FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, D.C. 20426
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OFFICE OF ENERGY PROJECTS

Project No. 2790-072 —Massachusetts and
New Hampshire
Lowell Hydroelectric Project
Boott Hydropower, LLC

Kevin Webb
Hydro Licensing Manager
Enel Green Power North America, Inc.
100 Brickstone Square, Suite 300
Andover, MA 01810

Reference: Study Plan Determination for the Lowell Hydroelectric Project

Dear Mr. Webb:

Pursuant to 18 C.F.R. § 5.13(c) of the Commission's regulations, this letter contains the study plan determination for the Lowell Hydroelectric Project No. 2790 (project), located on the Merrimack River, in Middlesex County, Massachusetts and Hillsborough County, New Hampshire. The determination is based on the study criteria set forth in section 5.9(b) of the Commission's regulations, applicable law, Commission policy and practice, and the record of information.

Background

On September 28, 2018, Boott Hydropower, LLC (Boott) filed its proposed plan for 13 studies related to fish and aquatic resources, recreation, aesthetics, historic resources, operation of the Lowell canal, and land ownership in support of its intent to relicense the project.

Boott held study plan meetings on October 18 and 19, 2018 to discuss the proposed study plan. Comments on the studies were filed by the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (FWS), National Park Service (Park Service), Massachusetts Division of Fisheries and Wildlife (Massachusetts DFW), New Hampshire Fish and Game Department (New Hampshire FGD), Massachusetts Division of Marine Fisheries (Massachusetts DMF), and American Whitewater.

Boott filed a revised study plan on January 28, 2019. Comments on the revised study plan were filed by Massachusetts DFW and FWS.

Study Plan Determination

Of the 13 studies proposed by Boott, two are approved with staff-recommended modifications and 11 are approved as filed by Boott (see Appendix A). No additional studies are required.

The specific modifications to the study plan and the basis for modifying Boott's study plan are discussed in Appendix B. Commission staff reviewed all comments and considered all study plan criteria in section 5.9 of the Commission's regulations; however, only the specific study criteria particularly relevant to the determination are referenced in Appendix B.

Nothing in this study plan determination is intended, in any way, to limit any agency's proper exercise of its independent statutory authority to require additional studies. Boott may choose to conduct any study not specifically required herein that it feels would add pertinent information to the record of this proceeding. Pursuant to section 5.15(c)(1) of the Commission's regulations, the initial study report for all studies in the approved study plan must be filed by February 25, 2020.

If you have any questions, please contact Amy Chang at (202) 502-8250.

Sincerely,

Terry L. Turpin
Director
Office of Energy Projects

Enclosures: Appendix A – Summary of Determination on Proposed Studies
Appendix B-- Staff Recommendations on Requested Study Modifications

APPENDIX A

SUMMARY OF DETERMINATION ON PROPOSED STUDIES

Study	Recommending Entity	Approved	Approved with Modifications	Not Required
1. Downstream American Eel Passage Assessment	Boott, FWS, NMFS, Massachusetts DFW, New Hampshire FGD		X	
2. Juvenile Alosine Downstream Passage Assessment	Boott, FWS, NMFS, Massachusetts DFW, New Hampshire FGD	X		
3. Upstream and Downstream Adult Alosine Passage Assessment	Boott, FWS, NMFS, Massachusetts DFW, New Hampshire FGD		X	
4. Fish Passage Survival Study	Boott, FWS, NMFS, Massachusetts DFW, New Hampshire FGD	X		
5. Three-Dimensional Computational Fluid Dynamics Modeling	Boott, FWS, NMFS, Massachusetts DFW, New Hampshire FGD	X		
6. Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach	Boott, FWS, NMFS, Massachusetts DFW, New Hampshire FGD	X		
7. Fish Assemblage Study	Boott, Massachusetts DFW	X		
8. Recreation and Aesthetics Study	Boott, NPS, American Whitewater	X		

