without significant break-up and if ice floes moving down river causing ice jams and impacting banks do not occur. This is consistent with the findings of the historic analysis conducted and with observations made during field monitoring which occurred during the 2014/2015 winter when much of the TFI was frozen over but the ice simply melted in place during the later winter, early spring of 2015. 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.” (p. 5-245)

This ice jam dismissal is cursory and not scientific, but also misses an important point: freeze-thaw processes can contribute to erosion even without ice flows. Landowners along the river have observed such erosion, potentially magnified by boat wakes, as they documented in a 2016 letter¹⁰⁰:

“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... 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

⁹⁸ FirstLight Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary. January 17, 2017. p. 2

⁹⁹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 5-245

¹⁰⁰ Bathory letter (2016) p. 2

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.” (p. 2)

In not measuring or considering freeze-thaw processes¹⁰¹ and ignoring these first-hand observations, FirstLight is potentially missing a major source of erosion, which Project-caused water fluctuations and devegetation could accentuate. Their contribution to erosion in the TFI must be rigorously quantified in order for the claims of erosion timing and attribution to be considered valid.

**2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 581 - 588
Observation Point No. 11 - November 13, 2013**



Photo No. 583

Figure 14. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 11 showing a wave-cut beach and incipient gully.

¹⁰¹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume I – Executive Summary and Summary. p. vii (“a quantitative analysis of the impact of ice as a cause of erosion was not possible given weather conditions during the monitoring period and available historic data”)

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 638 - 641
Observation Point No. 17 - November 15, 2013



Photo No. 638

Figure 15. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 17 showing a wave-cut bench, fallen-down sediment blocks, and incipient gullying.

2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 691 – 696, 698 - 699
Observation Point No. 24 - November 16, 2013



Photo No. 698

Figure 16. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 24 showing a wave-cut bench, fallen-down sediment blocks, and incipient gullying.

**2013 Connecticut River Full River Reconnaissance
Land-Based Observations Photographs Reference No. 705 - 710
Observation Point No. 25 - November 16, 2013**



Photo No. 709

Figure 17. Photograph from the FirstLight Relicensing Study 3.1.1 2013 Full River Reconnaissance, Observation Point Number 25 showing a wave-cut bench, fallen-down sediment blocks, and incipient gullying.

Figure J-4.1 Maple seeds (photo 0202, 9/28/2015)



Figure J-4.2 Location of photo #0202



Figure 18. Photograph from the FirstLight Relicensing Study 3.1.2 Appendix J, showing maple seed dispersal but also challenges with vegetation establishment, given frequent inundation and signs of incipient gullyng.

2.5 Moderate and flood flows transport eroded sediment away from toeslopes, beaches, and bars.

In the alluvial sections of the Connecticut River watershed, where the Turners Falls Dam is located, the substrate is mostly comprised of erosion-prone sediments and occasional bedrock¹⁰². Although Connecticut River streams and rivers generally erode slowly, sediment is mobilized during flooding that is endemic to the region. Moderate floods transport sediment that is not

¹⁰² Field (2007)

secured by vegetation¹⁰³. Larger floods can strip vegetation and undermine steep banks, leading to much more erosion. Even without high flows, riverbanks without perennial vegetation can erode as snowpack melts in the spring (typically March and April). However, during the summer low-water season, very little erosion occurs unless a flood occurs.

The role of flood flows in erosion in the TFI is summarized in Figure 19. The annotated images illustrate erosional processes consistent with flood transport. Erosion is a natural process that occurs along all rivers and does not, by itself, indicate compromised river health or processes. However, as is shown in the figure, natural erosion processes may be accentuated by Project operations, including steep or overhanging banks that are prone to erosion and lack of vegetation that can provide cohesion for sediments and slow flood flows, leading to deposition rather than erosion.

¹⁰³ Renshaw, C. E., Dethier, E. N., Landis, J. D., & Kaste, J. M. (2022). Seasonal and longitudinal variations in suspended load connectivity between river channels and their margins. *Water Resources Research*, 58(4), e2021WR031212.

Flows onto low banks and benches have removed soil. This can reduce the stabilizing effects of vegetation and undermine banks, causing trees to collapse. These effects and others are evident in numerous photographs from the Erosion Study.

2014 Connecticut River Detailed Site Assessments
Land-Based Survey Photographs Reference No. 836 - 843
Location ID BC-1R – September 24, 2014



Photo No. 840



Photo No. 841

Ripples on this beach indicate transport away from the base of the bank. The image shows clearly several fallen trees that have collapsed as the bank was undermined. Also clearly shown are the tree roots with soil removed from them.

Other examples: photos 874, 876, 877, 881, 882, 884, 887, 840, 841, 798, 904, 809, 812, 814, 826, 827, 828, 904

2014 Connecticut River Detailed Site Assessments
Land-Based Survey Photographs Reference No. 871 - 877
Location ID 7L – September 25, 2014



Photo No. 875

2014 Connecticut River Detailed Site Assessments
Land-Based Survey Photographs Reference No. 885 - 891
Location ID 8BL – September 25, 2014



Photo No. 887

Figure 19. Annotated photographs from FirstLight Relicensing Study 3.1.2, Locations 8C-1R (left), 7L (upper right), and 8BL (lower right), showing evidence of bank undercutting, sediment transport, and vegetation removal that are consistent with Project-caused water-level fluctuations.

In the Turners Falls Impoundment floods likely transport sediment in processes that resemble unregulated river reaches in the region. FirstLight identifies these floods as the sole “significant” or “dominant” cause of erosion in the TFI. Floods may be the largest cause of erosion in the reservoir¹⁰⁴. However, the geomorphic effectiveness of these floods is likely accentuated by the bank destabilization due to devegetation and saturation described above and in prior reviews by independent scientists^{105,106}.

The challenge of attributing erosion to flood flows alone was highlighted by Field (2007), who analyzed annual erosion at monumented cross sections in the TFI, relative to flood magnitudes for those years. They found that peak annual discharge did not have a direct relationship with measured erosion¹⁰⁷:

“The year with the highest peak discharge since 1990 at the Montague gauge was 1998, a year in which the greatest one-year change in bank position did not occur at any of the cross sections. A careful analysis of rainfall in the area preceding these flood events would be needed to determine if variations in soil moisture can explain the variations in response to these larger flood events. The most significant period of bank recession for several cross sections occurred in the early 1990’s with average rates of recession ranging between 1.7 and 4.5 ft/yr during this short time period (Table 5). No high flood discharges were recorded during this period (Figure 4).” (p. 30)

In addition, a raised water level allows floods to erode higher on the bank. Flood water levels will be elevated by the number of feet the water level is raised. Although FirstLight claims that there is minimal effect of Northfield Mountain generation during high flows, they actually report that flood heights are raised by as much as 1.5 feet when generation is at 10,000 cfs and river flows are 30,000; 40,000; 50,000; and 60,000 cfs. This is equivalent to 20–30% additional discharge during some floods¹⁰⁸. The erosional impact of this additional discharge and flood elevation is not quantified by FirstLight, nor do they claim responsibility for any additional erosion that may occur.

Project operations may also limit recovery. After an erosional event, relatively rapid revegetation can restabilize sediments, preventing chronic erosion. However, the normal recovery processes that follow floods are also consistently disrupted by post-flood inundation/exposure cycles during Project operations, extending the erosional sequence. These are summarized above in sections 1–3.

¹⁰⁴ U.S. Army Corps of Engineers, 1979, Report on Connecticut River Streambank Erosion Study: Massachusetts, New Hampshire and Vermont: Department of the Army New England Division Corps of Engineers: Waltham, MA, 185 p.

¹⁰⁵ Field (2007) p. 42. “Attempting to discern which of the causal mechanisms for erosion is the most important would fail to recognize that these various processes operate collectively to effect change on the riverbanks through time and space.”

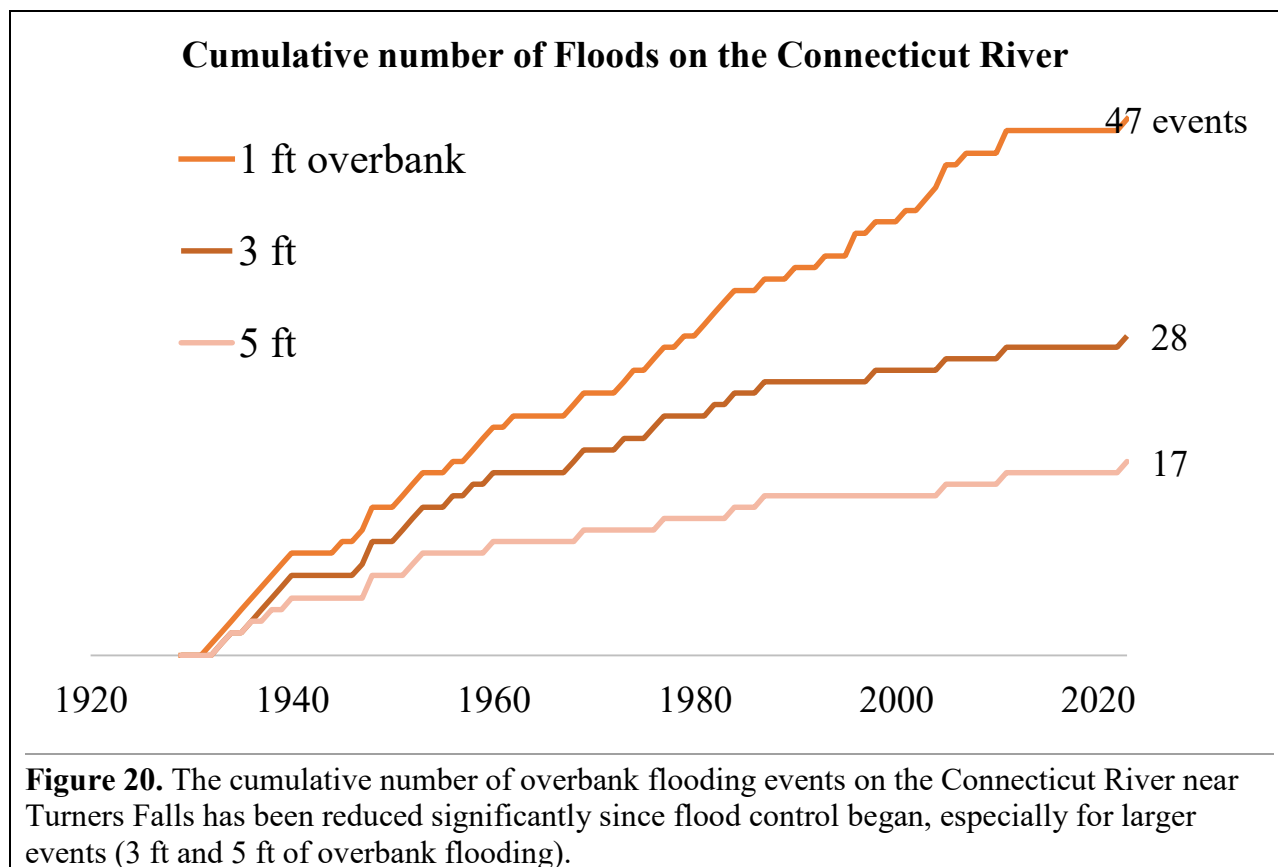
¹⁰⁶ Wildman, L., Woodworth, P., & Daniels, M. (October, 2016). Peer-Review of Relicensing Study 3.1.2 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report.

¹⁰⁷ Field (2007) p. 30.

¹⁰⁸ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 5-30 and accompanying figures.

2.6 Flood control and loss of vegetation limits overbank and bank deposition, so net change is erosional.

Prior to flow regulation by dams, the Connecticut River would regularly overtop its banks, replenishing floodplain sediments. Since flood-control dams were constructed in the mid-20th century, this natural floodplain exchange has been reduced. From 1961–present, the Connecticut River has only had substantial flow (> 3 ft) onto its floodplains 12 times (Figure 20).



In a normal alluvial reach in equilibrium, erosion is typically balanced by deposition. However, significant bank erosion is present throughout the reach, with only transient deposition on beaches, which are often destroyed by floods in the reservoir¹⁰⁹.

The presence of erosion without evidence of deposition may indicate that Project operations are both contributing to erosion and preventing deposition. Rapid erosion on both banks is also shown in cross sections surveyed by FirstLight. In 2007, Field¹¹⁰ noted that erosion occurred on both sides of the TFI, as opposed to a typical alluvial river in equilibrium, where erosion on one

¹⁰⁹ Field (2007). p. 32 (“However, if river currents still periodically remove sediment at the base of the bank or remove the accumulating beach sediment entirely, then notching and undercutting at the base of the bank can be rejuvenated and the bank will once again be prone to further erosion.”); p. 43 (“The presence of higher beach deposits preserved at the base of the bank, particularly in protected areas, suggest prior beaches have been removed by scour”).

¹¹⁰ Field (2007). Table 5.

bank is approximately balanced by deposition on the opposite bank or bars. This does not appear to be the case in the TFI, where erosion predominates (Figure 21).

The prevalence of these erosional sites are ignored or summarily downplayed by Erosion Causation Study text, particularly the Executive Summary¹¹¹. Considerably more slopes are vertical/overhanging than indicated in the study. Extensive erosion is also shown in the 2016 Hydraulic Study addendum¹¹². Evidence of deposition is not presented. Downplaying or underreporting erosion in the TFI is consistent with past reports by FirstLight¹¹³.

¹¹¹ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume I – Executive Summary and Summary Report

¹¹² Relicensing Study 3.2.2 Hydraulic Study Of Turners Falls Impoundment, Bypass Reach And Below Cabot Addendum. March 2016.

¹¹³ Field (Field Geology Services), 2012. p. 6 (“However, the dates on the photographs are in some cases inaccurate and the angles and distances from the bank vary between photographs giving rise to a misleading impression of bank stability when either no change has occurred or the purported change can’t be confirmed.”)

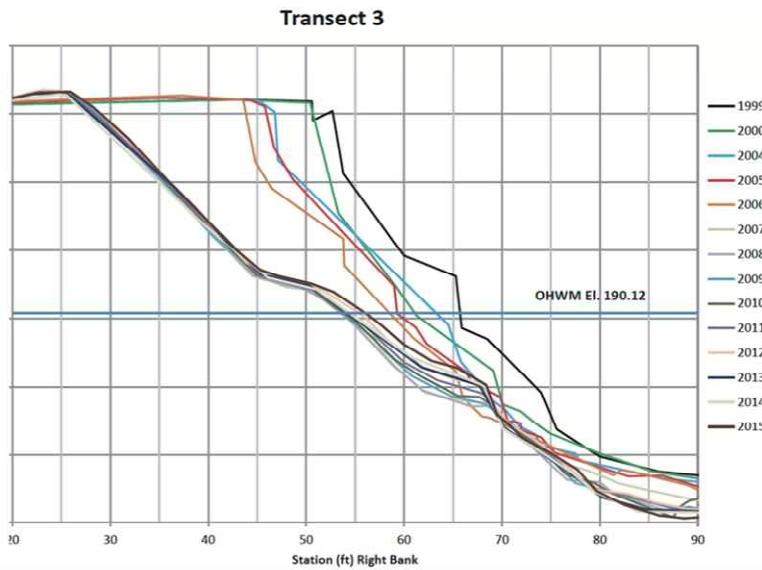
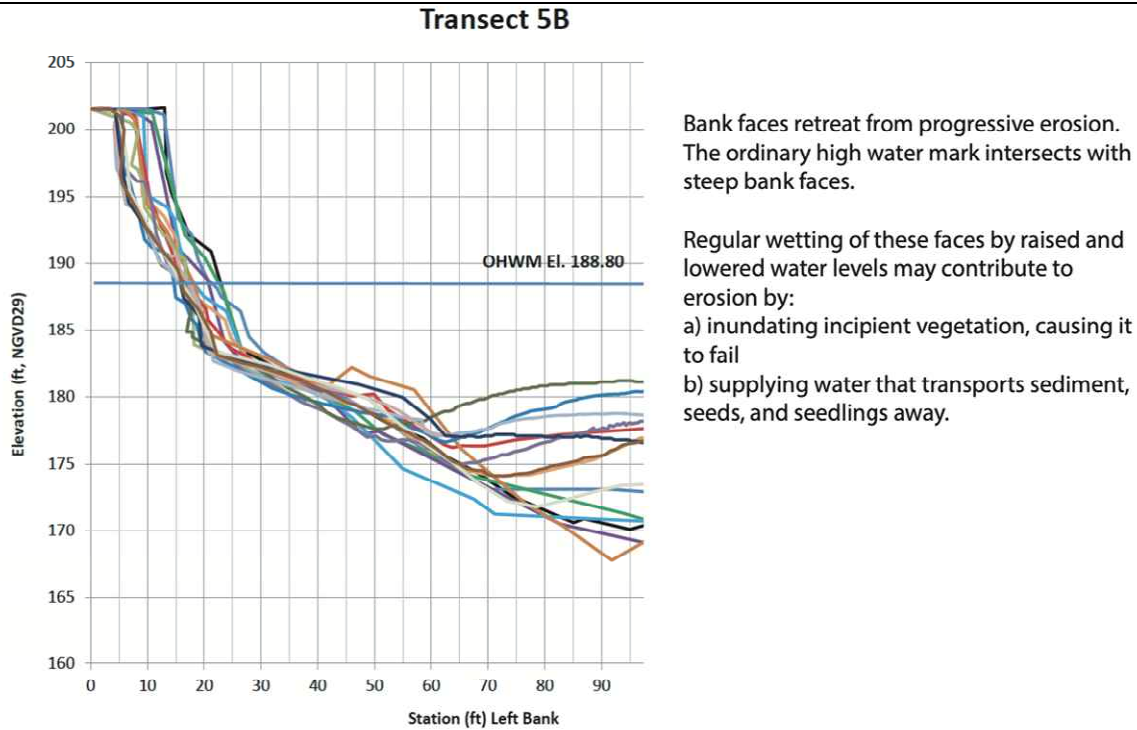


Figure 21. Cross-section profile analysis shows erosion of the shoreline in the Turners Falls Reservoir. These surveys have been conducted approximately annually by FirstLight as a requirement of its current FERC license. High rates of erosion have occurred coincident with large flood events; for instance, historic Tropical Storm Irene caused major flooding and erosion throughout the Connecticut River watershed in 2011. A single at-a-point erosion value per year at these sites does not provide sufficient detail to attribute erosion to certain mechanisms. However, these spatial erosion patterns are consistent both with erosion by flood flows and by water level fluctuations from Project operations, or, more likely, a combination of both.

3. Peer review of FirstLight reports and BSTEM methodology

3.1 Summary

Many of FirstLight's claims rest on a bank erosion model, BSTEM, which was developed by the consultants who prepared the Erosion Causation Study. BSTEM has been used for some peer-reviewed studies, which find it to be a sometimes useful, but inconsistent tool for estimating erosion¹¹⁴.

Because of the substantial back-and-forth about the Full River Reconnaissance, the Erosion Causation Study, and BSTEM, it seems more valuable to focus on the general failings of the FirstLight studies and BSTEM model (see above), as well as constructive steps to study and reduce erosion in the TFI. However, the following points emphasize specific continuing areas of concern that make the BSTEM model less certain than implied by FirstLight denials of responsibility. ***Any use of BSTEM by FirstLight should be strongly caveated until BSTEM suitability and statistical rigor can be shown.***

The BSTEM Model has substantial uncertainties and lack of transparency in its application to TFI. Although it has been used in several academic studies, a "state-of-the-science" review of BSTEM found it to have uneven success¹¹⁵:

"The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters." (p. 191)

There are several concerns documented below. These are in addition to, and have some overlap with, the many concerns raised by PrincetonHydro in their Peer Review, which were not satisfactorily rebutted by FirstLight in its rebuttal (*Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary*, date: 1/17/2017), as well as those by US Department of Agriculture scientist Eddy Langendoen¹¹⁶.

3.2 Rough field methods were used despite available of high-quality data

Due to the reduction in cohesive forces (vegetation root systems, sediment grain contacts) and increase in bank slope by undercutting, the slope stability of undercut banks is likely very low. A model evaluating the sources of erosion should incorporate these oversteepened banks, which are often vertical or overhanging. However, despite measuring detailed cross-sections in the TFI for decades as a requirement of its current FERC license, FirstLight does not incorporate the high-

¹¹⁴ Klavon, K., Fox, G., Guertault, L., Langendoen, E., Enlow, H., Miller, R., & Khanal, A. (2017). Evaluating a process-based model for use in streambank stabilization: insights on the Bank Stability and Toe Erosion Model (BSTEM). *Earth Surface Processes and Landforms*, 42(1), 191-213. p. 191 ("The review demonstrated that the model needs further testing and evaluation outside of the central United States. Also, further development is needed in terms of accounting for spatial and temporal variability in geotechnical and fluvial erodibility parameters, incorporating subaerial processes, and accounting for the influence of riparian vegetation on streambank pore-water pressure dynamics, applied shear stress, and erodibility parameters.")

¹¹⁵ Klavon et al. (2017).

¹¹⁶ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p.

resolution from these cross-sections in the BSTEM model¹¹⁷. Although it is not perfectly clear, given the confusing and sparse descriptions of their methods, it appears that FirstLight used an extremely simple bank geometry parameterization to run BSTEM, generated by “rough surveys of the tested banks”¹¹⁸:

Rough surveys of the tested banks were also carried out at each site with a tape and Brunton compass to provide bank heights, angles, and stratigraphic layering for the tested bank. The data collected in the field were used by Cardno to populate BSTEM-Dynamic 2.3. (p. 4-65)

“Rough surveys” are not sufficient for parameterizing this sensitive model, and no explanation is given for why detailed measurements were not used instead. Such rough surveys would underestimate the effect of locally high slopes. In particular, steep and overhanging slopes that are common in the reservoir are likely not captured in this approach, nor are locally high slopes that may be the nexus of knickpoint erosion (See Section 2.3).

The BSTEM model similarly does not appear to have a way of predicting progressive bank failure by undercutting or rotational failure that may occur when buttressing fails. This is a potentially serious oversight that would shift erosion attribution toward flood flows and away from failure of steep banks during periods of saturation.

Even when field data are incorporated into the model, measurements are often averaged and then applied generally, both at individual sites and by extrapolating to other sites in the TFI (see *Extrapolation*, below). This type of averaging is acceptable in some scientific approaches but must be accompanied by uncertainty and sensitivity analyses to demonstrate that the results do not change dramatically within the range of possible input data.

3.3 BSTEM toe transport is highly uncertain

Sediment transport at bank toes is a complex, highly uncertain process. This uncertainty, and its ramifications for the use of BSTEM, is described in the USACE manual for BSTEM use¹¹⁹:

“Also, it should be noted that most of these transport functions were derived for one-dimensional alluvial transport at the cross section scale. BSTEM applies these transport functions to bank scour at the node scale. This makes transport functions, already uncertain in their intended setting, loose process analogies in toe scour. *The transport functions often over predict scour substantially* and results should be interpreted carefully.” (Emphasis added)

Although written in technical language, the message from US Army Corps of Engineers is clear: BSTEM tends to overestimate erosion by flooding due to the uncertainty and bias in sediment transport functions in the model. This could directly lead to mis-attribution of erosion to flooding.

¹¹⁷ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. p. 4-65. (“Rough surveys of the tested banks were also carried out at each site with a tape and Brunton compass to provide bank heights, angles, and stratigraphic layering for the tested bank. The data collected in the field were used by Cardno to populate BSTEM-Dynamic 2.3.”)

¹¹⁸ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report

¹¹⁹ <https://www.hec.usace.army.mil/confluence/rasdocs/rasstd1d/1d-sediment-transport-user-s-manual/bstem-user-s-manual/transport-function-bstem>

Despite these cautions from independent reviewers of the BSTEM model, FirstLight in the Erosion Causation Study does not completely document or justify the shear stress and cohesion calculations used to estimate erosion. The erodibility coefficient (k), which is part of an equation with shear stress, t_c , was similarly calculated or established without justification, using just the equation published by Hanson and Simon (2001)¹²⁰:

$$k = 0.2 t_c^{-0.5}$$

They provide no satisfactory explanation for its suitability to the TFI, parameterization, or variability along the diverse reaches along the TFI, never mind vertically on the banks. The shear stress parameterization has been independently assessed as problematic. Klavon et al. (2017) states¹²¹:

“BSTEM users should be aware that the τ distribution methods used in BSTEM may be limited in being able to represent actual field conditions.” (p. 197)

The uncertainty in toeslope erosion leads to problematic results and discussion throughout the Erosion Causation Study. This uncertainty is essentially unacknowledged by the Erosion Causation Study. However, the approach is clearly highly uncertain. In particular, the jet tests for shear stress have more than an order-of-magnitude variation at individual sites. Yet the median value seems to be applied in each case with no acknowledgement or assessment of the range encapsulated in that median¹²².

The models of sediment transport at several sites also indicate the likely error in these analyses, especially during large modeled floods. For example, at Site 3L (and others) there is no shear stress that exceeds sediment transport, even at 100-yr flow event (see below). Yet this site has undergone the 5th most erosion of any site. ***This is not a plausible result in an alluvial reach, particularly one experiencing significant erosion, and suggests the underlying physics used to calculate erosion are incorrect.***

Numerous other sites require a 100-year flood event or greater to cause sediment transport. This is not a physically plausible condition and yet another key failure of the BSTEM model that is not acknowledged. At each site, the critical shear stress, t_c (required for sediment motion), is greater than the shear stress modeled by the Erosion Causation Study during a 100-year flood. The values of t_c and $t_{100\text{-year}}$ for these sites are below¹²³:

- Site 5CR (t_c : 1.03; $t_{100\text{-year}}$: 0.98)

¹²⁰ Hanson and Simon (2001)

¹²¹ Klavon et al. (2017).

¹²² FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Table 4.2.6.6-1: Jet Test Data for Bank Materials of the Turners Falls Impoundment

¹²³ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report. Table 5.5.1.1-1: Comparison of Critical Shear Stress and River2D Bed Shear Stress at Detailed Study Sites

- 6AL (tc: 0.64; $t_{100\text{-year}}$: 0.08)
- 7R (tc: 7.14; $t_{100\text{-year}}$: 0.22)
- 8BL (tc: 3.33; $t_{100\text{-year}}$: 0.88)
- 9R (tc: 10.3; $t_{100\text{-year}}$: 1.34)
- 10L (tc: 0.585; $t_{100\text{-year}}$: 0.17)
- 10R (tc: 3.47; $t_{100\text{-year}}$: 1.71)
- 11L (tc: 2.91; $t_{100\text{-year}}$: 0.03)
- 18L (tc: 3.27; $t_{100\text{-year}}$: 0.22)
- 29R (tc: 1.51; $t_{100\text{-year}}$: 1.09)
- 303BL (tc: 2.49; $t_{100\text{-year}}$: 0.45)

In each case, critical shear stress, tc, should be lower than the shear stress during an extremely large flood. The shear stress, as parameterized in the model, suggests that sediment is essentially immobile at these 11 sites. Given the clear evidence of sediment transport throughout the reservoir, this is clearly incorrect and undermines model results. Even if some of these sites have been stabilized and thus the critical shear stress is affected by an estimate for rip-rap mobility, evidence of erosion at rip-rap sites documented by Field (2007)¹²⁴ shows that modeling a no-erosion scenario there is not reasonable.

Discharge data, as modeled by the new “dynamic” version of BSTEM, is also not sufficiently rigorous to support the confidence with which FirstLight presents its results. A review by a US Department of Agriculture Scientist found¹²⁵:

“The hourly discharge and erosion records were then used to calculate erosion exceedance probabilities. 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.” (p. 3)

3.4 Cohesion and slope stability provided by vegetation is poorly quantified

Root cohesion, a critical parameter in the BSTEM model, was based on RipRoot outputs for 5 species that have not been tested independently except for in this study. In model parameterization by FirstLight consultants, the percent tree cover was established for the cross-section bank top and bank face, then the percent each tree species contributed was added. Some key deficiencies suggest widespread oversimplification and lack of rigor:

- Only a single, uniform value of cohesion was established for the bank top.

¹²⁴ Field (2007) Fig. 29; Fig. 35.

¹²⁵ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p.

- Only 9 cross sections had vegetation-derived cohesion for the bank face. As with the bank top, only a single cohesion value was established, not accounting for the variations in root structure through the face.
- No vegetation-derived cohesion was input for the bank toe, despite vegetation existing at the toe (see above: BSTEM Toe Transport Uncertainty).
- Root cohesion data was only collected for large trees. There is no consideration of grass and smaller vegetation that does much of the work of bank stability and velocity reduction.
- Waves from wind, current, and boat wakes, and flood erosion clearly exists in a feedback process with bank undermining and vegetation, but no consideration of these connected systems is provided, nor are secondary sources of erosion included in the cohesion model.

The additional vegetation-derived cohesion increased erosional resistance by 200% on average.

The large uncertainties in these vegetation methods thus dramatically increase the uncertainty of the BSTEM model. The insufficient field methods and averaging techniques are described below¹²⁶:

“BSTEM contains a root-reinforcement algorithm, RipRoot that currently contains a database of 25 species, for which root tensile strength and root architecture have previously been collected. The data collection has focused largely on Southeastern, and Western USA riparian species. As part of this study, five species commonly found along the study reach were investigated, to be added to the RipRoot database, and used in BSTEM model simulations of the TFI.

Collection and analysis of root architecture data is time consuming and laborious. To be efficient with this data collection, root architecture data was collected for a range of tree ages for each of the species, and the average distribution of root densities and diameters was calculated for the range of ages. Plant assemblage data (percent cover, species and age) was recorded at each of the BSTEM modeling sites, so that these average root-architecture parameters and species specific root tensile-strength relations could be applied to give a specific root-reinforcement value at each BSTEM modeling site.” (p. 4-97)

In addition, it seems as though no time variation of vegetation, or cohesion in general, was included in BSTEM modeling. Cohesion varies with changes in vegetation through the seasons and as vegetation is destroyed or regrows. This is potentially a consequential oversight that could rebalance the attribution of erosion in FirstLight’s analysis. No effort was made to address the uncertainty that stems from these omissions.

3.5 “Dynamic” groundwater estimates are based solely on literature values, rather than observations.

In the Princeton Hydro peer review, the scientists raise the issue of pore-water saturation and groundwater, which they identified as being insufficiently characterized in the model.

FirstLight’s response was that the model was informed by literature values¹²⁷:

¹²⁶ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report

¹²⁷ FirstLight Response to Stakeholder Requests for Study Modifications and/or New Studies Based on the Study Report and Meeting Summary. January 17, 2017. p. 2

“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.” (p. 9)

Groundwater is strongly dependent on local precipitation, vegetation, and event sequencing, and this rebuttal thus does not answer the Princeton Hydro question. Because no event-by-event observations of erosion have been made to validate the BSTEM model, the FirstLight claim that “No further study modifications are required given that the modeling results already take this dynamic groundwater table into account” is not supported. An independent review by a US Department of Agriculture Scientist similarly found the groundwater modeling to be insufficient¹²⁸. This over-reliance on literature values and absence of calibration to local values is characteristic of the FirstLight approach in applying BSTEM. As has been stated throughout, model success *must* be independently validated using independent test sites in the reservoir.

3.6 Extrapolation

The extrapolation from individual sites to the full TFI is summarized in the Erosion Causation Study at 6.1.2.1 Extrapolation Methodology (p. 6-20). The extrapolation presented by FirstLight is a subjective analysis, with no statistical rationale given for choosing the extrapolation method¹²⁹. The geomorphological rationale is not detailed beyond the following:

- “b. Identify the riverbank features, characteristics, and erosion conditions at those sites based on the results of the 2013 FRR;
- c. Identify other segments in hydraulic reach 4 (Vernon) or 2 (Northfield Mountain) that have the same features and characteristics.” (p. 6-21)

There was no effort made to test the accuracy of the extrapolation independently (using sites not incorporated in model development), which would be a bare minimum criterium for the wide application carried out here. *Without rigorous documentation of the statistical robustness of extrapolation, any conclusions should be treated as speculative.*

3.7 Boat wake and wind wave erosion

The processes invoked in wave erosion—by boat wakes and wind/current waves—are accentuated and/or facilitated by water level fluctuations. Erosional benches created by breaking waves become erosional fronts. As water comes back up, then is drawn down again, erosion will be focused on these vertical slopes. Knickpoints thus propagate through the beaches. Beach buffering and buttressing of upper slopes is thus diminished, increasing the likelihood of erosion from those areas.

¹²⁸ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p. p. 2 (“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.”)

¹²⁹ Study 3.1.2 *Northfield Mountain / Turners Falls Operations Impacts On Existing Erosion And Potential Bank Instability*. p. 6-21.

The hydropeaking process in the TFI may lead to higher-than-natural stages, particularly during summer days. Because boats are more common during sunny, warm summer days (when energy demand is highest), peaking is likely the most pronounced, with maximum water stored. As a result, boat waves likely cause more inundation and erosion than would normally occur (Figure 22). This is equivalent to the challenges with sea level rise and storms: with higher starting levels, storm surges are more pronounced.



Figure 5.5.3-3: Notching Due to Boat Waves

Figure 22. Figure 5.5.3–3 from Study 3.1.2 shows notching that FirstLight attributes to boat waves. Erosion has clearly occurred at two different levels, which is consistent with raising and lowering of the reservoir level.

3.8 Slope instability due to seepage is ignored/downplayed

According to FirstLight's Erosion Causation Study, seepage was "observed only at a few sites". FirstLight justifies its omission in the following passage and several others like it¹³⁰:

“Bank undercutting by seepage erosion is similarly not included in the version described herein. This is not considered a problem along the Turners Falls reach as evidence of seepage processes were observed at only a few sites by field crews. Finally, the hydrologic effects of riparian vegetation, including interception, evapotranspiration and the accelerated delivery of water along roots and macro pores cannot be simulated at this time.” (p. 4-65)

However, seepage is often difficult to identify in the field, or distinguish from other erosional landforms, particularly after some time has passed. Seepage may lead to other failure modes that would also obscure it as a root cause. Absent more timely, detailed observations, it is difficult to rule out the role of seepage, which thus may be far more relevant than is being implied. For example Field Geology Services in 2007 found that “Springs and seeps were observed repeatedly along banks exposed below higher terraces”¹³¹.

3.9 Floods are identified as important but erosion from floods is not documented

Despite FirstLight's insistence on the importance of floods in causing erosion, no flood erosion is documented except for during Hurricane Irene.

3.10 BSTEM Conclusion

Practitioners using BSTEM have found its results to be uneven and uncertain¹³². They describe how BSTEM requires extensive calibration, often produces erroneous or spatially inconsistent results, and is generally best suited to the Central United States, where it was developed¹³³.

This is no surprise. River erosion processes are notoriously difficult to model, with model inputs often having uncertainties that span orders of magnitude¹³⁴. This has been noted in past independent reviews of BSTEM, which urge caution in interpreting its results. A model like BSTEM is useful for helping to untangle processes in complex river systems. However, its results must be treated with caution, given the uncertainty in both its inputs and the processes it models. The certainty with which FirstLight treats its results is not sound scientific practice, particularly since no uncertainty metrics are presented in FirstLight reports. Instead of relying solely on a flawed model, FirstLight should account for the direct observational evidence that its consultants have collected in the impoundment.

¹³⁰ FirstLight Relicensing Study 3.1.2 2017 Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study Report. Volume II – Main Report

¹³¹ Field (2007) p. 39

¹³² Klavon et al. (2017).

¹³³ Klavon et al. (2017).

¹³⁴ Langendoen, E.J. Review of Relicensing Study No. 3.1.2 *Northfield Mountain / Turners Falls Operations Impact on Existing Erosion and Potential Bank Instability Study*, United States Department of Agriculture. November 28, 2016. 4 p. p. 2 (“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.”)

4. Conclusions and recommendations

Erosion in the TFI potentially threatens riparian land, archaeological artifacts, and infrastructure, riverine and riparian ecology, and reservoir functioning production due to sedimentation and turbine damage by eroded sediments. The erosion likely results at least in part from Project operations. As independent scientists have pointed out in several reports, claims by FirstLight that Project operations contribute minimally to erosion are not robustly supported by BSTEM modeling or field observations.

FirstLight should acknowledge and seek to mitigate the likely causes of this erosion in the TFI, regardless of source. This is in the best interest of the community and is also in FirstLight's interest, given the potential threat to dam operations posed by changing reservoir area and volume, the challenges from increased precipitation and flooding by climate change, and the good will that can be built by addressing valid community concerns regarding erosion.

I propose several straightforward recommendations to better address erosion in the Turners Falls Impoundment and mitigate ongoing erosion as much as possible. These recommendations are reasonable and consistent with prior recommendations by Connecticut River Conservancy and Franklin Regional Council of Governments, as well as independent reviewers.

High-resolution, repeatable monitoring of the reservoir has been lacking and is needed. Much of the monitoring technology is much cheaper than in the past and thus improved study need not be prohibitively expensive. At minimum, repeat lidar monitoring of leaf-off banks of the reservoir should be carried out annually during a fall low-water period. For too long, FirstLight has been able to defer responsibility because erosion monitoring has been too poor to resolve the respective importance of natural processes and Project operations. As numerous scientists have detailed in past reports, modeling with BSTEM does not robustly capture the processes at work in the reservoir. The results of BSTEM should not be treated as scientific fact and should not be a substitute for better monitoring, which could much more reliably identify the causes of erosion.

- The current project operational range for reservoir levels likely exacerbates erosion relative to a narrower range by exposing a large swath of the reservoir banks to erosive properties and raising the “base-level” for natural flooding, adding to flood heights and thus erosive power.
- Lack of rigorous, objective study prevents a complete understanding of erosion mechanisms in the TFI. Rather than just once per year, erosion should be monitored multiple times per year at existing cross-section surveys, using lidar (light detecting and ranging), side-scanning sonar, and other detailed survey techniques. In addition, continuous monitoring of riverbank erosion, using a combination of erosion pins and cameras, should be established at representative sites in the reservoir to better understand timing and causes of erosion events. Study design for these monitoring campaigns should target: a) regular fluctuations in water level during normal project operation; b) natural floods; c) freeze-thaw and snowmelt periods.

- Insights from improved study should inform Project operations to limit erosion. If flow modification cannot mitigate erosion, further bank stabilization techniques should be employed in high-erosion areas in the TFI. Better monitoring (see above) is necessary to identify reaches in need of stabilization, as well as stabilization success.

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- August 2020 Ph.D. in Earth Science, Dartmouth College
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ACCEPTED PUBLICATIONS

Dethier, E. N., Fields, J. F., Renshaw, C. E., and Magilligan, F. J. (2024, *accepted at GSA Bulletin*), Hillslope destabilization delays fluvial recovery from catastrophic flooding.

Gunther, A. B.*, Camill, P., Jr, C. E. U., Stansfield, A., & **Dethier, E. N.** (2024, *accepted at JGR Bioscience*). Using relationships between vegetation and surface soil biogeochemical properties to assess regional soil carbon inventories for South Baffin Island, Nunavut, Canada

Dethier, E.N., Camalan, S., Silman, M.R., Alqahtani, S., Pauca, P., Díaz Levia, J., Fernandez, L., Renshaw, Tomhave, P*, C. E., and Magilligan, F. J., Lutz, D.A. (2023). A global rise in alluvial mining increases sediment load in tropical rivers. *Nature*, 620(7975), 787-793. doi:10.1038/s41586-023-06309-9

Dethier, E.N., Silman, M. R., Fernandez, L. E., Espejo, J. C., Alqahtani, S., Pauca, P., & Lutz, D. A. (2023). Operation mercury: Impacts of national-level armed forces intervention and anticorruption strategy on artisanal gold mining and water quality in the Peruvian Amazon. *Conservation Letters*, 00, e12978. <https://doi.org/10.1111/conl.12978>

Dethier, E. N., Renshaw, C. E., & Magilligan, F. J. (2022). Rapid changes to global river suspended sediment flux by humans. *Science*, 376(6600), 1447-1452.

Cui, K., Camalan, S., Li, R., Pauca, V.P., Alqahtani, S., Plemmons, R., Silman, M., **Dethier, E.N.**, Lutz, D. and Chan, R., 2022, September. Semi-supervised Change Detection of Small Water Bodies Using RGB and Multispectral Images in Peruvian Rainforests. In *2022 12th Workshop on Hyperspectral Imaging and Signal Processing: Evolution in Remote Sensing (WHISPERS)* (pp. 1-5). IEEE.

Renshaw, C. E., **E. N. Dethier**, J. D. Landis, and J. M. Kaste (2022), Seasonal and Longitudinal Variations in Suspended Load Connectivity Between River Channels and Their Margins, *Water Resour. Res.*, 58(4), doi:10.1029/2021WR031212.

Camalan, S., K. N. Cui, V. P. Pauca, S. Alqahtani, M. Silman, R. D. Chan, R. J. Plemmons, **E. N. Dethier**, L. E. Fernandez, and D. A. Lutz (2022), Change Detection of Amazonian Alluvial Gold Mining Using Deep Learning and Sentinel-2 Imagery, *Remote Sensing*, 14(7), doi:10.3390/rs14071746.

Fields, J., C. Renshaw, F. Magilligan, **E.N. Dethier**, and R. Rossi (2021), A mechanistic understanding of channel evolution following dam removal, *Geomorphology*, 395, doi:10.1016/j.geomorph.2021.107971.

Dethier, E. N., Sartain, S.L.*, Renshaw, C.E., and Magilligan, F. J. (2020), Spatially coherent regional changes in seasonal extreme streamflow events in the United States and Canada since 1950. *Science Advances*.

Dethier, E. N., Renshaw, C.E., and Magilligan, F. J. (2020), Toward Improved Accuracy of Remote Sensing Approaches for Quantifying Suspended Sediment: Implications for Suspended-Sediment Monitoring. *Journal of Geophysical Research: Earth Surface*, 125(7), e2019JF005033. doi:10.1029/2019jf005033

Dethier, E. N., S. L. Sartain*, and D. A. Lutz (2019), Heightened levels and seasonal inversion of riverine suspended sediment in a tropical biodiversity hot spot due to artisanal gold mining. *Proceedings of the National Academy of Sciences of the United States of America*, 116(48), 23936-23941. doi:10.1073/pnas.1907842116

Renshaw, C. E., Magilligan F. J., Doyle, H. G., **E. N. Dethier**, and K. M. Kantack (2019), Rapid response of New England (USA) rivers to shifting boundary conditions: Processes, time frames, and pathways to post-flood channel equilibrium. *Geology*, 47(10), 997-1000. doi:10.1130/G46702.1.

Dethier, E.N., F. J. Magilligan, C. E. Renshaw, and K. H. Nislow (2016), The role of chronic and episodic disturbances on channel-hillslope coupling: the persistence and legacy of extreme floods. *Earth Surface Processes and Landforms*, 41(10), 1437-1447. doi:10.1002/esp.3958

PUBLICATIONS SUBMITTED AND IN PREPARATION

Lutz, D. A., Steele, B., **Dethier, E.N.**, Brentrup, J. A., Rubin, H. J.*, Herrick, C., Palace, M., Weathers, K. C., Ducey, M. J., Johnson, K. M., Cottingham, K. L. (2023, *submitted*), Estimating lake water clarity using Landsat imagery: a site-specific reflectance and machine learning approach.

Fields, J. F., Renshaw, C. E., **Dethier, E. N.**, Magilligan, F. J. (2024, *in review*). The longer arc of channel recovery post-dam removal.

Fields, J. F., Perotti, J.*, Kriesler, J.*, Renshaw, C. E., **Dethier, E. N.** (2024, *in review*). Temperature Controls Erosion along Arctic Rivers.

Valencius, I.*, Valencius, I., **Dethier, E. N.**, Sheehan, C., Snyder, N. (2024, *in prep*). Estimating River Suspended Sediment Concentration from Sentinel-2: Expansion of Satellite Methods and Applicability to Multi-Dammed Systems.

Erikson, C., Renshaw, C. E., **Dethier, E. N.**, Magilligan, F. J. (2024, *in review*). Watershed-Scale Runoff Efficiency Response to Climate Variability.

Boardman, E.N., Renshaw, C.E., Shriver, R.K., Walters, R., McGurk, B., Painter, T.H., Deems, J.S., Bormann, K.J., Lewis, G.M., Dethier, E.N., Harpold, A.A. (2024, *in review*). Sources of Seasonal Water Supply Forecast Uncertainty During Snow Drought in the Sierra Nevada.