Study	Recommending Entity	Approved	Approved with Modifications	Not Required
9. Historically Significant Waterpower Equipment Study	Boott, NPS	X		
10. Resources, Ownership, Boundaries, and Land Rights Study	Boott, NPS	X		
11. Water Level and Flow Effects on Historic Resources Study	Boott, NPS	X		
12. Whitewater Boating and Access Study	Boott, American Whitewater	X		
13. Operation Analysis of the Lowell Canal Study	Boott, FWS, Massachusetts DFW, New Hampshire FGD	X		

APPENDIX B

STAFF RECOMMENDATIONS ON REQUESTED STUDY MODIFICATIONS

The following discussion includes staff's recommendations on studies proposed by Boott Hydropower, LLC (Boott) and participants' requests for study modifications. We base our recommendations on the study criteria outlined in the Commission's regulations [18 C.F.R. § 5.9(b)(1)-(7)]. Except as explained below, the revised study plan filed on January 28, 2019 adequately addresses all study needs at this time.

Study 1: Downstream American Eel Passage Assessment

Applicant's Proposal

Boott proposes to conduct a study to assess the project's impact on the outmigration of adult silver-phase American eels. The objectives of this study are to: (1) quantify the movement rates and relative proportion of eels passing downstream via various routes at the project;[1] and (2) evaluate mortality of eels passed via each potential route. Boott proposes to use radio telemetry methods to estimate movement rates, route selection, and survival. Boott also proposes to use the results of a desktop turbine survival analysis that is being conducted as part of Study 4, *Fish Passage Survival Study*, to evaluate the mortality of adult out-migrating eels at the project.

As part of Study 1, Boott proposes to radio-tag 100 live adult eels, and to release the eels during a minimum of five separate release events in mid-October, in an attempt to capture a range of environmental and project operational conditions. The live eels would provide information on the rates and routes of adult eel movements. Boott also proposes to release a total of 10 radio-tagged dead eels into the draft tubes of the turbines to simulate "movements" of adult eels killed during downstream passage. An equal proportion of radio-tagged dead eels will be released in conjunction with each release of live test eels in mid-October. By comparing the movement rates of the dead radio-tagged eels with those of the live eels, Boott would be able to interpret which of the live radio-

[1] The project consists of the 1,093-foot-long, 15-foot-high Pawtucket Dam on the Merrimack River and the 5.5-mile-long Northern and Pawtucket Canal System. Available downstream fish passage routes include: (1) Pawtucket Dam; (2) the E. L. Field Powerhouse on the mainstem of the Merrimack River; (3) a downstream fish bypass facility and surge gate located near the E.L. Field Powerhouse; and (4) the Northern and Pawtucket Canal System that includes four power stations (*i.e.*, the Hamilton, Assets, Bridge Street, and John Street Power Stations) and multiple dams, canals, and wasteways that empty into the Concord and Merrimack rivers.

tagged eels are killed during passage at the project. Boott proposes to conduct this study in 2019, and to incorporate eel passage data into the study that was collected in 2017 and 2018 for other FERC projects.[2] Boott states that if the 2019 study produces an inadequate sample size or if river conditions are unusual, then it will consider a second year of study.

Balloon Tag Analysis

Comments on the Study

The Massachusetts Division of Fisheries and Wildlife (Massachusetts DFW) and U.S. Fish and Wildlife Service (FWS) recommend that Boott conduct a balloon tag analysis, in addition to the proposed radio telemetry analysis, in order to have more confidence in determining eel passage survival at the project. The balloon tag analysis would include an unspecified number of balloon-tagged live eels being injected into each different type of turbine at the project, and then recaptured downstream and inspected for injuries or fatalities. Massachusetts DFW states that it could be difficult to detect mortality events and determine the cause of mortality when only using radio telemetry because test eels are not recaptured and mortality must be assumed based on an interpretation of the eels' movement patterns.