* Denotes undergraduate student advisee

GRANTS AND AWARDS

- Aug., 2023 Principal investigator. *Satellite Monitoring of Rivers: A Distributed-Sampling Approach to Improve Satellite Estimates of River Water Quality on a Global Scale*. Funded by the National Aeronautics and Space Administration NSPIRES Program for 2023–2025 (\$579,451).
- June, 2020 Research Scientist. *Rapid Change from Alluvial Mining and Development in Madre de Dios, Peru: A Multi-Sensor Fusion Approach to Quantify Terrestrial and Aquatic Impacts and Test Policy Effectiveness*. Funded by the National Aeronautics and Space Administration NSPIRES Program for Jan. 2021– Jan. 2024 (\$748,224). (P.I. David Lutz)
- May, 2020 Guarini School of Graduate and Advanced Studies Award for Best Graduate Teaching. *Annually recognizes the individual in the Guarini Graduate School who best exemplifies the qualities of a college educator*.
<https://graduate.dartmouth.edu/news/2020/06/2020-guarini-teaching-award-recipient-evan-dethier>
- May, 2020 (also received 2017, 2018, 2019)
Outstanding Graduate Student Teacher, Dartmouth College. *Awarded to graduate students nominated by their undergraduate mentees in recognition of their outstanding teaching*.
- May, 2020 Dartmouth Earth Science Best Graduate Student Paper, 2020. *Recognizes the best peer-reviewed publication led by an Earth Science graduate student*.
- Jan, 2020 American Meteorological Soc. Annual Meeting Student Presentation Award in Hydrology, runner-up. *Awards presentations were judged on scientific content, presentation quality, and the overall effectiveness of the presentation*.
- April, 2017 AAG Gordon “Reds” Wolman Graduate Student Research Proposal Award. *Graduate student research grant awarded to the best written proposal, to help cover the costs of data acquisition, fieldwork, and laboratory analysis required to complete dissertation research*.
- April, 2017 AAG Graduate Student Paper Award. *Papers are evaluated on the research contribution to the field of geomorphology and on the effectiveness of the presentation*.
- June, 2017 Gary Malone ‘70 Memorial Award for most engaged graduate student. *Awarded to the graduate student in the Earth Science department who best exemplifies the qualities of Gary Malone ’70*.
- Mar., 2015 Presidential fellowship in graduate recruitment (Dartmouth College). *Awarded to the top PhD recruit for the Earth Sciences Department*.

Mar., 2014 Student Research Grant (Geological Society of America). *Award to provide partial support of Master's and Doctoral thesis research in the geological sciences for graduate students at universities in the United States, Canada, Mexico and Central America.*

INVITED PRESENTATIONS

February 5, 2024 University of Southern California, Dornsife Department of Earth Sciences.

December 14, 2023 AGU session, *Impacts of Mineral Extraction and Artisanal Mining on Societies and Natural Environments.*

October 18, 2023 AGU Earth and Planetary Surface Processes EPSP-Connects Webinar series

May 11, 2023. Bowdoin College, Department of Earth and Oceanographic Sciences.

April 21, 2023. University of Massachusetts, Department of Earth, Geographic, and Climate Sciences.

March 31, 2023. Colby College, Department of Geology.

October 26, 2022. Source to Sink Webinar Series.

February 9, 2022. Temple University, Department of Geology.

TEACHING EXPERIENCE

Primary instructor/mentor

Senior Thesis mentor (11 Honors Thesis students) ^{1,2}	2017–2022
Geomorphology ¹	2022
GIS and Spatial Analysis ^{1,3}	2022, 2024
Introduction to Geology, Lab instructor ³	2024
Introduction to Field Methods in Geology ³	2023
Advanced Hydrology, instructor ²	2020
Hydrology, co-instructor ²	2020
Geology, 11 th and 12 th grades ⁴	2012–2013
Earth Science, 8 th and 9 th grades ⁴	2011–2013
Writing and Journalism ⁴	2013
Anatomy, 7 th grade ⁴	2012

¹Bowdoin College (undergraduate)

²Dartmouth College (undergraduate, graduate)

³Occidental College (undergraduate)

⁴Green Mountain Valley School (Grades 7–12)

Teaching assistant at Dartmouth College

Advanced Methods – Environmental Data Analysis, TA and lecturer	2020
The Stretch, off-campus field program, TA	2014, 2015, 2017
River Processes and Watershed Sciences, TA	2015 & 2016
Environmental Applications of GIS, TA	2015
Remote Sensing, TA	2015
Hydrology and Watershed Resources, TA	2014
Hawaii Volcanology, off-campus field program, TA	2013
Intro to Earth Science: How the Earth Works, TA	2013

MENTORING AND VOLUNTEERING

Unlearning Racism in the Geosciences (URGE)
American Geophysical Union Earth and Planetary Surface Processes Executive Committee Graduate Student Representative to the Faculty, Dartmouth College
Faculty Hiring committee, Graduate Student Coordinator, Dartmouth College
Dartmouth Earth Science Like a Rock mentoring program
Ford Sayre Ski Club, Nordic Ski Coach for six seasons (2013–2018)

Reviewer for *Nature*, *Science*, *Nature Geoscience*, *JGR Earth Surface*, *Water Resources Research*, *Nature Communications*, *JGR Bioscience*, *Regional Environmental Change*, and *AGU Earth and Space Sciences*.

PROGRAMMING AND ANALYTICS

R Programming language used for statistical analysis and database management of large hydrologic datasets, particularly United States Geological Survey and Water Survey of Canada stream and lake monitoring records, Global Historical Climatology Network, and U.S. Historical Climatology Network precipitation and temperature records, and result of satellite remote sensing analysis in Google Earth Engine.

Python Used for retrieval and analysis of satellite imagery, geovisualization.

Google Earth Engine Used for massively scalable analysis of hydrological data, usually derived from satellite products.

Matlab Used for numerical modeling methods, but have mostly replaced Matlab with R.

JMP Used for rapid data visualization and some preliminary statistical analyses. Also sometimes used to teach statistics.

Cloud Compare Used for processing of high-resolution point cloud data derived from lidar or Structure-from-Motion analysis.

ArcGIS and QGIS Used for GIS analysis and teaching, though have transitioned to primarily using Google Earth Engine and R.

PRESS

Selected press for teaching and advising

Peter Tomhave '23 Contributes to Academic Article on Impact of River Mining. August 25, 2023. Tom Porter, Bowdoin College News. <https://www.bowdoin.edu/news/2023/08/peter-tomhave-23-contributes-to-academic-article-on-impact-of-river-mining.html>

EOS Professor Warns of Global Mining Crisis in Tropical Rivers. January 26, 2023. Jane Godiner, Bowdoin College News. <https://www.bowdoin.edu/news/2023/01/eos-professor-clears-up-murky-water-question-in-science-news-feature.html>

2020 Guarini Teaching Award Recipient: Evan Dethier. Jun. 25, 2020. Amy Skinner, Dartmouth Guarini School of Graduate and Advanced Studies, News. <https://graduate.dartmouth.edu/news/2020/06/2020-guarini-teaching-award-recipient-evan-dethier>

Women in Science Project Opens Door to Top Journal Publication. Nov. 26, 2019. Bill Platt, Dartmouth News. <https://news.dartmouth.edu/news/2019/11/women-science-project-opens-door-top-journal-publication>

In Dublin, an Undergraduate Dives Into Big Data. Sep. 27, 2018. Joseph Blumberg, Dartmouth News. <https://news.dartmouth.edu/news/2018/09/dublin-undergraduate-dives-big-data>

Two Juniors Named Goldwater Scholars. Apr. 29, 2020. Hannah Silverstein, Dartmouth News. <https://news.dartmouth.edu/news/2020/04/two-juniors-named-goldwater-scholars>

Selected press for mining in rivers

Ríos en riesgo: minería provoca cambios profundos en afluentes de todo el mundo. September 20, 2023. Antonio José Paz Cardona, Mongabay Latin America. <https://es.mongabay.com/2023/09/rios-en-riesgo-mineria-provoca-cambios-en-afluentes-de-todo-el-mundo-estudio/>

Satellite images show the widespread impact of mining on tropical rivers. August 23, 2023. Bryony Walmsley, Nature Vol 620, 729-730. <https://doi.org/10.1038/d41586-023-02349-3>

Illegal mining has muddied tropical rivers worldwide. January 11, 2023. Paul Voosen. Science, Vol 379, Issue 6628. <https://www.science.org/content/article/illegal-mining-has-muddied-tropical-rivers-worldwide>

Mercury-Based Gold Mining Haunts Peruvian Rain Forests. December 15, 2021. Alka Tripathy-Lang. EOS. <https://eos.org/articles/mercury-based-gold-mining-haunts-peruvian-rain-forests>

Illegal gold mining continues to harm Amazon ecosystem. December 15, 2021. Liza Lester. AGU News. <https://news.agu.org/press-release/illegal-gold-mining-continues-to-harm-amazon-ecosystem/>

Gold Mining Critically Impairs Water Quality in Rivers Across Peruvian Biodiversity Hotspot. Nov. 11, 2019. Dartmouth College Communications. https://www.dartmouth.edu/press/releases/gold_mining_critically_impairs_water_quality_in_rivers_across_peruvian_biodiversity_hotspot.html

Madre de Dios: imágenes satelitales muestran el impacto de 34 años de minería ilegal en ríos Translation: Madre de Dios: satellite images show the impact of 34 years of illegal river mining. Feb. 05, 2020. Mongabay Latam, El Comercio. <https://elcomercio.pe/tecnologia/ecologia/madre-de-dios-imagenes-satelitales-muestran-el-impacto-de-34-anos-de-mineria-ilegal-en-rios-fotos-noticia/>

Artisanal gold mining polluting Peruvian biodiversity hotspot—study. November 17, 2019. Valentina Ruiz Leotaud, mining.com. <https://www.mining.com/artisanal-gold-mining-polluting-peruvian-biodiversity-hotspot-study/>

Selected press for changing discharge and sediment flux

Satellites Show Magnitude of Human Influence on River Sediment Flux. July 12, 2022. Mohammed El-Said. EOS. <https://eos.org/articles/satellites-show-magnitude-of-human-influence-on-river-sediment-flux>

New analysis: Extreme flows in US streams are rising: mixed trends become clearer when similar streams are grouped together. December 05, 2020. Scott K. Johnson. Ars Technica. <https://arstechnica.com/science/2020/12/new-analysis-extreme-flows-in-us-streams-are-rising/>

Study Finds River Flooding on The Rise Across U.S. and Canada. January 31, 2021. The Weather Channel. <https://weather.com/news/weather/video/study-finds-river-flooding-on-the-rise-across-us-and-canada>

Selected press for rapid analysis of Hurricane Ida Flooding in Northeast US

Searches, sorrow in wake of Ida's destructive, deadly floods. September 3, 2021. Mike Catalini, Wayne Parry, and Michael R. Sisak. ABC News. <https://abcnews.go.com/US/wireStory/cleanup-mourning-continue-ida-soaks-northeast-us-79809550>

Ida's fatal power didn't shock scientists who study how climate change primed the pump. September 4, 2021. Frank Kummer. <https://www.inquirer.com/science/climate/ida-climate-change-philadelphia-flooding-tornado-20210904.html>

Ida's impact from the Gulf Coast to Northeast — by the numbers. September 3, 2021. Ian Livingston. <https://www.washingtonpost.com/weather/2021/09/03/hurricane-ida-numbers-surge-wind-pressure-damage/>

CONTRIBUTED PRESENTATIONS

- Dethier, E.N.**, Silman, M., Fernandez, L. E., Leiva, J. D., Alqahtani, S., Pauca, P., ... & Tomhave, P. (2023). A global 21 st century mining boom in tropical river systems: the driver of changes to forest health, riparian geomorphology, and suspended sediment transport. AGU23.
- Fields, J., Renshaw, C. E., Magilligan, F. J., & **Dethier, E.N.** (2023). Intrinsic and Extrinsic Controls of Channel Recovery Post-Disturbance and Lessons for River Restoration. AGU23.
- Dethier, E.N.**, Silman, M., Díaz Leiva, J., Alqahtani, S., Fernandez, L. E., Pauca, P., ... & Lutz, D. A. (2022, December). The recent rise of mining in rivers is a global crisis. In AGU Fall Meeting Abstracts (Vol. 2022, pp. H52C-03).
- Dethier, E.N.**, Renshaw, C.E. and Magilligan, F.J., 2021. Satellite analysis reveals global spatial and temporal variation in river suspended sediment transport. In *AGU Fall Meeting, 2021*.
- Dethier, E.N.**, Silman, M.R., Fernandez, L.E., Caballero Espejo, J., Alqahtani, S. Pauca, P. and Lutz, D.A., 2021. Changing Frequency of Flood and Drought on Rivers in the United States and Canada. In *AGU Fall Meeting, 2021*.
- Dethier, E.N.**, Sartain, S.L.*, Magilligan, F.J. and Renshaw, C.E., 2020, January. Shifts in the locus of artisanal gold mining and changes in water quality following national-level intervention in the Peruvian Amazon. In *100th American Meteorological Society Annual Meeting*.
- Dethier, E.N.**, Renshaw, C.E. and Magilligan, F.J., 2019. Temporal and spatial variations in watershed connectivity dictate suspended sediment source and fate. *AGUFM, 2019*, pp.EP51C-2103.
- Magilligan, F.J., Renshaw, C.E. and **Dethier, E.N.**, 2019. Bankfull Channel Adjustments to Episodic and Long-Term Changes in Sediment Supply. *AGU Fall Meeting, 2019*, pp.EP51F-2189.
- Dethier, E.N.**, Magilligan, F.J. and Renshaw, C.E., 2019, March. Timescales of response to a catastrophic flood: Quantifying “event” and “post-event” effects to assess stream recovery following Tropical Storm Irene. In *Northeastern Section-54th Annual Meeting 2019*. GSA.
- Dethier, E.N.**, Magilligan, F.J. and Renshaw, C.E., 2018, December. Elevated post-event sediment yield extends the impact of catastrophic flooding. In *AGU Fall Meeting Abstracts*.

- Dethier, E. N.**, Magilligan, F., and Renshaw, C., 2017b, The Legacy of an Extreme Flood: Landslides Extend Geomorphic Impacts to the Present, *in* Proceedings AAG Annual Meeting, Boston, MA.
- Dethier, E. N.**, Magilligan, F., and Renshaw, C., 2017a, Quantifying Suspended Sediment Concentration from Space: Global Variability and Trends, *in* Proceedings GSA Annual Meeting, Seattle, WA.
- Dethier, E. N.**, Magilligan, F., and Renshaw, C., 2016, Landslides Modulate Transient Adjustment to Catastrophic Flooding, *in* Proceedings GSA Annual Meeting, Denver, CO.
- Dethier, E. N.**, Magilligan, F., Renshaw, C., and Kantack, K., 2015, Response and recovery of streams to an intense regional flooding event, *in* Proceedings AGU Fall Meeting, San Francisco, CA.
- Dethier, E. N.**, Magilligan, F., Renshaw, C. E., and Sinclair, D. *, 2015, Irene-generated hillslope failures in New England: Widespread, persistent sources of sediment to streams, *in* Proceedings GSA Meeting, Northeast Section, Bretton Woods, NH.
- Doyle, H. G., Renshaw, C. E., Magilligan, F. J., and **Dethier, E. N.**, 2015, Stream Channel Adjustments to Dam Removal in Headwater Catchments, *in* Proceedings AGU, Fall Meeting, San Francisco, CA.
- Kantack, K., Renshaw, C., Magilligan, F., and **Dethier, E. N.**, 2015, Response and Recovery of Streams From an Extreme Flood, *in* Proceedings AGU Fall Meeting, San Francisco, CA.
- Dethier, E. N.**, Magilligan, F., Renshaw, C., and Sinclair, D., 2014, Persistence of Episodic Extreme Events: Sustained Colluvial Contributions of Fine Sediment to Vermont Rivers Post-Irene, *in* Proceedings AGU Fall Meeting, San Francisco, CA.
- Gartner, J., Renshaw, C., Magilligan, F., Buraas, E., **Dethier, E. N.**, and Dade, W., 2014, Spatial gradients in stream power and the implications for lateral and downstream transport of material during the 2013 Floods in Colorado and 2011 Irene Floods in Vermont, USA, *in* Proceedings AGU Fall Meeting, San Francisco, CA.
- Dethier, E. N.**, 2013, Knickpoint-Controlled Landscape Evolution In the Middle Boulder Creek Watershed, CO, *in* Proceedings GSA Meeting, Northeast Section, Bretton Woods, NH.



June 13, 2022

Secretary Bethany Card
Executive Office of Energy and Environmental Affairs
100 Cambridge St, Suite 900
Commonwealth of Massachusetts
Boston, MA 02114

via electronic mail

Re: Turners Falls Hydroelectric Project (FERC No. 1889) and Northfield Mountain Pumped Storage Project (FERC No. 2485) FERC Relicensing and Massachusetts Clean Water Act § 401 Certification

Dear Secretary Card,

As the settlement process of the Federal Energy Regulatory Commission (FERC) relicensing of Turners Falls Dam and the Northfield Mountain Pumped Storage Project on the Connecticut River moves closer toward completion, Connecticut River Conservancy (CRC) is compelled to raise several concerns that require the Massachusetts Department of Environmental Protection's (DEP) immediate attention. If DEP continues to wait for FirstLight's Clean Water Act (CWA) § 401 water quality certification application to fully engage in the FERC settlement process, it risks, among other things: (1) that FERC already will be presented with a settlement involving minimum flows below Turners Falls Dam that will not protect and restore designated uses for that river segment, and thus will not comply with Massachusetts surface water quality standards; (2) that the time and effort put in by the parties to reach a flawed settlement will be such that their positions will have solidified, making it more difficult to reach consensus during the CWA § 401 certification process; and (3) that the result of DEP's non-engagement earlier in the process will be protracted litigation over the § 401 certification. CRC would prefer to avoid the latter scenario because of the time and cost involved for everyone, which also delays implementation of those new license conditions that will result in improvements for the Connecticut River.

These are real and foreseeable risks. But they are not inevitable outcomes. CRC believes that if DEP fully engages in the process now, it can avoid or mitigate these risks. But time is of the essence.

Below we outline the four primary deficiencies in how the FERC process is unfolding as it relates to compliance with state surface water quality standards. This is by no means an exhaustive list—for example, it does not include significant concerns CRC has about erosion in the Turners Falls impoundment or the timing of fish passage installation at the dam. But the issues below are fundamental and must be addressed if DEP plans to issue a CWA § 401 certification for Turners Falls Dam and the Northfield Mountain Pumped Storage Project.

The starting point for DEP's § 401 certification analysis is the Clean Water Act. The objective of the CWA is "to *restore* and maintain the chemical, physical, and biological integrity of the Nation's waters."¹ Turners Falls Dam and the Northfield Mountain Pumped Storage Project cause, and without significant operational changes (that are currently not being contemplated), will continue to cause impairments to

¹ 33 U.S.C. § 1251(a) (emphasis added); see also 314 CMR § 4.01(3).

the Connecticut River that prevent the affected and legally impaired river segments from attaining and protecting existing and designated uses.

I. The Proposed Minimum Flows Below Turners Falls Dam Are Insufficient to Meet Water Quality Standards

On March 17, 2022, FirstLight submitted the Flows and Fish Passage Agreement in Principle ("AIP") to FERC.² The AIP set forth the proposed minimum flow schedule for releases at Turners Falls Dam. The months of concern for CRC are July through March, which prescribed proposed minimum flows as follows:

- o July 1–November 15: 250 cfs, with a chance of increased minimum flows up to 400 cfs pending further analysis on state-listed plant species
- o November 16–March 31: as close to 400 cfs as possible.

Under the Massachusetts Surface Water Quality Standards, 314 CMR 4.06, the Connecticut River from Turners Falls Dam to the Holyoke Dam is designated as Class B waters. 314 CMR 4.05 (b) states that Class B "waters are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. . . . These waters shall have consistently good aesthetic value." The existing and designated uses that must be legally protected are aquatic life use (ALU), boating, and fishing.

In the Massachusetts Year 2018-2020 Integrated List of Waters (finalized in February 2022), Segment 34-03 is the 3.7-mile segment between the Turners Falls Dam and the confluence with the Deerfield River. This segment is listed as impaired for *dewatering, flow regime modification*, E. coli bacteria, PCBs in fish tissue, and total suspended solids. Thus, the existing and designated uses in the river segment below the Turners Falls Dam described above are considered impaired under the current license conditions.

314 CMR 4.03(3)(b) states, "In waters where flows are regulated by dams or similar structures, the lowest flow condition at which aquatic life criteria must be applied is the flow equaled or exceeded 99% of the time on a yearly basis, or another equivalent flow agreed upon by the Department and the federal, state, or private entity controlling the flow.... When the Department issues a 401 Water Quality Certification of an activity subject to licensing by the Federal Energy Regulatory Commission, *flows shall be maintained or restored to protect existing and designated uses.*" (emphasis added).

Evidence currently available to DEP indicates that the flows proposed in the AIP for July through March will neither maintain nor restore existing and designated uses, specifically the ALUs and boating. A particularly startling implication is that proposed summertime flows will protect less than 6% of the wetted usable area for benthic macroinvertebrates in the area below the Turners Falls dam. CRC details that evidence in the attached Technical Memorandum for both ALUs and boating uses. See **Exhibit 2**. Based on that evidence, CRC recommends the following flow levels:

- July 1 to November 15: 1,000 cfs to provide habitat for fallfish, longnose dace, tessellated darter, and macroinvertebrates. This flow also will be a navigable flow for recreation.
- November 16-March 31: At least 500 cfs to maintain some of the wetted usable area for ALUs.

² See Docket No. P-2485, Accession No. 20220318-5004 (March 18, 2022), attached as **Exhibit 1**.

Any § 401 certification that includes minimum flows currently proposed in the AIP will be vulnerable to legal challenge. Thus, it is in DEP's interest, in order to have the best chance at avoiding protracted litigation, to conduct and provide its analysis of the proposed flow regime below Turners Falls Dam as soon as possible. CRC is confident that any such use attainability analysis will conclude that the flows proposed in the AIP are not sufficient to protect and restore existing and designated uses in the bypass reach below Turners Falls Dam, but that protection and restoration of ALUs and boating uses *are attainable* with the higher flow levels recommended by CRC.³

II. The Purported Protection of Two Plant Species Does Not Justify Low Flows That Do Not Protect Aquatic Life Uses

The current proposed minimum flows below Turners Falls Dam during the summer, fall, and winter are based primarily on a single biological factor—the presence of two rare plant species in the river segment below the dam⁴—and at the expense of impaired aquatic habitat protected by the CWA. When considered in light of the suite of designated ALUs and recreation uses that the proposed minimum flows will *not* protect or restore, the establishment of minimum flows based on two plants species is arbitrary and wilts under legal scrutiny for several reasons.⁵

First, the plants would not even be growing in their present locations in the bypass reach but for the artificial dewatering caused by the hydropower facilities. In other words, these plants only exist as a result of the ongoing impairment to the river. Using the plants to justify low flows so the plants are not harmed creates a logical fallacy: the listed impairment for that river segment (dewatering) created the condition that allowed the plants to establish there, which in turn prevents the impairment from being addressed. This factor weighs heavily against elevating protection of the plant species above all other ALUs in setting minimum flows below the dam.

Second, it is not clear that the plants at issue are even an ALU. Both species are listed in the U.S. Army Corps of Engineers National Plant List as facultative wetland species, meaning that they usually occur in wetlands. They are, however, occasionally found in nonwetlands and are thus not riverine species.⁶ If they are not an ALU, then they are not a designated use protected under the CWA, and the protection of actual ALUs would definitively trump the protection of these plants. Moreover, CRC has asked for—but has not yet received—the most up-to-date data and analysis regarding the locations and elevations of the plant communities in the bypass reach. While CRC understands and respects the need to keep locational information confidential, that information is being used to justify flows in the Connecticut River below Turners Falls Dam for the next 40–50 years, to the detriment of other aquatic life. Given the long-term ramifications of the FERC relicensings, the most current plant data and analysis must be

³ See 314 CMR § 4.03(4)(a)(4) (only allowing a removal of a use if there is a determination that it is not feasible to operate the dam “in a way that would result in the attainment of the use”).

⁴ The two species, Tussock Hairgrass (TH) (*Deschampsia caespitosa* ssp. *glauca*) and Tradescant's Aster (TA) (*Symphotrichum tradescanii*), have established themselves along portions of the bypass reach that were historically underwater.

⁵ To be clear, CRC is not advocating against protecting rare plants generally, but context matters. Here, if the rare plants *and* the ALUs cannot both be protected—a premise for which the data, evidence, and analysis are currently lacking—the plants must give way to the more sensitive use that requires more water, not less.

⁶ The fact that the plants are known to exist in nonwetlands suggests that there is a possibility of relocating them to an area that would not be impacted by the higher flows necessary to protect ALUs in that stretch of the river. Until an examination of this possibility is fully exhausted, the plants should not be part of any balancing analysis, even assuming they are aquatic fauna.

available for public scrutiny.⁷

Third, assuming for argument's sake that the plants are aquatic fauna and therefore a designated use under Massachusetts surface water quality standards, DEP's obligation when certifying a project as complying with state water quality standards is to identify the most sensitive existing or designated use and to ensure that use is enhanced, maintained, and protected. That obligation is different than the mission of the Massachusetts Division of Fish and Wildlife's Natural Heritage and Endangered Species Program (NHESP), which is to protect species listed as endangered or threatened under the Massachusetts Endangered Species list, irrespective of whether those species comprise designated uses under state water quality standards. Thus, DEP must undertake its own independent analysis to determine the most sensitive ALUs needing protection in the bypass reach below the dam.

Fourth, even if the plants are an ALU, the plain language of the CWA evinces a preference for "fish, shellfish, and wildlife," versus plants. See 33 U.S.C. § 1251(a)(2) ("[I]t is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983."). Thus, if there are competing ALUs, the CWA's explicit hierarchy weighs against favoring aquatic flora over "fish, shellfish, and wildlife."⁸

Fifth, the use of the plants to set flow levels ignores the needs of other Massachusetts fish species of special concern known to exist in the area below the dam. CRC expects that flows sufficient to support ALUs also would provide additional habitat to support two fish species that NHESP has listed as species of special concern, the burbot (*Lota lota*) and longnose sucker (*Catostomas catostomas*). Hartel et al. (2002) describes a 12-inch burbot caught in a pool below the Turners Falls dam in December 2000 by an angler who had noted that other specimens have also been caught there (see page 191). Young burbot feed on aquatic insects and crustaceans, while large adults feed on fish. Hartel et al. (2002) states that records from 1940–60 show that longnose sucker historically occurred in the Connecticut River and Westfield Rivers and at the mouth of the Chicopee River. Pollution and habitat alteration along the mainstems have limited surviving populations. The water quality in the Connecticut River has improved greatly in recent decades, and the relicensings provide a once-in-a-generation opportunity to reduce the negative effects of habitat alteration. Hartel et al. (2002) states that longnose suckers vacuum a wide variety of aquatic invertebrates and algae off the bottom of rivers, highlighting the need to protect flows suitable for benthic macroinvertebrates.

The available scientific evidence demonstrates that accommodating the minimum flows purportedly required for the plants will continue the degradation of water quality necessary to maintain and restore other ALUs and prevent the attainment of the boating recreation use. The applicable law does not permit this outcome. Further, to CRC's knowledge, there has been no demonstration that any anticipated harm to the rare plants due to higher flows cannot be mitigated by relocation of those plant communities. For all of these reasons, the protection of the state-listed plants found in the stretch of river below Turners Falls Dam due to the ongoing impairments to the river should not and cannot be

⁷ CRC believes this data and analysis should be available to the public, but at a minimum, CRC requests all available documents from state agencies related to the data and analysis of the locations of the rare plants in the bypass reach so it can conduct its own analysis of the threat to those species, if any, posed by higher flows. CRC would be willing to consider a protective order covering the information provided.

⁸ The CWA also explicitly mentions providing for recreation in and on the water as a national goal. 33 U.S.C. § 1251(a)(2).

used as justification to set future flow levels. We attach as **Exhibit 2** a memorandum recommending flows that will meet water quality standards.

III. Increases in storage capacity at Northfield Mountain Will Exacerbate Existing CWA Impairments and Impact Recreation

Massachusetts lists all three sections of the Connecticut River that make up the Turners Falls Impoundment (TFI) above Turners Falls Dam as “impaired” Class B waters under CWA § 303(d), in part due to flow regime modification.⁹ As is the case for the river sections below the dam, the existing and designated uses that must be legally protected are ALUs, boating, and fishing. Appendix 15 to the 2018–20 Massachusetts Integrated List states that these segments are “not supporting” the Fish, other Aquatic Life and Wildlife Use because of the ongoing impairments of flow modification and streambank alteration and, in the case of Barton Cove, several species of non-native invasive aquatic plants. To legally issue a CWA § 401 certification for the FERC relicensings of Turners Falls Dam and the Northfield Mountain Pumped Storage Project, DEP must ensure the protection and restoration of the designated uses the river segments are currently “not supporting.”

FirstLight is seeking to expand the elevation ranges (and therefore the amount of water it uses) from the upper reservoir.¹⁰ Full and unrestricted use of the extra volume in the upper reservoir will make impairments worse, rather than bring the TFI into attainment of designated uses. FirstLight’s Amended Final License Application (AFLA) proposes significant operational changes, including expansion of the upper reservoir, will continue to accelerate erosion and impact the legally protected recreation use. This has been amply demonstrated by the conditions created on June 12–13, 2021, when FirstLight operations brought the impoundment down to a water level of 177.5 msl, which was within the current and proposed allowed minimum elevation of 176 msl, as measured at the dam. This event stranded boats, exposed aquatic habitat, and was in response to the increasingly likely instances of low or negative cost energy prices created during times of high solar energy generation. Because there is little to no attention being given to addressing these issues, DEP will need to conduct a Use Attainability Analysis, which then must be approved by EPA, to determine if it is feasible to operate the facilities “in a way that would result in the attainment of the use.” 314 CMR 4.03(4)(a)(4). Such analysis requires FirstLight to submit to DEP the information necessary for its completion, and DEP must provide public notice and opportunity for a public hearing “prior to removal of a use or the designation of a partial.” *Id.* at 4.03(4)(b). There may be operational changes FirstLight can make to operate the facilities so as to attain the designated uses of the TFI, but those are not currently being contemplated in FirstLight’s AFLA.

IV. Requiring a Decommissioning Plan and Sufficient Funding Is Necessary to Avoid Future Water Quality Standard Violations When the Facilities Are Shuttered

⁹ MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION, FINAL MASSACHUSETTS INTEGRATED LIST OF WATERS FOR THE CLEAN WATER ACT 2018/2020 REPORTING CYCLE (Nov. 2021) at 168. Segment 34-01 is the 3.5-mile segment between the Vermont/New Hampshire/Massachusetts state line and the Route 10 bridge and is listed as impaired for alteration in stream-side or littoral vegetative covers, *flow regime modification*, and PCBs in fish tissue. Segment 34-02 is the 11.4-mile segment between the Route 10 bridge and the Turners Falls Dam, excluding Barton Cove and is listed as impaired for alteration in stream-side or littoral vegetative covers, *flow regime modification*, water chestnut, and PCBs in fish tissue. Barton Cove is MA34122 and is listed as impaired for curly-leaf pondweed, Eurasian water milfoil (*Myriophyllum spicatum*), fanwort, water chestnut, E. coli, and PCBs in fish tissue. *Id.*; 33 U.S.C. § 1313(d).

¹⁰ See TFI Technical Memorandum, attached as **Exhibit 3**, at 2–3.

At some point in the future—potentially before the end of the next license terms—either Turners Falls Dam, the Northfield Mountain Pumped Storage Project, or both will reach the end of their useful lives, as is happening to many other hydropower facilities around the country. On January, 11, 2022, CRC provided a memorandum to the Massachusetts Executive Office of Environmental Affairs (EEA) outlining the legal authority for DEP to require financial assurances from FirstLight as conditions of a CWA § 401 certification issued for these facilities (“Financial Assurances Memo”). The Financial Assurances Memo is attached here as **Exhibit 4**.

In that January 11th transmission and in follow-up, CRC requested a meeting to discuss the decommissioning funding issue but such a meeting has not yet been scheduled. As we stated in our Financial Assurances Memo:

Conditioning CWA § 401 certifications on such financial assurances will ensure that federal and state requirements are met and that the physical, chemical, and biological integrity of rivers, including unobstructed flows, are *restored* to protect existing and designated uses. Requiring such financial assurances also will ensure that the Massachusetts tax and ratepayers and host communities are not burdened with the bill for such restoration, which is good public policy already being practiced in the context of many other energy generating contexts throughout the state.

Through this letter, CRC again requests a meeting on the requirement for decommissioning and removal financial assurances and urges EEA and DEP to speed up the process of internally investigating that issue. Although we are completely confident in DEP’s authority to include financial assurances as a condition of its § 401 certification, such a condition may represent an issue of first impression for hydropower facilities in Massachusetts. As such, it will require appropriate vetting by state agencies, which will inevitably take time. Moreover, it may be necessary to develop a decommissioning plan in order to properly assess the amount of financial assurances necessary. This is yet one more reason for DEP to fully engage in this process *well in advance of* receiving FirstLight’s CWA § 401 certification application.

CONCLUSION

The stretches of the Connecticut River both downstream and upstream of the Turners Falls Dam have suffered impairments for decades caused by the operations of the dam and the Northfield Mountain Pumped Storage Project that have impeded restoration of those river stretches and prevented them from attaining state surface water quality standards. As one of the parties requesting a delay in the issuance of FERC’s ready for environmental analysis and the re-starting of long-stalled settlement discussions, CRC recognizes that there has been significant and positive progress in those talks. However, for the reasons outlined above, continued settlement talks without the engagement of DEP are creating more harm than good.

CRC requests DEP engage FERC and request issuance of the ready for environmental analysis and so begin the state § 401 water quality certification process. In the meantime, we request a meeting to review the issues outlined above and to discuss the public process supporting the formal § 401 water quality certificate.

CRC appreciates DEP’s consideration of these issues and the significant attention all of the state

agencies have been giving this complex and long-running licensing process.

Sincerely,

A handwritten signature in black ink, appearing to be 'A. Fisk'.

Andrew Fisk, Ph.D.
Executive Director

EXHIBIT 1: Fish and Flow Agreement in Principle (AIP) filed with FERC
EXHIBIT 2: Technical memo on flows below the Turners Falls Dam
EXHIBIT 3: Technical memo on TFI impairments and recommendations
EXHIBIT 4: Decommissioning memo

cc: Settlement service list; MassDEP Commissioner; EPA Region 1; FERC; FirstLight Power; MA legislative delegation; Kevin Cassidy; Ron Shems



Northfield Mountain Station
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Northfield, MA 01360
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Email: alan.douglass@firstlightpower.com

Alan Douglass
Regulatory Compliance Manager

March 17, 2022

Via Electronic Filing

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

Re: Turners Falls Hydroelectric Project (FERC No. 1889), FirstLight MA Hydro LLC, Northfield
Mountain Pumped Storage Project (FERC No. 2485), Northfield Mountain LLC, Status Update

Dear Secretary Bose:

As the Federal Energy Regulatory Commission (FERC) is aware from recent filings, over the course of the past several months, the licensees for the above-referenced projects (collectively, FirstLight) have been engaged with federal and state resource agencies, local communities, environmental organizations, Native American tribes, and other stakeholders in renewed discussions on a broad range of issues pertaining to fish passage, stream flows, recreation, and cultural resources related to relicensing of the projects.

On February 28, 2022, FirstLight filed with FERC Agreements-in-Principle (AIP) on Whitewater Boating Releases and Recreation Improvements. In that same letter, FirstLight indicated it had reached conceptual agreement on a Flows¹ and Fish Passage AIP. Please find attached the AIP for Flows and Fish Passage, including the signature pages.

FirstLight and the stakeholders are now negotiating a comprehensive, binding Settlement Agreement that aims to fully resolve all relicensing issues. FirstLight is targeting the summer 2022, for filing the Settlement Agreement and again requests FERC to reserve issuing its Ready for Environmental Analysis Notice until after the Settlement Agreement is filed. FirstLight and the stakeholders needed to adjust the previous Settlement Agreement schedule due to the delay in finalizing the Flows and Fish Passage AIP.

Thank you for your consideration.

Respectfully,

A handwritten signature in black ink that reads "Alan J. Douglass".

Alan Douglass
Regulatory Compliance Manager

Attachments: AIP for Flows and Fish Passage

¹ Flows refers to Project operations including bypass flows, base flows, ramping, and water level management.

**TURNERS FALLS HYDROELECTRIC PROJECT
FERC PROJECT NO. 1889**

**NORTHFIELD MOUNTAIN PUMPED STORAGE PROJECT
FERC PROJECT NO. 2485**

**AGREEMENT IN PRINCIPLE TO DEVELOP
A RELICENSING SETTLEMENT AGREEMENT**

March 17, 2022

WHEREAS, FirstLight MA Hydro LLC and Northfield Mountain LLC (collectively, FirstLight) are the Federal Energy Regulatory Commission (FERC) licensees for the Turners Falls Hydroelectric Project, FERC Project No. 1889 (Turners Falls Project) and Northfield Mountain Pumped Storage Project, FERC Project No. 2485 (Northfield Mountain Project), respectively. Both the license for the Turners Falls Project and the license for the Northfield Mountain Project expired April 30, 2018. The Projects have been operating on annual licenses pursuant to Section 15 of the Federal Power Act (FPA) since that time.

WHEREAS, in accordance with the requirements of the FPA and FERC's regulations, FirstLight filed a Final Application for New License (FLA) for the Turners Falls and Northfield Mountain Projects with FERC on April 29, 2016. Because certain environmental studies had not yet been completed as of the statutory deadline for filing of the FLA, FirstLight filed a separate Amended Final License Application for each Project on December 4, 2020 (AFLA), including FirstLight's proposed protection, mitigation and enhancement (PM&E) measures to be included in the new licenses and the scientific and evidentiary basis for those measures.

WHEREAS, since filing of the AFLAs, FirstLight has been engaged with federal and state resource agencies, local communities, environmental organizations, Native American Tribes, and other stakeholders to consider agency and stakeholder proposals for additional PM&E measures on a broad range of issues pertaining to fish passage, streamflows, recreation, and cultural resources, with the goal of developing a comprehensive settlement agreement.

WHEREAS, FirstLight has been engaged specifically with the Parties to this Agreement in Principle (AIP), including the Massachusetts Division of Fisheries and Wildlife (MDFW), Massachusetts Natural Heritage and Endangered Species Program (NHESP), National Marine Fisheries Service (NMFS), The Nature Conservancy (TNC), and the United States Fish and Wildlife Service (USFWS). The Parties have now achieved conceptual agreement on minimum bypass flows to benefit fisheries resources and their habitats, operational restrictions to benefit downstream fish and wildlife habitat, and project modifications to improve upstream and downstream fish passage, designed to function as part of a framework for FERC's proposed action to be analyzed in the ESA section 7 context, Federal Power Act Section 18 prescriptions and for development of a Final Settlement Agreement facilitating the resolution of all issues relating to the relicensing of the Projects. The Parties are still negotiating certain critical elements such as a protocol for dampening Great River Hydro (GRH) peaking flows, the Cobblestone tiger beetle mitigation plan, and fish passage performance metrics and adaptive management provisions.

NOW, THEREFORE, the Parties agree in principle as follows:

PART I: OVERVIEW AND INTENT

- A. The Parties agree to negotiate toward a Final Settlement Agreement based on the terms of this AIP, with the intention reaching a Final Settlement Agreement, if one can be reached, no later than June 30, 2022.
- B. All Parties enter into this AIP without any admission of law or fact. The Parties acknowledge that the Final Settlement Agreement must include other material terms that have not yet been agreed upon (for example impoundment bank erosion) and is subject to agreement on language embracing all of the terms agreed to in principle as set forth in Part II herein.
- C. The Parties recognize that the Final Settlement Agreement and any other related agreements negotiated pursuant to this AIP are subject to formal and final review and approval of the Parties' management, executives, boards of directors, and other leadership, as necessary and appropriate to comply with corporate, municipal and agency requirements. The signatories to this AIP are the principal negotiators for each Party, who represent by their signatures only that:
- They have informed their respective management or leadership of the terms of this AIP.
 - They have been authorized to negotiate toward a Final Settlement Agreement based in substance on the terms of this AIP.
- D. All Parties recognize and acknowledge that this AIP is not legally binding and does not give rise to any enforceable rights in contract.
- E. Unless and until a Final Settlement Agreement is executed by the Parties, any Party may take any action before FERC or any other agency as that Party unilaterally determines necessary to protect its interests.
- F. In the event that this AIP does not culminate in a Final Settlement Agreement, it shall be null and void. No Party shall use this AIP as evidence of any other Party's position on any issue addressed in this AIP or as evidence that any term should or should not be incorporated into the New Licenses for the Turners Falls and Northfield Mountain Projects.
- G. Nothing in this Agreement shall be construed as a waiver of any state or federal agency authority to carry out its statutory and regulatory mandates, including the requirement for FERC to engage in consultation under Section 7 of the Endangered Species Act. All parties understand that the terms conceptually agreed upon in this document do not circumscribe the authority of the agencies or their analyses under Section 7 of the Endangered Species Act.

PART II: PROTECTION, MITIGATION AND ENHANCEMENT MEASURES- OPERATIONS**1 OPERATIONS****1.1 Project Operations****1.1.1 Turners Falls Project Operations**

- (a) FirstLight shall operate the Turners Falls Hydroelectric Project in accordance with the following operational flow regime until the third (3rd) anniversary of the date of license issuance.

FirstLight has included two timing elements to address the new operational paradigm. From license issuance until the third (3rd) anniversary of the date of license issuance, FirstLight shall institute the minimum flows in the bypass and below Cabot Station and Cabot Station up/down ramping in paragraph (a) and (b), as a license condition, and also put processes in place with GRH and ISO-NE to assure success in meeting its obligations for Flow Stabilization restrictions described in paragraph (c). In addition, Station No. 1 upgrades (described later) will be completed during this period. FirstLight also will submit to FERC for approval no later than 1 year after license issuance a project operation, monitoring and reporting plan after consultation with the agencies. On the third (3rd) anniversary of the date of license issuance and upon FERC's approval of the project operation, monitoring and reporting plan, FirstLight shall institute the full suite of flow enhancements shown in paragraphs (a), (b) and (c) (i.e., minimum flows in bypass and below Cabot Station, Cabot Station up/down ramping and flow stabilization restrictions). Table 1.1.1-1 summarizes the operations from license issuance through the third (3rd) anniversary of the date of license issuance.

Table 1.1.1-1: Operating Conditions from License Issuance through the third (3rd) anniversary of the date of license issuance: Turners Falls Dam Minimum Flow, Station No. 1 Minimum Flow, below Cabot Station Minimum Flows, Cabot Station Ramping, and Flexible Operations

1. Date	2. Total Bypass Flow ²	3. Turners Falls Dam	4. Station No. 1-5	5. Below Cabot Station Minimum Flow	6. Cabot Station Ramping to Protect Shortnose Sturgeon and Odontates	7. Allowable Deviations from Ramping
01/01-03/31	1,500 cfs or the Naturally Routed Flow (NRF), whichever is less	400 cfs ³	1,100 cfs	3,800 cfs or NRF, whichever is less (1,500 cfs + 2,300 cfs)	N/A	0 hours of Flexible Operations
04/01-05/15	6,500 cfs or the NRF, whichever is less	4,290 cfs	2,210 cfs	8,500 cfs between midnight and 7 pm or NRF, whichever is less (6,500 cfs + 2,300 cfs)	Up/Down to 2,300 cfs/hour	0 hours of Flexible Operations
05/16-05/31	6,500 cfs or the NRF, whichever is less	4,290 cfs	2,210 cfs	8,500 cfs between midnight and 7 pm or NRF, whichever is less (6,500 cfs + 2,300 cfs)	Up/Down to 2,300 cfs/hour	0 hours of Flexible Operations
06/01-06/15 ¹	4,500 cfs or the NRF, whichever is less	2,990 cfs	1,510 cfs	6,800 cfs or NRF, whichever is less (4,500 cfs + 2,300 cfs)	Up/Down to 2,300 cfs/hour	0 hours of Flexible Operations
06/16-06/30 ¹	3,500 cfs of the NRF, whichever is less	2,280 cfs	1,220 cfs	5,800 cfs or NRF, whichever is less (3,500 cfs + 2,300 cfs)	Up/Down to 2,300 cfs/hour	0 hours of Flexible Operations
07/01-07/15	1,800 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,550 cfs	1,800 cfs or 90 % of the NRF, whichever is less	Up to 2,300 cfs/hour (8 am to 2 pm)	N/A
07/16-07/31	1,800 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,550 cfs	1,800 cfs or 90 % of the NRF, whichever is less	Up to 2,300 cfs/hour (8 am to 2 pm)	N/A
08/01-08/15	1,800 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,550 cfs	1,800 cfs or 90 % of the NRF, whichever is less	Up to 2,300 cfs/hour (8 am to 2 pm)	N/A
08/16-08/31	1,800 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,550 cfs	1,800 cfs or 90 % of the NRF, whichever is less	N/A	N/A
09/01-09/15	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less	N/A	N/A
09/16-09/30	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less	N/A	N/A
10/01-10/15	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less	N/A	N/A
10/16-10/31	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less	N/A	N/A
11/01-11/15	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less	N/A	N/A
11/16-11/30	1,500 cfs or 90 % of the NRF, whichever is less	400 cfs ³	1,100 cfs	1,500 cfs or 90 % of the NRF, whichever is less	N/A	N/A
12/01-12/31	1,500 cfs or the NRF, whichever is less	400 cfs ³	1,100 cfs	3,800 cfs or NRF, whichever is less (1,500 cfs + 2,300 cfs)	N/A	N/A

¹The flow split during these periods is approximately 67% from the Turners Falls Dam and 33% from Station No. 1. If Firstlight conducts further testing, in consultation with the National Marine Fisheries Service (NMFS), United States Fish and Wildlife Service (USFWS) and Massachusetts Division of Fish and Wildlife (MDFW) and determines that migratory fish are not delayed by passing a greater percentage of the bypass flow via Station No. 1, it may increase the percentage through Station No. 1 upon written concurrence of those agencies. If further testing shows that the flow split could potentially be modified, Firstlight shall consult with American Whitewater (AW), Appalachian Mountain Club (AMC), Zoar Outdoors, Crab Apple Whitewater, Inc and New England FLOW relative to any changes in the flow split and address those entities comments in any filing before FERC or the Massachusetts Department of Environmental Protection (MDPEP).