Discussion and Staff Recommendation

Boott proposes multiple analyses that will provide information on eel passage survival at the project. Boott will use the route selection information from the radio telemetry analysis (Study 1) to determine which turbines need to be analyzed during the desktop survival analysis (Study 4). The desktop analysis is a well-accepted methodology for evaluating entrainment mortality at hydroelectric projects [section 5.9(b)(6)], especially in cases where there is existing literature available from projects with turbines of similar type, size, speed, and hydraulic head and where similar species and life stages have been tested (Winchell, 2000). Indeed, most of the flow at the Lowell Hydroelectric Project goes through the two Kaplan turbines at the E.L. Field

[2] In 2017, 14 eels released at the Amoskeag Development of the Merrimack River Project (FERC Project No. 1893) were tracked via radio telemetry through the Lowell Project and further downstream to the Lawrence Project (FERC Project No. 2800). At the proposed study plan meeting in October 2018, Boott personnel indicated that 60 tagged eels would be released at the Amoskeag Development in late 2018 and tracked through the same river reach as those in 2017.

Powerhouse.[3] These Kaplan turbines are not unusual in their specifications, and similar turbines have been studied at other projects (Heisey et al., 2017).

In addition to the desktop analysis, Boott proposes to estimate adult eel mortality by evaluating the movement patterns of radio-tagged live and dead adult eels. The radio telemetry data from the live and dead eels will help verify the results of the desktop analysis, and *vice versa*.

The information from the radio-telemetry and desktop analyses should provide an adequate estimate of the survival rates of adult eels through the spillage, fish bypass, and turbine passage routes [section 5.9(b)(5)]. If, however, the initial study report contains inconclusive findings for eel passage survival, then Commission staff could consider the need for additional data collection during the second study season.[4] Based on the information that will be provided by Studies 1 and 4, there is no justification for the additional estimated cost of $75,000 for the balloon tag analysis [section 5.9(b)(7)], and we do not recommend it for 2019 study season.

Timing of Study

Comments on the Study

Massachusetts DFW and FWS recommend beginning the study in mid-September rather than mid-October as proposed by Boott. Massachusetts DFW states that eel migration can occur as early as August and is highly dependent on river conditions.

Discussion and Recommendations

Because there is no known source of adult silver eels from the Merrimack River that could be used as test fish for this study, Boott proposes to collect and tag silver eels from the St. Croix River in Maine for the study. Due to the migration timing of the St. Croix River eels (August through October; Shepard, 2015) and because fish imported to Massachusetts from Maine must be certified free of bacterial or viral pathogens (a process taking at least 21 days), it does not appear to be feasible for Boott to begin this study before early October. For example, if eels are successfully captured and obtained in late August, then they would not be available for transport to Massachusetts for transmitter implantation and release into the Merrimack River until at least late

[3] Of the 14 adult eels tracked in the 2017 study, at least 13 of them went either through these Kaplan turbines, through the fish bypass, or over the spillway. One eel went through the canal system after entering the Pawtucket Canal or went the same route as the other 13 eels. All 14 eels were detected alive at the downstream Lawrence Project.

[4] *See* 18 C.F.R. § 5.15 (2018).

September. Therefore, while we encourage Boott to begin the releases of tagged eels as soon as possible, we do not recommend beginning the study in mid-September.

Dead Eel Sample Size

Comments on the Study

Massachusetts DFW and FWS recommend that Boott increase the total number of dead eels released during the study in order to better estimate the drift rates and movement characteristics of dead eels. The agencies recommend using 10 dead eels for each operational scenario,[5] as opposed to Boott's proposal to use a total of 10 dead eels.

Discussion and Recommendations

The agencies do not provide a basis for why 10 dead eels are needed during each release event. Boott proposes to release a total of 10 dead eels and 100 live eels in equal proportion across five or more release events. For example, if there are five release events, then each event would include the release of 20 live eels and two dead eels. Absent anomalous conditions, releasing two dead eels should provide sufficient information to simulate dead eel movements and allow Boott to interpret which of the live radio-tagged eels are killed during passage at the project.