²If the NRF is less than 6,500 cfs (04/01-05/31), 4,500 cfs (06/01-06/15) or 3,500 cfs (06/16-06/30) the flow split will still be set at approximately 67% of the NRF from the Turners Falls Dam and 33% of the NRF from Station No. 1 subject to footnote 1. If 90% of the NRF is less than 1,800 cfs (7/1-8/31) or 1,500 cfs (9/1-11/15), Firstlight shall maintain the Turners Falls Dam discharge at 250 cfs or a maximum of 400 cfs, subject to footnote 6. If the NRF is less than 1,500 cfs (11/16-3/31), Firstlight shall maintain the Turners Falls Discharge at 400 cfs subject to footnote 3.

³The design maximum capacity of the canal gate is 400 cfs. Firstlight commits to opening the attraction flow gate to its maximum opening and will implement ice mitigation measures to maintain the maximum opening, if necessary, and monitor gate operations to determine if supplemental measures, such as cable heating the gate, are needed to maintain flows at or as close to 400 cfs as possible.

⁴To maintain the flow split, Station No. 1 must be automated, which will not occur until Year 3 of the license. Firstlight proposes to maintain the flow split such that the Turners Falls Dam discharge will be as shown above, or higher flows will be spilled, in cases where the additional flow cannot be passed through Station No. 1.

⁵The Turners Falls Hydro (TFH) project (FERC No. 2622) and Milton Hilton, LLC project (unlicensed) are located on the power canal and discharge into the Bypass reach upstream of Station No. 1. The hydraulic capacities of the TFH project and Milton Hilton, LLC project are 289 and 113 cfs, respectively. If the TFH project is operating, Firstlight may reduce its Station No. 1 discharge by 289 cfs. If the Milton Hilton, LLC project is operating, Firstlight may reduce its Station No. 1 discharge by 113 cfs.

⁶The 250 cfs is subject to an inspection of rare plant species in the bypass under Turners Falls Dam spillage flows ranging from 250-400 cfs in the first 4 years after license issuance. The entity conducting the inspection of rare plants will be resolved by the Parties as part of the Comprehensive Settlement Agreement. Pending the results of the study, NHESP may authorize that the Turners Falls Dam discharge be increased up to a maximum of 400 cfs with the portion of the bypass flow coming from Station No. 1 reduced by the corresponding amount. The Parties agree to discuss this issue further as part of Comprehensive Settlement discussions due to competing interests from multi-day through paddlers and flatwater paddlers.

The bypass flows and minimum flow below Cabot Station may be modified temporarily: (1) during and to the extent required by operating emergencies beyond the control of FirstLight; and (2) upon mutual agreement among FirstLight for Projects Nos. 1889 and 2485 and the USFWS, NMFS, MDEP, and MDFW.

- (b) The NRF represents the inflow to the Turners Falls Dam. The NRF is defined as the sum of the Vernon Hydroelectric Project total discharge from 12 hours previous, Ashuelot River United States Geological Survey (USGS) gage flow from 12 hours previous, and Millers River USGS gage flow from 12 hours previous.
- (c) FirstLight shall operate the Turners Falls Project in accordance with the conditions in paragraph (a) and the following operational flow regime beginning on the third (3rd) anniversary of the date of license issuance (see Table 1.1.1-2).

Table 1.1.1.2: Operating Conditions starting on the third (3rd) anniversary of the date of license issuance: Turners Falls Dam Minimum Flow, Station No. 1 Minimum Flow, below Cabot Station Minimum Flow, Flow Stabilization, Cabot Station Ramping and Flexible Operations

1. Date	2. Total Bypass Flow ²	3. Turners Falls Dam	4. Station No. 1 ^{4,5}	5. Below Cabot Station Minimum Flow	6. Flow Stabilization to Protect Shad Spawning (4/1-5/15), Puritan and Cobblestone Tiger Beetles, and state listed mussel and plant species (5/16-11/30)	7. Cabot Station Ramping to Protect Shortnose Sturgeon and Odonates	8. Allowable Deviations from Flow Stabilization
01/01-03/31	1,500 cfs or the Naturally Routed Flow (NRF), whichever is less	400 cfs ³	1,100 cfs	3,800 cfs or NRF, whichever is less (1,500 cfs + 2,300 cfs)	N/A	N/A	0 hours of Flexible Operations
04/01-05/15	6,500 cfs or the NRF, whichever is less	4,290 cfs	2,210 cfs	8,800 cfs between midnight and 7 pm or NRF, whichever is less (6,500 cfs + 2,300 cfs)	Provide NRF ±10% below Cabot Station from 7 PM to Midnight, with deviations up to +/-20% allowed for up to 22 hours.	Up/Down to 2,300 cfs/hour (ramping will take precedence over flow stabilization)	0 hours of Flexible Operations
05/16-05/31	6,500 cfs or the NRF, whichever is less	4,290 cfs	2,210 cfs	8,800 cfs between midnight and 7 pm or NRF, whichever is less (6,500 cfs + 2,300 cfs)	Provide NRF ±10% below Cabot Station from 7 pm to Midnight, with deviations up to +/-20% for up to 18 hours.	Up/Down to 2,300 cfs/hour (ramping will take precedence over flow stabilization)	0 hours of Flexible Operations
06/01-06/15 ¹	4,500 cfs or the NRF, whichever is less	2,990 cfs	1,510 cfs	6,800 cfs or NRF, whichever is less (4,500 cfs + 2,300 cfs)	Provide NRF ±10% below Cabot Station, with deviations up to +/-20% for up to 7 hours	Up/Down to 2,300 cfs/hour (ramping will take precedence over flow stabilization)	0 hours of Flexible Operations
06/16-06/30 ¹	3,500 cfs of the NRF, whichever is less	2,280 cfs	1,220 cfs	5,800 cfs or NRF, whichever is less (3,500 cfs + 2,300 cfs)	Provide NRF ±10% below Cabot Station, with deviations up to +/-20% for up to 7 hours	Up/Down to 2,300 cfs/hour (ramping will take precedence over flow stabilization)	0 hours of Flexible Operations
07/01-07/15	1,800 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,550 cfs	1,800 cfs or 90 % of the NRF, whichever is less			20 hours of Flexible Operations with no more than 7 flex events per month (Jul).
07/16-07/31	1,800 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,550 cfs	1,800 cfs or 90 % of the NRF, whichever is less	Provide NRF ±10% below Cabot Station, with deviations up to +/-20% for up to 55 hours	N/A	26 hours of Flexible Operations with no more than 7 flex events per month (Aug).
08/01-08/15	1,800 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,550 cfs	1,800 cfs or 90 % of the NRF, whichever is less			23 hours of Flexible Operations with no more than 7 flex events per month (Sep).
08/16-08/31	1,800 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,550 cfs	1,800 cfs or 90 % of the NRF, whichever is less	Provide NRF ±10% below Cabot Station, with deviations up to +/-20% for up to 27 hours	N/A	20 hours of Flexible Operations with no more than 7 flex events per month (Oct).
09/01-09/15	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less		N/A	28 hours of Flexible Operations with no more than 7 flex events per month (Nov).
09/16-09/30	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less		N/A	
10/01-10/15	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less		N/A	
10/16-10/31	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less		N/A	
11/01-11/15	1,500 cfs or 90 % of the NRF, whichever is less	250 cfs ⁶	1,250 cfs	1,500 cfs or 90 % of the NRF, whichever is less		N/A	
11/16-11/30	1,500 cfs or 90 % of the NRF, whichever is less	400 cfs ³	1,100 cfs	1,500 cfs or 90 % of the NRF, whichever is less	Provide NRF ±10% below Cabot Station, with deviations up to +/-20% for up to 11 hours	N/A	
12/01-12/31	1,500 cfs or the NRF, whichever is less	400 cfs ³	1,100 cfs	3,800 cfs or NRF, whichever is less (1,500 cfs + 2,300 cfs)	N/A	N/A	N/A

1. Date	2. Total Bypass Flow ²	3. Turners Falls Dam	4. Station No. 1 ^{4,5}	5. Below Cabot Station Minimum Flow	6. Flow Stabilization to Protect Shad Spawning (4/1-5/15) and Puritan Tiger Beetles (5/16-1/15)	7. Cabot Station Ramping to Protect Shortnose Sturgeon and Odonates	8. Allowable Deviations from Ramping and Flow Stabilization
¹ The flow split during these periods is approximately 67% from the Turners Falls Dam and 33% from Station No. 1. If Firstlight conducts further testing, in consultation with the NMFS, USFWS and MDPW, and determines that migratory fish are not delayed by passing a greater percentage of the bypass flow via Station No. 1, it may increase the percentage through Station No. 1 upon written concurrence of those agencies. If further testing shows that the flow split could potentially be modified, Firstlight shall consult with American Whitewater (AW), Appalachian Mountain Club (AMC), Zoar Outdoors, Crab Apple Whitewater, Inc and New England FLOW relative to any changes in the flow split and address those entities comments in any filing before FERC or the Massachusetts Department of Environmental Protection (MDER).							
² If the NRF is less than 6,500 cfs (04/01-05/31), 4,500 cfs (06/01-06/15) or 3,500 cfs (06/16-06/30) the flow split will still be set at approximately 67% of the NRF from the Turners Falls Dam and 33% of the NRF from Station No. 1, subject to footnote 1. If 90% of the NRF is less than 1,800 cfs (7/1-8/31) or 1,500 cfs (9/1-1/15), Firstlight shall maintain the Turners Falls Dam discharge at 250 cfs or a maximum of 400 cfs, subject to footnote 6. If the NRF is less than 1,500 cfs (11/16-3/31), Firstlight shall maintain the Turners Falls Discharge at 400 cfs subject to footnote 3.							
³ The design maximum capacity of the canal gate is 400 cfs. Firstlight commits to opening the attraction flow gate to its maximum opening and will implement ice mitigation measures to maintain the maximum opening, if necessary, and monitor gate operations to determine if supplemental measures, such as cable heating the gate, are needed to maintain flows at or as close to 400 cfs as possible.							
⁴ To maintain the flow split, Station No. 1 must be automated, which will not occur until Year 3 of the license. Firstlight proposes to maintain the flow split such that the Turners Falls Dam discharge will be as shown above, or higher flows will be spilled, in cases where the additional flow cannot be passed through Station No. 1.							
⁵ The Turners Falls Hydro (TFH) project (FERC No. 2622) and Milton Hilton, LLC project (unlicensed) are located on the power canal and discharge into the bypass reach upstream of Station No. 1. The hydraulic capacities of the TFH project and Milton Hilton, LLC project are 289 and 113 cfs, respectively. If the TFH project is operating, Firstlight may reduce its Station No. 1 discharge by 289 cfs. If the Milton Hilton, LLC project is operating, Firstlight may reduce its Station No. 1 discharge by 113 cfs.							
⁶ The 250 cfs is subject to an inspection of rare plant species in the bypass under Turners Falls Dam spillage flows ranging from 250-400 cfs in the first 4 years after license issuance. The entity conducting the inspection of rare plants will be resolved by the Parties as part of the Comprehensive Settlement Agreement. Pending the results of the study, NHESP may authorize that the Turners Falls Dam discharge be increased up to a maximum of 400 cfs with the portion of the bypass flow coming from Station No. 1 reduced by the corresponding amount. The Parties agree to discuss this issue further as part of Comprehensive Settlement discussions due to competing interests from multi-day through paddlers and flatwater paddlers.							

FirstLight agrees that as part of an off-license agreement, it will plan for and begin implementation of the proposed flow stabilization measures in Table 1.2.1-2 upon license issuance, recognizing that it will not be required to demonstrate to FERC or the Parties that it is meeting the flow stabilization requirements in Column 6 of Table 1.2.1-2 until the third (3rd) anniversary of the date of license issuance. FirstLight agrees to provide reports to the Parties to demonstrate substantive progress towards implementing the flow stabilization requirements. The Parties agree to determine the frequency of reporting as part of the Comprehensive Settlement Agreement.

In addition, FirstLight will have restricted discretionary flexible operating capability to respond to elevated energy prices (as defined in paragraph (d) below) between July 1 and November 30, as well as unrestricted capability to respond to emergencies, ISO-NE transmission and power system requirements, and other regulatory requirements (as defined in paragraph (e) below).

(d) Flexible operations allow for deviation from the prescribed operating limits (defined as Flow Stabilization and Cabot Station Ramping which are shown in Columns 6 and 7 of Table 1.2.1-2 in paragraph (c)). Such flexible operations are limited to the July 1 to November 30 period and will occur at the discretion of FirstLight and will be limited by a maximum number of hours and events per period as shown in Column 8 of Table 1.2.1-2 in paragraph (c).

(e) If compliance with the prescribed operating limits (defined as Flow Stabilization and Cabot Station Ramping which are shown in Columns 6 and 7 of Table 1.2.1-2 in paragraph (c)) would cause FirstLight to violate or breach any law, any applicable license, permit, approval, consent, exemption or authorization from a federal, state, or local governmental authority, any agreement with a governmental entity, or any tariff, capacity rating requirement, ramping criterion, or other requirement of the ISO-NE or its successors (ISO-NE)¹, FirstLight may deviate from the prescribed operating limitations to the least degree necessary in order to avoid such violation or breach. In addition, FirstLight may deviate from the operating limits for the following reasons:

- To implement Flood Flow Operations as defined in paragraph (g) below.
- To perform demonstrations of the resources' operating capabilities under ISO-NE rules and procedures. FirstLight will use best efforts to be allowed by ISO-NE to perform these demonstrations at times that will not cause it to deviate from the operating limits, with recognition that the April 1 to June 30 period will be avoided to the maximum extent possible.
- To manage the Turners Falls Impoundment (TFI) to stay within license limits, with recognition that the April 1 to June 30 period will be avoided to the maximum extent possible.
- If compliance with the prescribed operating limitations would cause a public safety hazard or prevent timely rescue.

From license issuance until the third (3rd) anniversary of the date of license issuance, FirstLight shall document on an hourly basis for each day any deviations from the Cabot Station Ramping restrictions and the same in the third (3rd) anniversary of the date of license issuance to license expiration from the Cabot Station restrictions and Flow Stabilization restrictions. Each day, between April 1 and November 30 any deviations would be recorded in a spreadsheet showing the daily deviations, the reason for the deviation, the number of hours and scope. The Parties agree to determine the frequency of reporting as part of the

¹ISO-NE requirements are conditions when ISO-NE requires FirstLight to be fully available and, if necessary, responsive. Some examples include ISO-NE reserve deficiencies (a.k.a. reserve constraint penalty factors) when reserves are depleted on the power grid, for fuel security emergencies or scarcity events, for ISO-NE system (or system) stability (e.g., VAR support), and system over supply (negative prices).

Comprehensive Settlement Agreement. In addition, FirstLight shall provide the total number of deviations and supply it to the USFWS, NMFS, MDFW and MDEP on an annual basis no later than March 1 of each year. Deviations will be tracked as follows:

- Identify Deviations: At the top of each hour, FirstLight will record the maximum and minimum total Project discharge and Cabot Station discharge which occurred over the past hour. The NRF (as detailed in paragraph (b) of the “Operational Regime” section) will be compared with the recorded range of Project discharge in a given hour to identify if a Flow Stabilization deviation occurred over the past hour. The recorded range of Cabot Station discharge will be reviewed each hour to see if a Cabot Station Ramping violation occurred. Any deviation within the hour will be counted in one-hour increments.
 - Categorize Deviations: When a deviation is identified it will be categorized as either Regulatory (as detailed in paragraph (e) of the “Turners Falls Project Operations” in Section 1.2.1 of this Proposal), NRF Allowance (as detailed in paragraph (d) of the “Turners Falls Impoundment Water Level Management” in Section 1.2.2 of this Proposal), or Discretionary (as detailed in paragraph (d) of the “Operational Regime” section of this Proposal).
- (f) Cabot Emergency Gate Use. FirstLight shall use the Cabot Emergency Gates under the following conditions: a) in case of a Cabot load rejection², b) in the case of dam safety issues such as potential canal overtopping or partial breach, and c) to discharge approximately 500 cfs between April 1 and June 15 for debris management. FirstLight shall avoid discharging higher flows through the gates from April 1 to June 15 whenever possible; however, if necessary, FirstLight shall coordinate with NMFS to minimize potential impacts to Shortnose Sturgeon in the area below Cabot Station.
- (g) Flood Flow Operations. FirstLight shall operate the Turners Falls Project in accordance with its existing agreement with the United States Army Corp of Engineers (USACOE). This agreement, memorialized in the *Reservoir and River Flow Management Procedures* (1976), as it may be amended from time to time, governs how the Turners Falls Project shall operate during flood conditions³ and coordinate its operations with the Licensee of the Northfield Mountain Project (FERC No. 2485).
- (h) The Parties agree that as part of the Final Settlement Agreement they will work to develop a mutually-agreeable protocol to dampen the magnitude of Great River Hydro’s (GRH) Vernon Hydroelectric Project (FERC No. 1904) flexible operations discharges (i.e., peaking releases) below FirstLight’s Turners Falls Project from July 1 through November 30 .

1.1.2 Turners Falls Impoundment Water Level Management

- (a) FirstLight shall operate the TFI, as measured at the Turners Falls Dam, between elevation 176.0 feet and 185.0 feet NGVD29.
- (b) FirstLight shall limit the rate of rise of the TFI water level, as measured at the Turners Falls Dam, to be less than 0.9 feet/hour from May 15 to August 15 between the hours of 8:00 am and 2:00 pm for the protection of odonates.

² A load rejection is when the Cabot Station units are suddenly shut off. If this were to occur, the canal could potentially be overtopped. To prevent overtopping, the Cabot Emergency Gates open so that incoming flow down the power canal can be discharged via the Cabot Emergency Gates. Load rejections could occur at any time.

³ These procedures define a flood as the NRF in excess of 65,000 cfs. However, these procedures implement measures for flood control when the NRF reaches 30,000 cfs.

- (c) The rate of rise of the TFI may be modified temporarily: (1) during and to the extent required by operating emergencies beyond the control of FirstLight; and (2) upon mutual agreement among the Licensees for Projects Nos. 1889 and 2485 and the USFWS, NMFS and MDFW.
- (d) FirstLight is entitled to increase the allowable NRF deviation from $\pm 10\%$ to $\pm 20\%$ in order to better manage TFI water levels. The increased flow deviation would be limited by the number of hours shown in Column 6 of Table 1.2.1-2 in paragraph (c) of "Turners Falls Project" in Section 1.2.1 of this Proposal. The allowance for an increased flow deviation outlined in this paragraph is different from the exceptions outlined in paragraphs (d) and (e) of "Turners Falls Project" in Section 1.2.1 of this Proposal. As such, the increased flow deviations outlined in this paragraph shall not count against any time allotment for exceptions outlined in paragraphs (d) and (e) of "Turners Falls Project" in Section 1.2.1 of this Proposal, and similarly operations meeting the exception criteria outlined in paragraphs (d) and (e) of "Turners Falls Project" in Section 1.2.1 of this Proposal shall not count against any time allotment for deviations outlined in this paragraph. Additionally, flow deviations in excess of $\pm 10\%$ of NRF resulting from conflicting operational requirements shall not count against any time allotment for deviations outlined in this paragraph.

1.1.3 Northfield Mountain Pumped Storage Project Operations

- (a) Flood Flow Operations. FirstLight shall operate the Northfield Mountain Project in accordance with its existing agreement with the USACOE. This agreement, memorialized in the Reservoir and River Flow Management Procedures (1976), as it may be amended from time to time, governs how the Northfield Mountain Project shall operate during flood conditions and coordinate its operations with the Licensee of the Turners Falls Project (FERC No. 1889).
- (b) Upper Reservoir Water Level Management: FirstLight shall operate the Northfield Mountain Project Upper Reservoir between elevation 1004.5 and 920.0 feet NGVD29.

1.1.4 Cobblestone Tiger Beetles

As part of Final Settlement FirstLight agrees to work with the Settlement Parties to develop a Cobblestone Tiger Beetle Mitigation Plan. This plan will not include any requirements that limit the capacity of Cabot Station.

PART II: PROTECTION, MITIGATION AND ENHANCEMENT MEASURES- FISH PASSAGE

2 FISH PASSAGE

2.1 Provisions to Provide Bypass Flows

2.1.1 Station No. 1- Improve Operating Range of Turbines

FirstLight will automate the Station No. 1 turbines to throttle the station over a range of flows within 3 years of license issuance.

2.2 Fish Passage Design and Consultation, Fish Passage Efficiency Metrics and Adaptive Management Plans

The Parties agree to the following:

- For any new fish passage facility described in this AIP, FirstLight will consult and obtain approval from the MDFW, NMFS and USFWS on the facility design and on operation and maintenance procedures. For any new fish passage facility, the Parties will attempt to meet agency design guidelines to the extent practicable.
- As part of the Final Settlement Agreement, the Parties will negotiate upstream and downstream fish passage efficiency and timing metrics for the Projects and include the metrics, if agreed upon, as part of the Final Settlement Agreement. The Parties will also negotiate adaptive management measures to be followed if the agreed upon fish passage metrics are not achieved.

2.3 Downstream Fish Passage

2.3.1 Intake Protection at the Northfield Mountain Pumped Storage Project Intake/Tailrace

FirstLight will install a barrier net as conceptually proposed in the Amended Final License Application for the period August 1 to November 15 to protect out-migrating juvenile shad and silver eel, to be operational no later than August 1 of Year 7 after license issuance. The barrier net will be 3/8-inch on the top and 3/4-inch on the bottom. The Parties agree to FirstLight's proposed operational period so long as there is a mechanism for expanding the operational period if daytime pumping operations at the Northfield Mountain Project during the adult alosine fish passage season increase substantially and there is demonstrated additional entrainment. FirstLight will be required to provide the agencies with annual logs of daily operation data with respect to the timing of pumping and generating. FirstLight will also be required to include the Northfield Mountain Project in the study design for effectiveness studies of upstream and downstream fish passage measures at the Turners Falls Project (e.g., deploy receivers at the Northfield Mountain Project lower reservoir intake and sites upstream and downstream of the intake, as well as in the Northfield Mountain Upper Reservoir).

The Parties agree to discuss the possibility of a fund to be used for habitat improvement projects and/or alosine management activities to offset the potential loss of ichthyoplankton through entrainment as part of final settlement discussions.

2.3.2 Cabot Intake Protection and Downstream Passage Conveyance

Within 4 years⁴ of license issuance, FirstLight will replace the existing trashrack structure with a new full depth trashrack with 1-inch clear spacing. In terms of general design concepts, the Parties agree that the new trashracks will have multiple openings for fish passage and that those openings will include both the top and bottom of the water column. The Parties further agree that they will attempt to maximize the hydraulic capacity of these openings within the constraints of the conveyance mechanisms. The Parties have analyzed a number of alternatives and believe the following conceptual design has merit for future exploration of detailed design alternatives:

The new trashrack will have multiple surface entrances including a.) between Units 2 and 3; b.) between Units 4 and 5; and c.) at the right wall of the intake (looking downstream) at Unit 6. These openings will be 3-feet-wide by 2-feet-tall and will connect to the existing trash trough located behind the racks. Each opening at the top of the trashrack will have an approximate hydraulic capacity of 24 cfs, and the existing trash trough will convey a total hydraulic capacity of approximately 72 cfs from these openings. The new trashrack will have an additional entrance near the bottom at the left wall of the intake (looking downstream) at Unit 1. This entrance will be approximately 3-feet-wide by 3-feet-tall and will connect to a vertical pipe to safely convey fish to the existing trash trough or log sluice. This entrance will be sized to provide a velocity that attracts fish to the bypass relative to the turbine intakes (approximately 5 feet-per-second).

In addition to the entrances integral to the new trashrack structure, fish will be conveyed via a new uniform acceleration weir (UAW) and log sluice. The log sluice will be resurfaced to limit turbulence and injury to migrants. A steel panel (or equivalent) will be provided below the UAW to exclude migrants from being delayed in the space below the UAW. Total flow from all downstream passage components at Cabot Station will be at least 5% (685 cfs) of maximum hydraulic station capacity (13,728 cfs). The conveyance at each bypass entrance will be determined during the design phase.

FL will consult and obtain approval from the Agencies during the design process as described in Section 2.2.

2.3.3 Station No. 1 Bar Rack

FirstLight will construct a ¾-inch clear-spaced bar rack at the entrance to the Station No. 1 branch canal the same year (see footnote 6) the Cabot Intake Protection and Downstream Passage Conveyance is built, so as to minimize canal outage time.

2.3.4 Plunge Pool below Bascule Gate No. 1

FirstLight will construct a plunge pool downstream of the Bascule Gate No. 1 as part of the construction of the Spillway Lift, to be operational no later than April 1 of Year 9 after license issuance.

⁴ Relative to the Cabot Intake Protection and Downstream Passage Conveyance and the Station No. 1 Bar Rack, the times cited are from license issuance based on the time needed to complete construction. The actual first year of operation of these two facilities will depend on when the license is issued.

2.4 Upstream Fish Passage

2.4.1 Anadromous Passage

2.4.1.1 Spillway Lift

FirstLight will construct a new Spillway Lift at the Turners Falls Dam to be operational no later than April 1 of Year 9 after license issuance irrespective of what quarter the license is issued.

2.4.1.2 Rehabilitate Gatehouse Trapping Facility

FirstLight will rehabilitate the Gatehouse Trapping facility (sampling facility) to be operational no later than April 1 of Year 9 after license issuance.

2.4.1.3 Retire Cabot Ladder and Portions of Gatehouse Ladder

FirstLight will retire the Cabot ladder and the canal portions of the Gatehouse ladder once the new Spillway Lift is operational.

2.4.2 Eel Passage

2.4.2.1 Eel Passage Measures

FirstLight will conduct the following measures:

- Install and operate interim upstream eel passage in the vicinity of the Spillway Ladder within 1 year of license issuance and continue operating until permanent upstream eel passage becomes operational. The location and design of interim eelway(s) will be determined in consultation with the agencies.
- Conduct up to 2 years of eel ramp siting studies, using a similar methodology to relicensing Study 3.3.4 (both years). Siting surveys will be initiated the year the new Spillway Lift becomes operational.
- Based on siting survey results, design, construct, operate, and maintain up to two permanent upstream eel passage facilities at the Turners Falls Project no later than 3 years after completing the final siting survey. The Parties agree that final eel ramp siting will take into account the ability to maintain the facilities in light of spillage conditions at the Project. In particular, the Parties agree not to site any ramps immediately at the foot of any active spillway structures.

PART III SIGNATURES

Organization: FirstLight MA Hydro LLC and Northfield Mountain LLC (collectively, FirstLight)

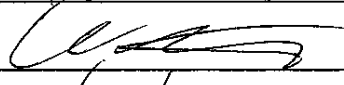
By: Justin Trudell

Title: *Justin Trudell*

Signature: Chief Operating Officer

Date: 3/17/2021

Organization: Massachusetts Division of Fisheries and Wildlife

By: Caleb Slater
Title: Chief of Hatchery
Signature: 
Date: 3/17/2022

Organization: Massachusetts Natural Heritage and Endangered Species Program

By: Jesse Leddick

Title: Chief of Regulatory Review

Signature:

A handwritten signature in blue ink, appearing to read 'Jesse Leddick', is written over a horizontal line. The signature is stylized with loops and a trailing flourish.

Date: March 17, 2022

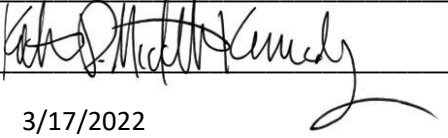
Organization: National Marine Fisheries Service

By: Christopher Boelke
Title: New England Branch Supervisor, Habitat and Ecosystem Services
Signature: 
Date: 3/17/22

Organization: The Nature Conservancy

By: Katie Kennedy

Title: Applied River Scientist

Signature: 

Date: 3/17/2022

Organization: United States Department of the Interior, United States Fish and Wildlife Service

By: Audrey Mayer, Ph.D.

Title: Field Supervisor, New England Field Office

Signature: AUDREY MAYER Digitally signed by AUDREY MAYER
Date: 2022.03.17 11:38:00 -04'00'

Date: 03/17/2022

Document Content(s)

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EXHIBIT 2 TECHNICAL MEMORANDUM

Basis for minimum flows directly downstream of the Turners Falls Dam between July 1 and December 31 to meet Clean Water Act and Massachusetts Surface Water Quality Standards

1. Background and regulatory basis

This memorandum presents a technical basis for minimum flow recommendations that will meet water quality standards below the Turners Falls Dam for July 1 to March 31 under the new license. As part of the 401 Water Quality Certificate, Massachusetts DEP will need to determine a flow that will protect existing and designated uses of the Connecticut River. If uses are not protected, DEP will need to perform a use attainability analysis to justify their decision.

In the Flows and Fish Passage Agreement in Principle (AIP) dated March 17, 2022, signed by FirstLight and agencies, and filed with FERC, it laid out the proposed minimum flow schedule for releases at the Turners Falls Dam, at Station No. 1, and below Cabot Station. The volume of releases at the dam during fish passage season is split into three different time frames to protect different species. CRC is of the opinion that these flows, and supplemented further downstream with Station No. 1 flows (not listed here) will meet water quality standards. The following flows are the Turners Dam minimum spill amounts in the AIP:

April 1 -May 31: 4,290 cfs
June 1 - June 15: 2,990 cfs
June 16-June 30: 2,280 cfs

The AIP proposes the following minimum flows for the remainder of the year:

- **July 1-November 15: 250 cfs.** There is a footnote saying, *"The 250 cfs is subject to an inspection of rare plant species in the bypass under Turners Falls Dam spillage flows ranging from 250-400 cfs in the first 4 years after license issuance. The entity conducting the inspection of rare plants will be resolved by the Parties as part of the Comprehensive Settlement Agreement. Pending the results of the study, NHESP may authorize that the Turners Falls Dam discharge be increased up to a maximum of 400 cfs with the portion of the bypass flow coming from Station No. 1 reduced by the corresponding amount. The Parties agree to discuss this issue further as part of Comprehensive Settlement discussions due to competing interests from multi-day through paddlers and flatwater paddlers."*
- **November 16-March 31: 400 cfs.** There is a footnote saying, *"The design maximum capacity of the canal gate is 400 cfs. FirstLight commits to opening the attraction flow gate to its maximum opening and will implement ice mitigation measures to maintain the maximum opening, if necessary, and monitor gate operations to determine if supplemental measures, such as cable heating the gate, are needed to maintain flows at or as close to 400 cfs as possible."*

CRC believes that the flows, particularly between July 1 to November 15, are far lower than those that are necessary to meet water quality standards. For comparison, in their Amended Final License Application, the upstream licensee, Great River Hydro, is proposing seasonal base flows at Vernon of 1,400 cfs during the summer and these increase to 1,600 cfs in October. The Ashuelot River and the Millers River provide additional flow between Vernon the Turners Falls Dam. According to EPA Fact Sheets for NPDES permits for Hinsdale NH and Erving MA, the 7Q10 for the Ashuelot River is 40.2 cfs and the 7Q10 for the Millers River is 43.7 cfs. Therefore, FirstLight has sufficient flow volume from upstream and tributary sources available to discharge flows above 250 cfs in the summer and fall.

The river segment below the dam is listed as impaired

Under the Massachusetts Surface Water Quality Standards, 314 CMR 4.06, the Connecticut River from Turners Falls Dam to the Holyoke Dam is designated as a Class B warm water river with the CSO qualifier. 314 CMR 4.05 (b) states that Class B “...waters are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation... These waters shall have consistently good aesthetic value.”

In the Massachusetts Year 2018-2020 Integrated List of Waters (finalized in February 2022), Segment 34-03 is the 3.7-mile segment between the Turners Falls Dam and the confluence with the Deerfield River. This segment is listed as impaired for *dewatering, flow regime modification*, E. coli bacteria, PCBs in fish tissue, and total suspended solids. It is not currently attaining these statutory standards, and is not meeting the aquatic life use.

2. Relevant Guidance and Technical Information

A. Massachusetts Surface Water Quality Standards

314 CMR 4.03(3)(b) states, “In waters where flows are regulated by dams or similar structures, the **lowest flow** condition at which aquatic life criteria must be applied is the flow equaled or exceeded 99% of the time on a yearly basis, or another **equivalent** flow agreed upon by the Department and the federal, state, or private entity controlling the flow. ... When the Department issues a 401 Water Quality Certification of an activity subject to licensing by the Federal Energy Regulatory Commission, **flows shall be maintained or restored to protect existing¹ and designated uses.**”

The designated uses that must be legally protected are aquatic life use, boating, and fishing. As noted above, these uses in the river segment below the Turners Falls Dam are officially listed as impaired under the current license conditions.

Section 314 CMR 4.03(3)(b) refers to the Q99, which is the flow equaled or exceeded 99% of the time on an annual basis. In 2018, CRC computed the Q99 at the Turners Falls Dam by using data from the most recent 30 years, 1988 to 2017, at the Montague City USGS station and subtracting a minimum flow of 206 cfs for the Deerfield River (this is the required minimum flow of the most downstream hydropower

¹ Note: existing uses are those attained on or after November 28, 1975. Northfield Mountain started commercial operation on November 30, 1972.

station on the Deerfield River). The Q99 we computed is 1,814 cfs.

A 2015 study² conducted in New England by the Midwest Biodiversity Institute compiled data from large rivers in New England. According to the author, the upper section of the reach below the Turners Falls Dam at River Mile 67.9 had the lowest (i.e., poorest) Index of Biological Integrity (IBI) score out of nearly 500 sites sampled in New England 2002-9 (see Table 27 on page 134).

i. Attainment of aquatic life use

Relicensing Study 3.3.1, the Instream Flow Habitat Assessments in the Bypass Reach and Below Cabot Station (referred here as the IFIM Study), analyzed transects within the bypass reach. The section directly downstream of the Dam is a complex area, and as a result four separate analyses were done, which were different than those done for the rest of the bypass reach.

- Left channel: A single transect looking at the cross-sectional water height at different dam release flows for zone of passage.
- Center channel: This channel is a fast chute, and only a hydraulic analysis was done.
- Right channel: This channel was the area where fish habitat was analyzed by wetted usable area for different river species.
- Plunge pool (not shown on map): A wetted area and wetted volume curve was calculated for the pool areas directly below the dam.

² Yoder, C.O., E.T. Rankin, and Lon E. Hersha. 2015. Development of Methods and Designs for the Assessment of the Fish Assemblages of Non-Wadeable Rivers in New England. MBI Technical Report MBI/2015-3-3. U.S. EPA Assistance Agreement RM-83379101. U.S. EPA, Office of Research and Development, Atlantic Ecology Division, Narragansett, RI and U.S. EPA, Region I, Boston, MA. 152 pp. <http://www.midwestbiodiversityinst.org/>.

Exhibit 2: CRC minimum flow recommendations below Turners Falls Dam



Further downstream, Transects T-10 and T-11 are the only transects upstream of Station 1. The analyses looked at high and low backwater scenarios for when Station 1 is operating or not. Under the proposed operations, river conditions should mostly be a high backwater situation because Station 1 will be operating most of the time.



Analyses

The Massachusetts Consolidated Assessment and Listing Methodology 2018 Guidance Manual (CALM) explains that MassDEP uses a weight-of-evidence approach, considering results from biological and habitat, toxicological, physico-chemical, sediment, and body burden investigations, to assess the attainment of Aquatic Life Use as defined at 314 CMR 4.02.

The 2018 CALM states that ALU is supported when the fish community includes fluvial specialist/dependent species or at least one fluvial species in moderate abundance. Fluvial specialist (FS) species require flowing water for all of their life-history requirements. According to Appendix B in the CALM, longnose dace, fallfish, and tessellated darter are all fluvial specialist species and these species were used as target species in the IFIM study for Turners Falls.

Appendix A of the IFIM shows the habitat suitability curves for target species in the study. We note that adult fallfish and tessellated darter (juvenile and adult) find wide ranges of substrate as suitable habitat, including bedrock, which is dominant in this upper reach. For Longnose dace, cobble and boulder are the most suitable.

Tables 7.1.1.1-1 (revised in an errata filing dated November 2016) and 7.1.1.2-2 show the percentage of maximum weighted usable area (WUA) for flows within the right channel in Reach 1 and at Transects 10 and 11 under high backwater conditions, respectively.

In the right channel of Reach 1, maximum WUA flow for adult fallfish was 1,583 cfs; for adult longnose dace was 591 cfs, tessellated darter was 562 cfs, and macroinvertebrates was 1,719 cfs.

Exhibit 2: CRC minimum flow recommendations below Turners Falls Dam

Table 7.1.1.1-1 corrected showing the percentage of weighted usable area for the Right Channel of Reach 1.

Species	Life stage	Months Present	Maximum WUA Total Release from Dam (cfs)	Maximum WUA Flowing in the Right Channel (cfs)	Maximum WUA (ft²)	Total Release from Dam											
						500 (cfs)	562 (cfs)	591 (cfs)	670 (cfs)	802 (cfs)	1,281 (cfs)	1,583 (cfs)	1,719 (cfs)	2,106 (cfs)	2,551 (cfs)	3,062 (cfs)	4,105 (cfs)
						0.07 (cfs/m)	0.08 (cfs/m)	0.08 (cfs/m)	0.09 (cfs/m)	0.11 (cfs/m)	0.18 (cfs/m)	0.22 (cfs/m)	0.24 (cfs/m)	0.29 (cfs/m)	0.36 (cfs/m)	0.43 (cfs/m)	0.57 (cfs/m)
Fallfish	Spawning/Incu	May-June	802	250	86,628	80%	90%	95%	97%	100%	88%	68%	56%	34%	26%	20%	13%
Fallfish	Fry	May-June	591	140	66,936	97%	99%	100%	92%	79%	65%	43%	39%	32%	17%	12%	8%
Fallfish	Juvenile	Year Round	802	250	83,561	80%	83%	89%	93%	100%	83%	77%	68%	46%	35%	32%	24%
Fallfish	Adult	Year Round	1583	662	33,506	42%	49%	52%	60%	72%	96%	100%	98%	88%	76%	66%	39%
Longnose Dace	Juvenile	Year Round	802	250	83,561	70%	83%	89%	93%	100%	83%	77%	68%	46%	35%	32%	24%
Longnose Dace	Adult	Year Round	591	140	74,344	94%	98%	100%	99%	97%	63%	43%	37%	29%	23%	21%	13%
White Sucker	Spawning/Incu	May-June	591	140	41,330	94%	98%	100%	95%	87%	70%	48%	37%	26%	28%	21%	8%
White Sucker	Fry	Apr-May	591	140	66,936	97%	99%	100%	92%	79%	65%	43%	39%	32%	17%	12%	8%
White Sucker	Adult/Juvenile	Year Round	0	0	-	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Walleye	Spawning/Incu	April-May	3062	1,500	86,372	5%	8%	10%	14%	21%	45%	60%	72%	92%	98%	100%	99%
Walleye	Fry	April-May	562	125	13,105	100%	100%	92%	75%	42%	16%	5%	9%	16%	1%	3%	2%
Walleye	Juvenile	Year Round	591	140	58,234	94%	98%	100%	90%	75%	47%	30%	25%	18%	24%	13%	5%
Walleye	Adult	Year Round	0	0	-	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Tessellated Darter	Adult/Juvenile	Year Round	562	125	38,259	100%	100%	98%	81%	54%	28%	16%	12%	17%	17%	5%	5%
Sea Lamprey (Agency)	Spawning/Incu	May-June	2106	1000	121,903	40%	46%	50%	55%	66%	94%	100%	100%	100%	83%	72%	47%
Macroinvertebrates	Larva	Year Round	1719	750	74,190	35%	41%	45%	53%	68%	95%	99%	100%	96%	93%	87%	79%
Shallow Slow	Shallow Slow	Year Round	562	125	45,830	100%	100%	91%	75%	44%	23%	3%	7%	23%	1%	2%	4%
Shallow Fast	Shallow Fast	Year Round	562	125	56,586	100%	100%	97%	88%	69%	32%	23%	20%	22%	16%	8%	5%
Deep Slow	Deep Slow	Year Round	1281	500	14,944	0%	7%	17%	35%	66%	100%	36%	16%	0%	0%	0%	0%
Deep Fast	Deep Fast	Year Round	1719	750	98,741	0%	0%	3%	12%	24%	70%	89%	96%	100%	89%	80%	63%

Table 7.1.1.2-2 showing the percentage of weighted usable area for T-10 and T-11 in Reach 1 under high backwater conditions is below. Please see the IFIM study for larger version of this table.