Boott has indicated in the study plan, however, that it might conduct more than five release events. If Boott releases a total of 10 dead eels across more than five release events, then at least one of the release events would include a single dead eel for simulating downstream movement. Releasing a single dead eel may be problematic if the eel becomes trapped somewhere in the tailrace soon after exiting the draft tube or otherwise fails to provide useful movement data. While Commission staff do not have a basis for recommending the use of 10 eels per release event, we do recommend the use of at least two dead eels per release event to increase the likelihood of receiving useful information on dead eel drift rates in the downstream reach [section 5.9(b)(5)].

Two-Year Study

Comments on the Study

Massachusetts DFW and FWS recommend a second year of study if there are radio telemetry "receiver failures, poor detection efficiency, failed units, *etc*."

[5] Because the project is operated in a run-of-river mode, staff assumes the agencies are referring to operational scenarios that vary the amount of flow being utilized for project generation.

Discussion and Staff Recommendation

There is no indication at this time that an additional year of study will be necessary to meet the goals and objectives of the study [section 5.9(b)(4)]. However, if the first year of study does not adequately meet the study objectives and provide the information necessary for evaluating project effects, then participants will have an opportunity to file a request to modify the study to collect additional information.[6] Therefore, we do not recommend a second study season at this time.

Study 2: Juvenile Alosine Downstream Passage Assessment

Boott proposes to radio tag juvenile alosines[7] to evaluate the effects of project operation on the downstream migration of juvenile alosines. The objectives of the study include: (1) assessing the effects of the Pawtucket Dam on the timing, orientation, passage routes, and migration rates of juvenile alosines; (2) determining the proportion of juvenile alosines that select the Pawtucket Canal versus the E.L. Field Powerhouse, fish bypass facility, or Pawtucket Dam as a downstream passage route; and (3) determining if there are any delays associated with downstream movement related to either dam spill or the E.L. Field Powerhouse.

As part of the study, Boott proposes to tag 150 juvenile alosines with radio tags and release them in 10 groups of 15 fish during October 2019. Boott proposes to release the tagged fish approximately 1 mile upstream of the project. Boott also proposes to estimate total project survival by conducting a desktop analysis of entrainment, impingement, and turbine survival for the downstream passage routes that juvenile alosines select during the radio telemetry analysis (*i.e.*, Study 4, *Fish Passage Survival Study*).[8]

[6] *See* 18 C.F.R. § 5.15 (2018).

[7] Alewife, American shad, and blueback herring belong to the genus *Alosa* and are referred to collectively as "alosines."

[8] The study proposal does not specifically use data from the radio-tagged fish to estimate downstream passage survival rates. However, in Appendix C of the study plan, Boott states that it may be possible to use the telemetry data to qualitatively identify downstream passage routes with poor survival.

Balloon Tag Analysis

Comments on the Study

Massachusetts DFW and FWS recommend that Boott conduct a balloon tag analysis to estimate juvenile alosine downstream passage survival. Massachusetts DFW states that a balloon tag assessment will provide empirical estimates of survival through the various passage routes, and will avoid the need to rely on the results of a desktop survival study and its underlying assumptions.

Discussion and Staff Recommendation

As described above in Study 1, the desktop turbine survival analysis proposed by Boott is a well-accepted methodology for evaluating entrainment mortality at hydroelectric projects and is consistent with studies conducted at other FERC projects [section 5.9(b)(6)]. Accordingly, there is no indication that the desktop analysis will be insufficient to determine the project's effects on the survival of juvenile alosines, and no justification for the additional estimated cost of $75,000 for the balloon tag analysis [section 5.9(b)(7)]. To the extent that the initial study report contains inconclusive findings for juvenile alosine passage survival, then Commission staff can consider the need for additional data collection at that time.[9] Therefore, we do not recommend that Boott conduct a balloon tag analysis for juvenile alosines at this time.

Two-year Study

Comments on the Study

Massachusetts DFW and FWS recommend that Boott collect juvenile alosine downstream passage data over a two-year period because variability in environmental conditions between years can affect project operation, fish behavior, and downstream migration through the project.

Discussion and Staff Recommendation

There is no indication that an additional year of study will be necessary to meet the goals and objectives of the study [section 5.9(b)(4)]. Conducting the study for two consecutive years would not guarantee that environmental conditions would differ substantially between the two years. However, if the first year of study does not adequately meet the study objectives and provide the information necessary for

[9] *See* 18 C.F.R. § 5.15 (2018).

evaluating project effects, then participants will have an opportunity to file a request to modify the study to collect additional information.[10] Therefore, we do not recommend a second study season at this time.

Study 3: Upstream and Downstream Adult Alosine Passage Assessment

Applicant's Proposal

To evaluate the effects of project operation on the upstream and downstream migration and survival of adult American shad and river herring,[11] Boott proposes to assess migration behavior, route selection, passage success, survival, and residence duration of adult alosines during upstream and downstream migrations through the project. The objectives of the study include: (1) assessing the effects of project operation on the timing, orientation, routes, and migration rates of shad and river herring; (2) determining route selection and behavior of upstream migrating shad and river herring at the project under varied operating conditions, including a range of spill conditions; (3) determining residence duration or fallback of upstream migrants in the northern canal; (4) assessing attraction to, and efficiency of, the fish lift and ladder under a range of spill conditions;[12] (5) evaluating the internal efficiency of the fish ladder;[13] (6) collecting fish ladder and lift efficiency data, including rates of approach to fishway entrances, entry into fishways, and passage under varied operating conditions; (7) determining the proportion of post-spawn adults that select the power canal as a downstream passage route under varied operating conditions; (8) determining post-spawn adult downstream migration route selection, passage efficiency, and residence duration associated with the power canal under various operating conditions; and (9) comparing residence duration and movement along the routes utilized during passage.

Boott proposes to use radio tags to collect information on movement rate, delay, and route selection during upstream and downstream migration. Boott also proposes to

[10] *See* 18 C.F.R. § 5.15 (2018).

[11] Blueback herring and alewife are difficult to distinguish visually and are therefore often collectively referred to as river herring.

[12] The fish lift is located at the E. L. Field Powerhouse, and the vertical slot fish ladder is located at the Pawtucket Dam.

[13] In general, the "internal efficiency" of a fishway measures aspects of fish movement through the fishway.

use passive integrated transponder tags (PIT tags)[14] to collect information about movements within the Pawtucket Dam fishway, the E. L. Field Powerhouse fish lift, and the power canal.

Downstream Passage Survival

Boott proposes to tag a total of 10 dead shad and river herring with radio tags, release them into the draft tubes of the E. L. Field Powerhouse, and monitor their downstream progression to simulate "movements" of adult alosine killed during downstream passage. An equal proportion of radio-tagged dead alosines will be released in conjunction with each release of live test alosines. The live alosines would provide information on the rates and routes of adult alosine movements; and, by comparing the movement rates of the dead radio-tagged alosines with those of the live alosines, Boott would be able to interpret which of the live radio-tagged alosines are killed during passage at the project. Boott also proposes to estimate total project survival by conducting a desktop analysis of entrainment, impingement, and turbine survival for the downstream passage routes that adult alosines select during the study (*i.e.*, Study 4, *Fish Passage Survival Study*).

Comments on the Study

Massachusetts DFW and FWS recommend that Boott conduct a balloon tag analysis to evaluate the injury and mortality rates for adult alosines for each potential passage route at the project.

Discussion and Staff Recommendations

The study plan includes multiple analyses for determining the effects of the project on adult alosine passage survival. Boott proposes to estimate total project survival for adult alosines as part of Study 4 by conducting a desktop analysis of survival for the downstream passage routes that are used by adult alosines during Study 3. As described above in Study 1, the desktop turbine survival analysis proposed by Boott is a well-accepted methodology for evaluating entrainment mortality at hydroelectric projects and is consistent with studies conducted at other FERC projects [section 5.9(b)(6)].