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)
INSTREAM FLOW HABITAT ASSESSMENTS IN THE BYPASS REACH AND BELOW CABOT STATION STUDY REPORT

Table 7.1.1.2-2: Percentage of the Maximum Weighted Usable Area (WUA) for Various Flows within Reach 1 (Transects 10 & 11) for High Backwater Condition

Species	Life stage	Months Present	Maximum WUA Flow (cfs)	Maximum WUA (ft²)	120 (cfs)	150 (cfs)	200 (cfs)	250 (cfs)	400 (cfs)	500 (cfs)	600 (cfs)	700 (cfs)	800 (cfs)	1000 (cfs)	1200 (cfs)	1400 (cfs)	1600 (cfs)	1800 (cfs)	2000 (cfs)	3000 (cfs)	4000 (cfs)	5000 (cfs)
American Shad	Spawning/Incu	May-June	7,500	898,488	17.6%	18.7%	20.6%	22.5%	27.2%	29.1%	30.6%	32.2%	33.7%	36.6%	40.9%	45.5%	49.8%	54.5%	59.8%	72.4%	81.9%	89.0%
American Shad	Juvenile	June-Oct	2,000	668,444	43.9%	47.7%	53.5%	58.6%	52.9%	55.3%	57.5%	59.2%	61.2%	64.6%	74.4%	83.0%	88.7%	94.4%	100.0%	95.5%	88.1%	80.6%
American Shad	Adult	May-June	2,000	695,459	23.1%	24.0%	25.7%	27.2%	29.1%	30.1%	31.1%	32.2%	33.3%	35.2%	37.7%	40.7%	43.1%	46.3%	50.3%	66.2%	80.2%	90.7%
Shortnose Sturgeon	Spawning	April-May	6,000	893,383	0.5%	1.6%	5.6%	9.7%	23.1%	27.9%	31.0%	32.6%	33.5%	35.0%	39.6%	45.4%	52.3%	60.8%	70.8%	87.7%	96.0%	99.5%
Shortnose Sturgeon	Egg-Larvae	May	3,000	1,360,780	38.9%	43.8%	51.1%	57.5%	42.9%	46.9%	51.0%	55.0%	59.3%	66.6%	77.6%	85.8%	91.5%	95.9%	99.9%	100.0%	100.0%	99.7%
Shortnose Sturgeon	Fry	May	500	64,776	44.5%	54.9%	71.4%	85.1%	99.3%	100.0%	99.9%	99.8%	99.9%	98.3%	94.8%	93.8%	91.8%	91.3%	92.4%	73.1%	56.9%	43.5%
Fallfish	Spawning/Incu	May-June	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fallfish	Fry	May-June	150	25,172	96.3%	100.0%	99.7%	98.5%	87.3%	82.4%	75.3%	61.6%	50.7%	39.0%	32.6%	28.2%	24.3%	20.9%	17.8%	6.1%	1.8%	1.0%
Fallfish	Juvenile	Year Round	1,800	260,011	57.8%	63.6%	71.2%	77.0%	73.3%	74.3%	76.2%	77.6%	79.5%	82.8%	89.5%	93.4%	98.0%	100.0%	99.5%	80.4%	61.6%	44.0%
Fallfish	Adult	Year Round	2,000	549,907	67.5%	70.9%	76.2%	80.6%	75.7%	75.7%	71.2%	67.1%	63.5%	59.8%	70.4%	80.6%	86.7%	93.4%	100.0%	89.6%	74.3%	60.5%
Longnose Dace	Juvenile	Year Round	1,800	155,504	13.0%	16.4%	22.0%	27.6%	23.1%	27.7%	31.3%	34.2%	37.4%	44.0%	64.0%	81.7%	95.7%	100.0%	94.9%	39.8%	12.7%	3.6%
Longnose Dace	Adult	Year Round	2,000	413,608	9.3%	11.7%	15.8%	19.8%	16.1%	18.5%	20.4%	22.8%	25.4%	31.5%	51.4%	69.4%	84.2%	94.0%	100.0%	54.4%	17.0%	4.2%
White Sucker	Spawning/Incu	Apr-May	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
White Sucker	Fry	May-June	120	1,000,248	100.0%	99.6%	97.6%	95.7%	84.7%	79.3%	75.2%	74.9%	76.4%	79.7%	75.7%	66.4%	51.8%	36.6%	20.8%	4.3%	1.0%	0.8%
White Sucker	Adult/Juvenile	Year Round	250	362,803	75.0%	85.5%	95.4%	100.0%	82.0%	71.1%	60.5%	50.9%	43.7%	45.5%	63.6%	77.0%	78.1%	73.4%	63.4%	29.9%	8.2%	2.6%
Walleye	Spawning	April-May	3,000	139,817	14.5%	14.9%	15.5%	16.2%	19.3%	21.4%	25.8%	29.8%	35.2%	45.0%	51.0%	55.9%	59.7%	64.4%	62.8%	100.0%	96.3%	85.7%
Walleye	Fry	April-May	120	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Walleye	Juvenile	Year Round	120	870	100.0%	82.4%	52.9%	32.4%	26.5%	23.5%	17.6%	14.7%	11.8%	8.8%	4.7%	3.5%	3.5%	2.4%	2.9%	0.0%	0.0%	0.0%
Walleye	Adult	Year Round	120	36,453	100.0%	80.4%	48.8%	24.5%	19.4%	15.8%	13.0%	12.9%	13.1%	13.5%	14.1%	14.6%	14.9%	15.6%	20.0%	14.3%	4.4%	4.4%
Tessellated Darter	Adult/Juvenile	Year Round	1,800	133,736	12.2%	15.4%	20.9%	26.5%	18.0%	22.0%	26.7%	31.9%	36.7%	45.3%	66.1%	84.5%	98.2%	100.0%	96.7%	28.7%	0.9%	0.0%
Sea Lamprey	Spawning/Incu	May-June	1,800	3,870	0.0%	0.0%	0.0%	0.3%	41.4%	56.6%	69.4%	62.8%	59.0%	69.8%	56.4%	74.0%	91.3%	100.0%	94.8%	34.9%	12.3%	2.3%
Macroinvertebrates	Larva	Year Round	4,000	918,412	0.0%	0.1%	0.4%	0.9%	6.0%	10.0%	14.0%	17.7%	21.3%	26.9%	30.4%	36.1%	44.7%	55.2%	67.1%	91.6%	100.0%	97.6%
Shallow Slow	Shallow Slow	Year Round	700	818,354	93.6%	94.1%	95.4%	97.1%	96.6%	97.5%	98.3%	100.0%	100.0%	93.0%	80.8%	78.2%	75.5%	71.7%	68.0%	21.5%	0.0%	0.0%
Shallow Fast	Shallow Fast	Year Round	1,600	535,297	24.8%	30.7%	40.4%	49.7%	26.1%	31.1%	36.2%	41.7%	49.0%	63.3%	83.5%	96.4%	100.0%	97.1%	88.9%	32.3%	9.1%	2.9%
Deep Slow	Deep Slow	Year Round	500	615,160	90.7%	91.4%	93.3%	95.7%	96.1%	100.0%	88.5%	65.0%	59.0%	67.0%	73.3%	78.5%	80.3%	64.2%	54.8%	22.2%	3.6%	1.2%
Deep Fast	Deep Fast	Year Round	3,000	124,411	2.4%	6.7%	15.0%	23.1%	37.8%	53.4%	69.1%	79.4%	82.8%	89.5%	88.3%	89.1%	91.6%	94.4%	99.6%	100.0%	89.8%	52.9%

In Transects 10 and 11, peak WUA for adult fallfish, tessellated darter, and white sucker were all around at flows between 1,600 and 2,000 cfs. The maximum WUA flow for macroinvertebrates was 4,000 cfs. Flows of 600-1,000 cfs would offer at least 20% WUA for fluvial specialists. A flow of 1,200 cfs would offer 30% WUA for macroinvertebrates. The Agreement in Principle (AIP) for fish passage and flows sets the summer minimum flow of 250 cfs with an opportunity to increase to 400 cfs, which represents only

0.9% to 6% WUA for macroinvertebrates. Both the 250 and 400 flows are far less than necessary to “maintain or restore” the designated Aquatic Life Use.

If flows were provided sufficient to support ALU, CRC expects that additional habitat would be created that would support two fish species that NHESP has listed as species of special concern, the [burbot](#) (*Lota lota*) and [longnose sucker](#) (*Catostomas catostomas*). Hartel et al. (2002)³ describes a 12-inch burbot caught in a pool below the Turners Falls dam in December 2000 by an angler who had noted that other specimens have been caught there (see page 191). Burbot are stated to be nocturnal and they spawn under ice. Young burbot feed on aquatic insects and crustaceans, while large adults feed on fishes. Hartel et al. (2002) states that records from 1940-1960 show that longnose sucker historically occurred in the Connecticut River and Westfield Rivers and at the mouth of the Chicopee River. Pollution and habitat alteration along the mainstems have limited surviving populations. The water quality in the CT River has improved greatly in recent decades, and the relicensing provides a once in a generation opportunity to restore habitat for these at risk species. Hartel et al. states that longnose suckers are benthic feeders taking a wide variety of aquatic invertebrates and algae from the bottom of rivers, highlighting the need to protect flows suitable for macroinvertebrates.

ii. Attainment of boating use

At the request of stakeholders including CRC FirstLight conducted a Boating Navigability Study completed in December 2021. This study targeted an evaluation of releases at the dam of 500, 670, 1100, and 900 cfs. Due to previously unknown calibration issues to determine flows from the Turners Falls dam, the study was only able to achieve an evaluation of dam releases of 214, 276, 545, and 376 CFS. The failure of FirstLight to be able to accurately gauge flows from the dam demonstrates clearly the immediate need for calibration of released flows. The flow of 545 cfs was determined to be a minimum navigable flow for paddling in a canoe or kayak. Flows higher than 545 cfs would also be navigable.

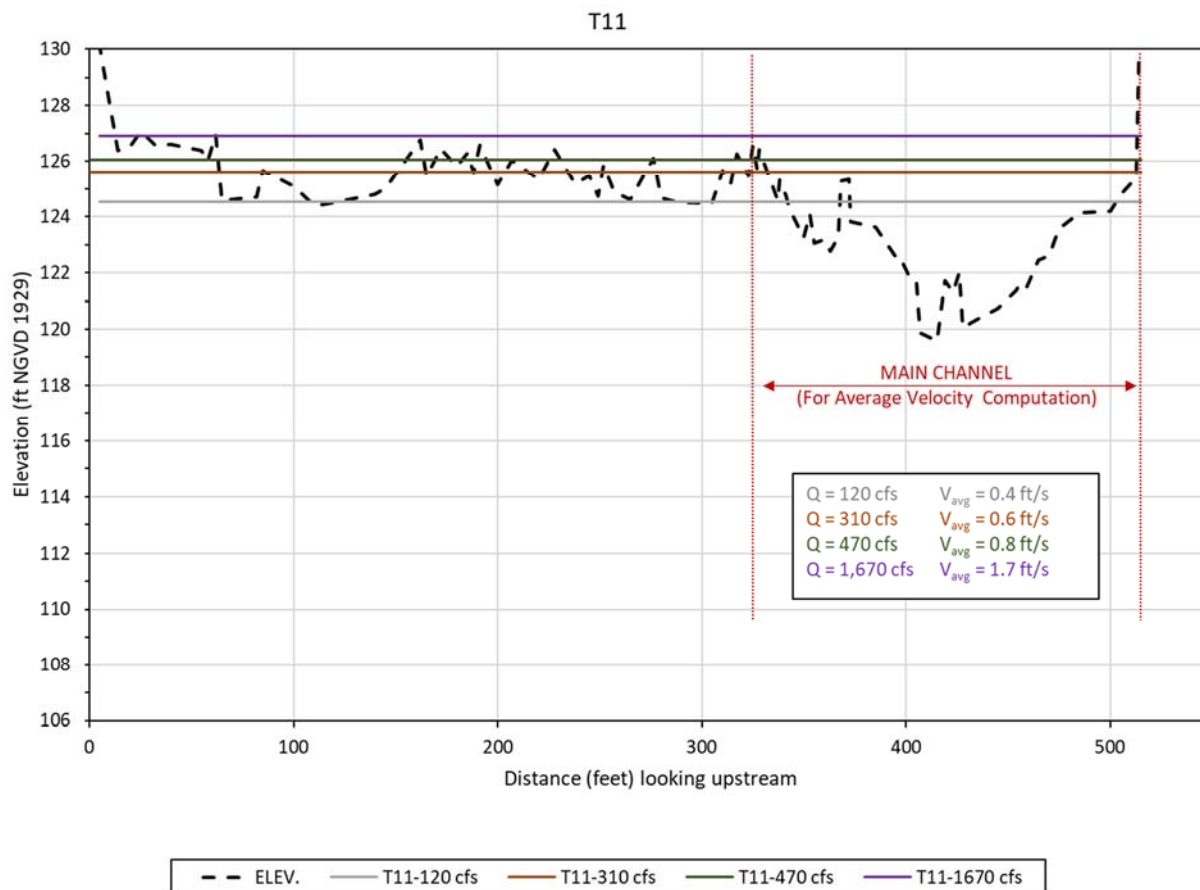
B. Wetted perimeter Method

The Wetted-Perimeter method is based on the assumption that there is a direct relation between the wetted perimeter in a riffle and fish habitat in streams (Annear and Conder, 1984; Lohr, 1993). The wetted perimeter of a stream, defined as the width of the streambed and stream banks in contact with water for an individual cross section, is used as a measure of the availability of aquatic habitat over a range of discharges (Annear and Conder, 1984; Nelson, 1984). EPA has approved the use by states of this simplified method that requires anywhere between 50% and 75% of wetted width of a river or stream. This percentage is statistically validated based on data sets of benthic macroinvertebrate assemblages at various conditions. It is statistically rigorous and provides for a simplified determination of attainment of the most sensitive aquatic life use.

While the geology of the river segment below the dam is complex, this method can be applied in the straighter section below the island and upstream of Station 1. For the IFIM Study, there were two transects in that section, T-10 and T-11. A slide prepared by FirstLight using data from the IFIM is shown below. Looking at the figure below, it seems that flows of at least 470 cfs upstream would be necessary

³ Karsten E. Hartel, David B. Halliwell, and Alan E. Launer. Inland Fishes of Massachusetts. Published by the Massachusetts Audubon Society, 2002.

to achieve 50% wetted width, possibly higher.



3. Flow recommendation

The IFIM results and recreation navigable flow study both show that much higher minimum flows are needed to meet Water Quality Standards below the dam. Taking into account aquatic life use and boating navigability, CRC finds that the following minimum flows at the Turners Falls Dam are needed to meet Surface Water Quality Standards.

July 1 to October 31: 1,000 cfs to provide habitat for fallfish, longnose dace, tessellated darter, and macroinvertebrates. This flow will also be a navigable recreational flow in the river for through-paddlers.

November 1-March 31: at least 500 cfs to maintain some of the wetted area provided during the summer period. Small fish shelter in place in the winter. Adequate spill will reduce forced movements by smaller fishes to restricted pool habitats. Predator fishes more effectively predate upon small bodied native fluvial species forced from shallow water habitat. Ideally, the spill at the dam during the winter would be at least 1,000 cfs during the winter, yet CRC acknowledges the economic value of power generation during the winter period.



EXHIBIT 3 TECHNICAL MEMORANDUM

Recommendation for conditions upstream of Turners Falls Dam to meet Clean Water Act and Massachusetts Surface Water Quality Standards

1. Background and regulatory basis

This memorandum presents a technical basis for recommendations that will attempt to meet water quality standards above the Turners Falls Dam. As part of the 401 Water Quality Certificate, Massachusetts DEP will need to determine the conditions that will protect existing and designated uses of the Connecticut River. If uses are not protected, DEP will need to perform a use attainability analysis to justify their decision.

The river segments above the dam are impaired

Under the Massachusetts Surface Water Quality Standards, 314 CMR 4.06, the Connecticut River from the Vermont, New Hampshire, and Massachusetts state line to the Turners Falls Dam is designated as a Class B warm water river. 314 CMR 4.05 (b) states that Class B “...waters are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation... These waters shall have consistently good aesthetic value.”

In the Massachusetts Year 2018-2020 Integrated List of Waters (finalized in February 2022), there are three different segments that make up the Turners Falls impoundment (TFI). All three are listed as impaired, as follows:

- Segment 34-01 is the 3.5-mile segment between the Vermont/New Hampshire/Massachusetts state line and the Route 10 bridge. This segment is listed as impaired for *alteration in stream-side or littoral vegetative covers*, *flow regime modification*, and PCBs in fish tissue.
- Segment 34-02 is the 11.4-mile segment between the Route 10 bridge and the Turners Falls Dam, excluding Barton Cove. This segment is listed as impaired for *alteration in stream-side or littoral vegetative covers*, *flow regime modification*, *water chestnut*, and PCBs in fish tissue.
- Barton Cove is MA34122 and is listed as impaired for curly-leaf pondweed, Eurasian water milfoil (*Myriophyllum spicatum*), fanwort, water chestnut, E. coli, and PCBs in fish tissue.

Appendix 15 to the 2018-2020 Massachusetts Integrated List states that these segments are “not supporting” the Fish, other Aquatic Life and Wildlife Use because of the impairments described above, although the impairments other than the invasive plants were worded as “stream bank alteration,” “flow modification.” These impairments, except for PCBs, are all related to the existence of the impoundment and/or project operations.

314 CMR 4.03(3)(b) states, “In waters where flows are regulated by dams or similar structures, the

lowest flow condition at which aquatic life criteria must be applied is the flow equaled or exceeded 99% of the time on a yearly basis, or another equivalent flow agreed upon by the Department and the federal, state, or private entity controlling the flow. ... When the Department issues a 401 Water Quality Certification of an activity subject to licensing by the Federal Energy Regulatory Commission, flows shall be maintained or restored to protect existing and designated uses.”¹ Waters behind a dam are not specifically addressed in this regulation; impoundments become lake-like and would need to be managed to maintain river functions.

The designated uses that must be legally protected are aquatic life use, boating, and fishing.

2. Recommendations for addressing impairments

A. Management and Removal of Non-Native Invasive Aquatic Plants to Restore Habitat and Improve Water Quality

The presence of the dam contributes to the existence of invasive plant species that prefer lakes and coves, such as water chestnut. FirstLight should re-draft the Invasive Plant Management Plans that were submitted in the Amended Final License Application (AFLA) dated December 2020. These plans should be merged into a single plan for both projects, and should commit to efforts to monitor, remove and manage aquatic invasives plants that are in the Turners Falls impoundment and in the Turners Falls canal system. FirstLight should work with state and federal agencies, as well as continue to work with organizations like the Connecticut River Conservancy, in this endeavor.

B. Operational recommendations to address flow modification and stream bank alteration impairments

1. Manage Operations of the Upper Reservoir to protect Aquatic Life, Wildlife Habitat and Fisheries

In the AFLA, FirstLight is requesting to use additional space in the upper reservoir on a permanent basis. The fish and flow Agreement in Principle (AIP) allows this with no restrictions. In the past, FirstLight and its predecessor companies has applied for and received temporary license amendments to use this additional volume of water during certain winter periods and one summer period. A permanent license amendment request was denied because it would have required a full endangered species act analysis due to a confirmed find of a federally endangered shortnose sturgeon below the Vernon Dam.² The table below shows the amount of water in the upper and lower reservoirs under the current and proposed operations.

Use of the expanded reservoir will provide more opportunities for FirstLight to pump to river levels that continue and increase impairments. The extra space in the upper reservoir was built into the plans at Northfield Mountain as part of a scheme to divert water for drinking water supply for the Boston metropolitan area. This water would have been diverted to Quabbin Reservoir via a pipeline that has never been built. When the Massachusetts legislature approved this deal in 1970, they limited diversions only to days when the flows of the CT River in Montague were above 17,000 cfs. The river at the Montague gage exceeds 17,000 cfs approximately 25% of the year.

¹ Note: existing uses are those attained on or after November 28, 1975. Northfield Mountain started commercial operation on November 30, 1972.

² CRC is not aware if the agencies will require this as part of the new license.

This information is significant because the additional volume in the upper reservoir, though available, was never designed to be used on a regular basis throughout the year, especially during the lower flow months. The table below summarizes the volumes available.

	Current License (acre ft) – Existing Requirements	New License – FirstLight Proposed Requirements (acre-ft)	Implications
Upper reservoir	12,318 acre-ft 1000.5 -938 ft elevation range	15,327 acre-ft 1004.5-920 ft elevation range	Expanded volume is 3,009 more acre ft than under the current license.
Water available in TFI for lower reservoir	Total TFI to elevation 185 ft is 20,300 acre-ft. The storage amount between 176 and 185 is 16,150 acre-ft. The amount that was created for Northfield Mountain by raising the dam is 12,600 acre-ft, which is equal to the upper reservoir storage amount.	12,600 acre-ft was originally for Northfield Mountain operations. Total between the requested elevations is 16,150 acre-ft (used for operations at Turners Falls and minimum flows).	No additional acre ft is being created in the impoundment. Extra volume used for the upper reservoir will need to be “borrowed” from water available in the Connecticut River.

Note: the information on the upper reservoir storage comes from Figure 2.3-1 in Exhibit B in the AFLA for Northfield Mountain. The information on the TFI storage comes from the previous license and Figure 2.3-1 in Exhibit B in the AFLA for Turners Falls Dam.

Section 2.3 of Exhibit B in the AFLA shows that FirstLight strives to maintain a near balanced condition or a positive balance where the combined useable storage is close to 12,318 acre-ft. If FirstLight is allowed to use the 15,327 acre-ft in the upper reservoir, Northfield could need to “borrow” water available in the Connecticut River. Model outputs FirstLight have shown indicates they will be keeping the TFI at an average elevation 0.5-1.0 ft higher than they have historically (for the months and years that were shown to stakeholders). We have previously observed the same pattern, TFI held 0.5 ft higher, during temporary amendment periods when FirstLight was required to release impoundment data to the public. CRC filed a Motion to Intervene for a temporary license amendment dated November 21, 2016, observing that FirstLight’s 2015-2016 Amendment Report showed that the average lower reservoir elevation was half a foot higher, 181.7 ft during the 2015-2016 amendment period, compared to 181.2 ft during non-amendment years. This was also the case during the 2014-2015 amendment period. For additional information why that is a concern from an erosion standpoint, please see a response letter filed with FERC by CRC and the Franklin Regional Council of Governments dated November 9, 2017.

Full and unrestricted use of the extra volume in the upper reservoir will likely lead to larger TFI fluctuations and make impairments worse, and therefore CRC recommends that it only be allowed under very limited scenarios or emergency circumstances.

2. Manage Recreation Impacts to Protect Boating and Fishing

At the Turners Falls Dam

Exhibit 3: CRC recommendations above Turners Falls Dam

The current license allows FirstLight to vary the water elevation of the impoundment from 176 to 185 ft above mean sea level, as measured at the Turners Falls Dam. FirstLight is requesting the same range in the new license.

The existing license allows FirstLight to bring water levels down so low that Barton Cove cannot be adequately used for boat recreation and safety boat use. This was especially evident last June, when the impoundment levels dipped low enough that FERC received a complaint and issued a letter to FirstLight requesting information to make sure the license parameters were followed. FirstLight's response dated June 23, 2021 stated that the reservoir levels reached a low of 177.5 ft msl during June 12-13, 2021. These levels are within the license limits. Photos below were posted on Facebook.



Franklin County Boat Club at Barton Cove in Gill on June 12-13, 2021



Connecticut River shoreline during June 12-13, 2021, as posted on Facebook

After the low water level occurrence, the month of July in 2021 was unusually rainy, and water levels were kept so high that boaters also had trouble launching boats and using boat ramps. This indicates that the upper end of the allowable range is also problematic for boating.

Relicensing Study 3.6.6 Assessment of Effects of Project Operation on Recreation and Land Use Study Report evaluated water levels at recreation sites. Section 4.2.6 concludes that water level elevations need to be above 179 ft msl to adequately launch an emergency motorboat. Figure 4.2.6-4 shows that the boat ramp elevation is at 184 ft msl, so when the TFI is above this elevation, parts of Barton Cove on the Gill side are under water. Figure 4.2.6-5 is a HEC-RAS analysis showing that the impoundment levels are below 184 ft 100% of the time and are above 179 ft approximately 97% of the time during the summer months under current operations. These historical analyses of water levels do not predict how FirstLight will operate Northfield Mountain into the future. Indeed, the June 2021 event appears to be in response to FirstLight's price seeking of low (or even the potentially likely instances of negative) energy prices for the operation of Northfield. It is clear that summertime renewable energy generation

during the daytime will create instances of abundant electricity on the grid and so significant revenue opportunities for FirstLight.

CRC recommends that the impoundment be kept within the range of 179 -184 msl. Deviations below 179 would need to be an exceptional occurrence. Deviations above 184 would happen only during high water times of the year. Under current operations, these conditions are already met 97% of the time.

These water level recommendations will also be beneficial for fish protection. The fish and flow AIP provides for downstream fish passage protection at Northfield Mountain by installing a barrier net. Based on the fish barrier net study and Relicensing Study 3.3.9, velocities at the net during pumping are higher during the low impoundment scenarios. If river levels are kept above 179 ft at the dam and 181 ft at Pauchaug, that will result in less of a chance of fish entrainment.

Water levels at Pauchaug Boat Ramp

Relicensing study 3.6.6 also looked at water levels at Pauchaug Boat ramp, and concluded that water levels needed to be above 181 for the boat ramp to be usable for emergency motor boats. Figure 4.2.2-3 indicates water levels dip below this level about 20% of the time in the recreation season. CRC's analysis in the comment letter on this study dated December 15, 2016 analyzed water level logger data and demonstrated that during summer months, it is common that water levels at Pauchaug are below 181 during the morning hours. While the new minimum flows coming from Great River Hydro's Vernon Dam may help improve this situation, we believe the elevation dips are related more to Northfield Mountain's cycles of pumping and generating.