In addition to the desktop analysis, Boott proposes to estimate adult alosine mortality by evaluating the movement patterns of radio-tagged live and dead alosines.

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[14] PIT tags are very small tags that respond to specific radio frequencies at close range (2 feet or less) to transmit a tag identification number. The PIT tags will be used to gather information about downstream movements in the power canal and upstream movements within the Pawtucket Dam fishway and the E. L. Field Powerhouse fish lift.

However, Boott does not define the criteria that it will use to estimate downstream passage survival with radio telemetry. In Study 1, Boott proposes to use the MARK program (White and Burnham, 1999) to conduct a Cormack-Jolly-Seber (CJS) model analysis to estimate downstream passage survival for adult American eels.[15] Because the data Boott proposes to collect for Studies 1 and 3 are similar, Commission staff recommend that Boott conduct a CJS analysis of the adult alosine radio tag data to estimate downstream passage survival [section 5.9(b)(6)].

Altogether, the combination of the radio-telemetry data and the desktop analysis is likely to provide an adequate estimate of the survival rates of adult alosines through the spillage, fish bypass, and turbine passage routes. If, however, the initial study report contains inconclusive findings for adult alosine passage survival, then Commission staff can consider the need for additional data collection at that time.[16] Based on the information that will be provided by Studies 1 and 4, there is no justification for the additional estimated cost of $75,000 for the balloon tag analysis [section 5.9(b)(7)], and we do not recommend it for the 2019 study season.

Sample Size for Dual-tagged Fish

Boott proposes to tag 200 shad with PIT tags and 180 shad with radio and PIT tags (dual-tagged fish). Boott also proposes to tag 200 river herring with PIT tags and 150 river herring with radio and PIT tags.

Comments on the Study

Based on fallback[17] rates reported in other telemetry studies, Massachusetts DFW states that Boott should assume a fallback rate of 40 to 50 percent for upstream migrating fish that are tagged and released. Massachusetts DFW and FWS recommend that Boott dual tag 200 shad and 200 river herring with both radio tags and PIT tags to ensure that sufficient data will be collected to understand how fish move past the project under a range of environmental conditions.

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[15] The CJS model incorporates the presence/absence of a fish within a telemetered reach to provide an estimate of survival.

[16] *See* 18 C.F.R. § 5.15 (2018).

[17] The term "fallback" refers to when tagged fish move downstream after being released, instead of continuing upstream to spawn.

Discussion and Staff Recommendation

Fallback behavior is a common occurrence in alosine tagging studies (Frank *et al*., 2009). In the study plan, Boott reports fallback rates ranging from 25 to 60 percent for shad, based on studies conducted in the Connecticut, Kennebec, Merrimack, and Saco Rivers.[18] In addition, Boott states that the fallback rates for river herring were 21 and 27 percent during two studies conducted in the Saco River. In recent adult shad tagging studies in the Connecticut River, 25 to 73 percent of shad exhibited fallback behavior or otherwise provided no usable upstream passage information (Kleinschmidt and Gomez and Sullivan, 2017; Normandeau, 2017a; Normandeau, 2017b; Normandeau, 2018).

Boott's proposal to dual tag 180 shad and 150 river herring is based on a fallback rate of 33 percent for shad and 21 percent for river herring. These fallback rates are within the range of fallback rates observed in the studies discussed above [section 5.9(b)(6)]. Further, even if 50 percent of the 180 dual-tagged shad fall back, as suggested by Massachusetts DFW, the study would still provide data for about 90 dual-tagged shad that could be used to evaluate the effects of the project on adult alosine migration (in addition to any PIT-tagged shad that enter the fishways). Similarly, even if 27 percent of the 150 dual tagged river herring fall back, the study would still provide data for approximately 110 dual-tagged river herring that could be used to evaluate the effects of the project on adult alosine migration. There is no evidence to suggest that this information would be insufficient to meet the study goals and objectives.