In addition to the water level constraints noted above CRC recommends that Northfield Mountain pump at a more gradual rate in order to maintain navigable water levels (>181 ft msl) during the recreation season.

Barton Cove siltation

Barton Cove is filling up with sediment due to the presence of Turners Falls Dam, raised in elevation in the early 1970's to build Northfield Mountain pumped storage. Sediments naturally precipitate to the bottom of impounded areas. More sediment has been added by erosion that has occurred in the impoundment since the installation and operation of Northfield Mountain, combined with events like the 2010 Northfield Mountain upper reservoir maintenance disaster and Tropical Storm Irene in 2011. It is increasingly difficult to navigate boats to the Gill side of Barton Cove during low water. During the course of the next license period, there should be a feasibility study and environmental assessment of some level of dredging in non-archaeologically sensitive portions of Barton Cove.

C. Addressing stream bank alteration impairments

1. Develop and Implement an Adaptive River Management Plan

Five hydropower facilities are being relicensed on the mainstem Connecticut River at the same time. As part of the 401 Water Quality Certificates for all the projects, there should be an Adaptive River Management Plan for the entire five-project area that treats the area as a system and provides a similar approach across project areas.

Rapid drawdown of the river level can impair bank stability, and can cause seepage, tension crack development, and ultimately slope failure along a rotational slip surface. Rapid rising of water levels along a riverbank can also cause bank stability problems.³ Operational changes are proposed at all 5 projects, and these may impact erosion positively or negatively.

We envision a process during which stakeholders involved in the five projects and the two companies, together with consultants, develop an Adaptive River Management Plan for the Connecticut River to monitor and mitigate the impacts of the operation/management of the 5 hydro projects and restore, enhance, and protect riverine functions to provide habitat, protect riparian land and cultural/historic artifacts, and recreation areas. We envision a process outlined below.

- I. Create stakeholder group with FirstLight, Great River Hydro, state agencies, towns, regional planning agencies, landowners, and nongovernment organizations (does not have to be those signing on to a settlement agreement)
- II. Establish goals
 - a. Identify the resource areas and ecosystem attributes that are important to restore, enhance, and protect
 - b. Identify a systems or conceptual model to use as framework (e.g., Interdam Sequence Conceptual Model⁴)
 - c. Maintain as many riverine processes as possible given the presence of the dams/pumped storage
 - o Bar and bend geomorphology
 - o Sediment flushing
 - d. Protect archaeological sites, agricultural land, and infrastructure that can't easily be moved.
 - e. Identify jurisdictional boundaries for state and federal wetlands
- III. Monitor and Study
 - a. Establish baseline conditions using principles and science of fluvial geomorphology.
 - b. Identify data gaps
 - c. Geomorphic function
 - d. Riparian habitat attributes
 - e. Land use practices
 - f. Seepage/groundwater movement
 - g. Erosion and deposition on inside and outside bends
 - h. Establish 3rd-party monitoring that has buy-in from project owners and stakeholders
 - i. Monitor stabilized and treated banks
 - j. Build success/fail criteria
 - k. Document monitoring protocol in a Quality Assurance Project Plan

³ See page 15 of "Run-of-river Hydroelectric Dam Bank Erosion and Cultural Resources in VT" by G. Robert Brakenridge of University of Colorado, December 2021.

⁴ Katherine J. Skalaka, Adam J. Benthem, Edward R. Schenk, Cliff R. Huppa, Joel M. Galloway, Rochelle A. Nustad, Gregg J. Wiche. Large dams and alluvial rivers in the Anthropocene: The impacts of the Garrison and Oahe Dams on the Upper Missouri River. In Anthropocene Volume 2, Pages 1-102 (October 2013), Geomorphology of the Anthropocene: Understanding the Surficial Legacy of Past and Present Human Activities. Edited by Anne J. Jefferson and Karl W. Wegmann.

http://www.swc.nd.gov/pdfs/oct_2013_impacts_garrison_oahe_upper_missouri.pdf

IV. Restore/Adapt

- a. Protection of banks where there are archaeological resources that should not be losst
- b. If fail criteria triggered, establish remediation approach where needed
- c. Appropriate treatment techniques
- d. Schedule in review and updates to process

2. *Minimize Impacts to Shoreline Areas to Mitigate Erosion*

Studies show that the cyclic process of wetting and drying the banks lead to increased rates of bank erosion. We assume that in the 50 years that Northfield Mountain has been operating, that the river has begun some process of adjusting to the operational pattern. Changing an average elevation during the next license period would initiate a new period of destabilization (please see above B(1)).

CRC looked at the historic TFI levels provided by FirstLight for the months of August and November of the years 2009, 2015, 2016, and 2017, which were the years and months that Great River Hydro provided of their modeled proposed flex ops and for which FirstLight also ran their model (the model runs themselves are not public during settlement discussions).

We are calling the “daily delta” to be maximum elevation minus the minimum elevation in a calendar day. The average daily delta for a month has been in the range of 2.1 to 3.1 ft, as measured at the dam. The difference between the lowest low elevation and the highest high elevation for each month ranges between 3.7 (November 2016) and 5.9 ft (August 2009). This represents the wetted range for the months of August and November, which are not typically high flow months.

Looking upstream of Northfield Mountain, the average monthly river elevation at the Northfield USGS gage located near the Route 10 bridge ranges from 11.1 to 14.2 ft gage height. According to USGS, the Northfield USGS gage is at elevation 170 ft (NAVD1988; personal communication from Timothy Sargent dated 11/26/2018). This means the average monthly river elevation ranges from 181.1 ft to 184.2 ft. The lowest average monthly elevations can happen June through September.

At the Northfield USGS gage, the average daily delta for each month between June of 2019 and this year has ranged from 1.5 to 3 ft. The average daily delta tends to be highest in the summer months of June, July, and August, typically having been a little below or above 2.5 ft.

CRC recommends that there be stipulations put in place such that conditions not get worse. That means, the *average* river elevations should remain the same and the average daily and monthly deltas should not increase. In other words, **TFI should be kept at an average elevation over a month of 181 to 182.5 ft. The average daily delta for a month should not be above 3.5 ft, and the average min vs. max elevation over the course of a month should not be greater than 6 ft, except in high flow/flooding conditions.**

Summary of CRC recommendations

FirstLight AIP proposal	FirstLight AIP or AFLA proposal	CRC recommendations
Aquatic invasive species	Invasive species management plan as submitted in the AFLA, which did not address aquatic invasives	FirstLight update invasive species management plan in consultation with agencies and CRC to include commitment to work on removing aquatic invasive plants in the TFI and TF canal system.
TFI limit as measured at the dam	176-185 ft	179-184 ft, with deviations allowed during extreme situations of flow/energy needs
River levels at Pauchaug boat ramp	NA	Maintain water levels > 181 ft by pumping more gradually
Barton Cove siltation	NA	During the new license period, a feasibility study and environmental assessment of sediment dredging in a portion of Barton Cove (consultation with archeologists and indigenous groups needed)
Adaptive River Management Plan	NA	FL contribute to creating and implementing an Adaptive River Management Plan for all 5 CT River projects.
Maintain river at an established average monthly elevation	NA	TFI should be held at an <i>average</i> monthly elevation similar (within an acceptable difference) to the historic average for that month over the previous 20 years of operations.
Average daily delta (TFI elevation from each hour of each day averaged for each month)	NA	< 3.5 ft
Range of wetted bank: maximum elevation minus minimum elevation for each month	NA	< 6 ft

Exhibit 4

To: Massachusetts Executive Office of Energy and Environmental Affairs (“EEA”)
From: Connecticut River Conservancy; Earthrise Law Center
RE: Financial Assurances as Conditions of a Clean Water Act § 401 Water Quality Certification
Date: December 23, 2021

QUESTION PRESENTED

Does Massachusetts, under authority granted to it by Clean Water Act (“CWA”) Title 33 U.S.C. § 1431(d) (“CWA § 401”), have the authority to require from hydropower facilities seeking CWA § 401 water quality certification for a Federal Energy Regulatory Commission (“FERC”) license the financial assurances sufficient to decommission and remove a non-operating hydropower project once that license expires or the project is otherwise abandoned?

SHORT ANSWER

Yes. Multiple provisions of Massachusetts’ water quality standards applicable to the Connecticut River, including those specific to waters influenced by hydropower facilities, provide support, independently and collectively, for requiring decommissioning and removal costs be included in a facility’s CWA § 401 certification and thus incorporated into its FERC license.

STATUTORY BACKGROUND

The Clean Water Act implements a cooperative federalism model to “*restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.*” 33 U.S.C. § 1251 (emphasis added). States are granted authority to impose conditions on federal permits to ensure that discharges not only meet water quality standards, but other requirements of state law. 33 U.S.C. 1342(a)(2). A CWA § 401 certification shall set forth “effluent limitations and other limitations” to ensure that the federal license or permit “compl[ies] with any applicable ... limitations ... and with any other appropriate requirement of State law.” 33 U.S.C. § 1341(d). Conditions imposed by a State “shall become a condition on any Federal license or permit.” *Id.*; *see also Am. Rivers, Inc. v. F.E.R.C.*, 129 F.3d 99 (2d Cir. 1997). Section 401 has been interpreted broadly to grant State agencies significant authority to impose conditions for the preservation of both state water quality standards, state-established designated uses, as well as other legislative goals.¹ *See PUD No. 1 of Jefferson Cty. v. Washington Dep’t of Ecology*, 511

¹ The Trump administration promulgated a rule articulating a narrower interpretation of this CWA provision that has been successfully challenged in federal court. *See In Re Clean Water Act Rulemaking*, 2021 WL 4924844 (N.D. Cal. Oct. 21, 2021) (vacating the Trump EPA’s CWA 401 Rule and remanding to EPA). On December 17, 2021, EPA released a document entitled *Clean Water Act Section 401 Water*

US 700 (1994); *see also, e.g., In re Morrisville Hydroelectric Project Water Quality*, 211 Vt. 233 (2019); *Trout Unlimited v. U.S. Dep’t of Agric.*, 210 F. Supp.2d 1090 (D. Colo. 2004); *Friends of Merrymeeting Bay v. Olsen*, 839 F. Supp. 2d 366, (D. Me. 2012). Because of the broad statutory language and cooperative federalism scheme found in the CWA, there are multiple avenues of support for imposing decommissioning and removal costs in the CWA § 401 certification process broadly, as well as in the context of certain portions of the Connecticut River specifically.

PRECEDENT IN MASSACHUSETTS FOR REQUIRING FINANCIAL ASSURANCES

Requiring decommissioning funding for large infrastructure projects is not a novel concept. Industrial solar facilities, wind turbines, nuclear power plants, and landfills all pose environmental and public health risks to the communities where they are sited once their useful operational life is over. And they all require significant financial expenditures to decommission safely. Accordingly, the facility owners are typically required to provide financial assurance, either at the federal, state or local level—often in the form of a surety bond or proof of a decommissioning fund—in order to build and/or continue operating such facilities.² Requirements for such funds are good public policy to prevent host communities and/or taxpayers from bearing the financial burden if the owner/operator does not adequately plan for decommissioning.

Hydropower facilities, both large and small, are also expensive to decommission and pose similar environmental and public health risks and impacts when they are no longer operating (e.g., ongoing adverse impacts to habitat, obstruction of fish passage, dangers of breaching and flooding risks). Accordingly, Massachusetts must also require financial assurances for their decommissioning and removal, especially since (1) there is a clear trend toward removing old dams and restoring natural river flows; (2) unlike some of the other facilities discussed above,

Quality Certification Questions and Answers on the 2020 Rule Vacatur, which confirmed that the 1971 regulations preceding the vacated Trump EPA’s rule again govern the CWA § 401 certification process. *See* <https://www.epa.gov/system/files/documents/2021-12/questions-and-answers-document-on-the-2020-cwa-section-401-certification-rule-vacatur-12-17-21-508.pdf>.

² In our earlier memorandum transmitted to Beth Card and Stephanie Cooper on September 28, 2021 (“CRC Decom Memo 1”), we cited to examples of states, including Massachusetts, requiring financial assurances for other energy generating infrastructure. *See* CRC Decom Memo 1, at 4–5. For example, Massachusetts’ model ordinance for wind energy facilities contains a financial surety provision at 3.12.3. *See* <https://www.mass.gov/doc/wind-model-bylaw-mar-2012pdf/download>.

hydropower facilities use and impact rivers, a public trust resource; (3) federal licenses for dams can last up to 50 years, meaning some of the dams being relicensed today will be nearly a century old (and some far older since they existed before their original FERC licenses) when their new license expires; and (4) it is good public policy as evidenced by the similar requirements imposed on other energy-generating facilities.

While FERC could condition its licenses with financial assurances for decommissioning and removal,³ CRC is unaware of FERC ever exercising this authority. Thus, it is incumbent upon Massachusetts to exercise its authority under CWA § 401(d) and Massachusetts SWQS to require such assurances. Such a proactive approach to financing dam removal would be consistent with Massachusetts' efforts to remove derelict dams throughout the state.⁴ It also would be consistent with the positions of several federal resource agencies. For example, the U.S. Fish and Wildlife Service recently told FERC it supported financial assurances for decommissioning funds, stating:

The Service also recommends that financial assurances address decommissioning costs, including the removal of project infrastructure and the restoration of habitat when a licensee or exemptee surrenders its license or otherwise voluntarily abandons a project. This would ensure projects that are abandoned do not pose a risk to the environment and would reduce the risk that taxpayers and ratepayers would have to pay to remove project infrastructure and restore habitat if a project is abandoned.⁵

The U.S. Fish and Wildlife Service clearly articulates the risk of *not* conditioning CWA § 401 certification on financial assurances for decommissioning and removal: local communities, taxpayers and ratepayers will be stuck with an enormous bill for removing deadbeat dams and restoring river habitat.

**MASSACHUSETTS SURFACE WATER QUALITY STANDARDS PROVIDE A BASIS
FOR REQUIRING DECOMMISSIONING AND REMOVAL COSTS**

There is ample support in Massachusetts' Surface Water Quality Standards ("SWQS"), 314 CMR 4.00, *et. seq.*, for the goal of restoring rivers to their original conditions, which necessarily

³ 60 Fed. Reg. 339, 340 (Jan. 4, 1995), available at <https://www.govinfo.gov/content/pkg/FR-1995-01-04/pdf/95-63.pdf>.

⁴ See, e.g., <https://www.mass.gov/info-details/river-run-a-story-of-dam-removal-in-massachusetts>.

⁵ U.S. Fish and Wildlife Service Comments on the Federal Energy Regulatory Commission's Notice of Inquiry on Financial Assurance Measures for Hydropower Projects, Docket RM21-9-000, at pdf page 4 (March 26, 2021).

includes decommissioning and removing a hydropower facility at the end of its useful life. Given this clear and direct nexus to water quality, a condition in a state's CWA § 401 certification requiring hydropower facilities provide financial assurances sufficient to decommission and remove a non-operating hydropower project falls squarely within the scope of CWA § 401(d). We set forth the specific Massachusetts SWQS supporting such a condition below.

314 CMR 4.01: Massachusetts SWQS impose a “duty and responsibility” upon DEP to “protect the public health and enhance the quality and value of the water resources of the Commonwealth” and “direct[] the Department to take all action necessary or appropriate to secure the Commonwealth the benefits of the Clean Water Act.” 314 CMR 4.01(4). In turn, the Purpose provision of the SWQS explicitly incorporates the seminal objective of the CWA, which is “the *restoration* and maintenance of the chemical, physical, and biological integrity of the Nation’s waters.” *Id.* (emphasis added). The plain meaning of “integrity” is the state of being whole and undivided.”⁶ Dams, whether operational or not, divide rivers and disrupt their chemical, physical and biological integrity. Decommissioning and removal financial assurances directly relate to the “restoration” prong, a value that is emphasized expressly in the state regulations, including those specific to dams as discussed further below. Thus, conditioning a CWA § 401 certification on a hydropower facility providing adequate financial assurances for decommissioning and removal falls squarely within the very purpose of Massachusetts SWQS.

314 CMR 4.03(3): The Hydrologic Conditions provision of Massachusetts’ SWQS directly addresses state waters containing dams and other hydropower facilities, and sets forth a clear mandate: “When the Department issues a 401 Water Quality Certification of an activity subject to licensing by the Federal Energy Regulatory Commission, flows shall be maintained or *restored* to protect existing and designated uses.” 314 CMR 4.03(3)(b) (emphasis added). This is perhaps the most applicable SWQS provision as it deals directly with FERC-licensed dams and CWA § 401 certifications, and specifically contemplates *restoration* of flows, which would occur if a dam or other hydropower facility were decommissioned and removed. Thus, requiring financial assurances that would achieve such restoration finds direct support in this provision.

314 CMR 4.03(4): Massachusetts SWQS must balance competing public interest goals when it comes to *operating* hydropower facilities. In cases where dams preclude the attainment of a

⁶ <https://www.merriam-webster.com/dictionary/integrity>.

designated use, DEP may remove that use, after a Use Attainability Analysis, so long as “it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use.” 314 CMR 4.03(4)(d). This provision provides support for requiring financial assurances in two ways. First, it explicitly contemplates restoring a river to “its original [undammed] condition,” which is precisely what funding decommissioning and removal would accomplish. Second, it highlights a negative, and perhaps unintended, consequence of *not* requiring financial assurances. Once a dam is no longer operating and therefore no longer making money, it may make it easier for the facility owner/operator to argue that it is not “feasible” to restore the waterbody to its original condition, thus paving the way for the removal of whatever use cannot be obtained while the dam exists. On the other hand, if financial assurances for decommissioning and removal are required as part of the CWA § 401 certification, it negates a non-feasibility argument from the facility owner/operator.

314 CMR 4.05 (Designated Uses): Massachusetts SWQS designate the most sensitive uses “for which the various waters of the Commonwealth shall be enhanced, maintained and protected.” 314 CMR 4.01(4). The stretch of the Connecticut River adjacent to the Turners Falls Dam and the Northfield Pump Station is listed as Class B waters, which are designated “as habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation.” 314 CMR 4.05(3)(b). It is indisputable that the Turners Falls Dam and Northfield Pump Station have negative impacts—including flow impairment, temperature increases, impingement and entrainment, and habitat alteration and erosion, among others—on these designated uses.⁷ In fact, it is far from clear to CRC how Massachusetts will be able to certify that the operations of those facilities, as currently proposed, will meet SWQS as part of their FERC relicensing process. However, once the facilities are no longer operational, their presence in the river will *per se* violate SWQS. Further, given that the FERC licenses last for decades, there is tremendous

⁷ The Draft Massachusetts Integrated List of Waters for the Clean Water Act 2018/2020 Reporting Cycle lists the section of the Connecticut River between the Northfield Pump Station and the Turners Falls Dam as impaired due to Flow Regime Modification and Alteration in stream-side or littoral vegetative covers. See <https://www.mass.gov/doc/draft-massachusetts-integrated-list-of-waters-for-the-clean-water-act-20182020-reporting-cycle/download>, at 168. The river section below the Turners Falls Dam is listed as impaired due to Flow Regime Modification and Dewatering, among other impairments. *Id.*

uncertainty regarding what the existing and designated uses of that portion of the Connecticut River will be when the licenses expire. For example, will there be additional species listed as threatened or endangered under the Endangered Species Act in that portion of the river that are negatively impacted by the presence of the non-operational hydropower facilities? Requiring financial assurances sufficient to decommission and remove such facilities—especially given the uncertainty of river conditions when the licenses expire—has a direct nexus to and clearly supports DEP’s mandatory duty set forth in the SWQS to protect and enhance designated uses.

314 CMR 4.05(5): In addition to the specific water quality criteria associated with Class B waters to protect and enhance those designated uses, all surface waters in Massachusetts shall be free from “from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms.” 314 CMR 4.05(5)(b). Non-operational dams constitute such alterations, and, as such, requiring financial assurances for their decommissioning and removal is supported by this SWQS as well.

THE PUBLIC TRUST DOCTRINE SUPPORTS REQUIRING FINANCIAL ASSURANCES FOR DECOMMISSIONING AND REMOVAL COSTS

The public trust doctrine, codified in both the Massachusetts Constitution, as well as the General Laws, provides another basis of support to require financial assurances for decommissioning and removal of hydropower facilities. *See* Mass. Const. art. XLIX, as amended by art. XCVII; *see also* G.L. 91 § 2 (2016). Using trust-like language, DEP is charged with the “effective planning and management of water use and conservation in the commonwealth” to “ensure an adequate volume and quality of water for all citizens of the commonwealth, both present and future.” Mass. Gen Laws Ann ch. 21G, § 3. DEP, through its regulations, defines “trust lands” as “present and former waterways in which the fee simple, any easement, or other proprietary interest is held by the Commonwealth in trust for the benefit of the public.” 310 CMR § 9.02. These statutes and regulations are evidence of the Commonwealth of Massachusetts adopting the public trust doctrine into State law, which brings it within the purview of CWA 33 U.S.C. § 1341(d).

The Connecticut River is one of the few geographic areas explicitly listed as “trust lands” in state regulations. *See* 310 CMR § 9.04(1)(b). Accordingly, Massachusetts can require financial assurances pursuant to its public trust obligations for the Connecticut River, which have been

codified in state law. Arguably, *not* requiring such financial assurance would constitute a breach of Massachusetts' duty to protect an identified trust resource. This is especially the case when a hydropower facility is no longer operational. At that point, there is no countervailing public benefit—electricity generation—to offset the ongoing impairment of the trust resource.

CONCLUSION

This memorandum is not intended to provide an exhaustive list of state laws that provide a basis for requiring financial assurances as a condition of CWA § 401 certification. There may be other state laws related to protection of aquatic species and habitat, or addressing climate change or flood control that also are applicable. But, at a minimum, the provisions of Massachusetts' SWQS discussed above and the public trust doctrine provide more than ample nexus and support for the state to require financial assurances from hydropower owners and operators sufficient to decommission and remove a non-operating hydropower facility, especially since some of those facilities will have been in operation for a century when their renewed licenses expire. Conditioning CWA § 401 certifications on such financial assurances will ensure that federal and state requirements are met and that the physical, chemical, and biological integrity of rivers, including unobstructed flows, are *restored* to protect existing and designated uses. Requiring such financial assurances also will ensure that the Massachusetts tax and ratepayers and host communities are not burdened with the bill for such restoration, which is good public policy already being practiced in the context of many other energy generating projects throughout the state.