Because the study is likely sufficient to provide information to develop license requirements [section 5.9(b)(5)], the additional cost of approximately $17,500 to dual tag 20 additional shad and 50 additional river herring is not warranted at this time [section 5.9(b)(7)]. Therefore, we do not recommend that Boott dual tag 200 shad and 200 river herring.

Tagged Fish Transport

Boott proposes to collect the adult shad and river herring from the Essex Dam fish lift at the Lawrence Project (FERC Project No. 2800) that is located approximately 11 miles downstream on the Merrimack River. Boott proposes to release the dual-tagged fish approximately 0.25 mile upstream of Essex Dam to track their upstream migration through the project. To augment the number of downstream migrants, Boott proposes to radio tag an additional 150 shad and 150 river herring at the Essex Dam fish lift and

[18] Boott incorrectly states that the fallback rate reported by Normandeau (2017a) was 60 percent. Of the 100 radio-tagged shad released by Normandeau (2017a), 36 shad entered the study area. Therefore, 64 percent of the shad exhibited fallback behavior or otherwise failed to enter the study area.

release 100 individuals of each species upstream of Pawtucket Dam and 50 individuals of each species into the project power canal.

Comments on the Study

To reduce tagging stress and fallback rates, Massachusetts DFW and FWS recommend that Boott release the tagged fish at the Lawrence Project instead of transporting fish upstream to the Lowell Project.

Discussion and Staff Recommendations

Any radio-tagged fish that fallback after release upstream of the Lowell Project would provide information that is useful for determining the effects of the project on downstream passage. If released at or near the Lawrence Project, a proportion of these fish may not reach the Lowell Project or may otherwise fail to provide downstream passage information. Therefore, to maximize the number of radio-tagged fish available to provide downstream passage information, we do not recommend that Boott release the radio-tagged fish at the Lawrence Project as requested by the agencies.

Timing of Study

Comments on the Study

Massachusetts DFW and FWS recommend that Boott release at least one group of river herring after May 20 to coincide with the period when blueback herring are most likely ascending the fish lift at the Lawrence Project.

Discussion and Staff Recommendation

While blueback herring and alewives are often referred to collectively as "river herring," blueback herring do spawn later in the spring than alewives and may exhibit different behavior when encountering upstream fishways. Conducting at least one release after May 20 would increase the likelihood that some blueback herring are included in the study. Boott proposes to start the study in early May and conduct six release events, but does not specify a schedule for the release. Therefore, we recommend that Boott conduct at least one release event after May 20.

Additional Bypassed Reach Telemetry Monitoring Stations

Comments on the Study

Massachusetts DFW and FWS recommend installing additional monitoring stations by the downstream-most and upstream-most weirs in the bypassed reach to quantify the amount of time required for fish to traverse the weirs.[19]

Discussion and Staff Recommendation

The study plan shows two receivers in the vicinity of the concrete weirs. Based on Figures 8-2 and 8-3 of the study plan and satellite imagery, the proposed location of Station M9 appears to be located approximately 50 feet upstream of the upstream-most weir, and the proposed location of station M8 appears to be located approximately 775 feet downstream of the downstream-most weir in the bypassed reach. In Appendix C of the study plan, Boott states that the proposed receiver locations are approximations of where the receivers will actually be installed. Boott also states that the exact placement of the receivers will be a function of site access, crew safety, and site security. However, Boott states that it will attempt to ensure that any potential effects from the in-stream concrete weirs on upstream movement can be quantified.

The bypassed reach between the downstream-most weir and station M8 appears to be a pool with no obvious obstructions to upstream movement. Movement through this section of the bypassed reach should therefore be relatively rapid. Given the lack of obvious obstacles between station M8 and the downstream-most weir, the data collected by stations M8 and M9 should be sufficient to evaluate the effects of the concrete weirs. The results of Study 6, *Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach*, will also provide information about locations in the bypassed reach where the zone of passage may be insufficient at certain flows. Altogether, the movement data provided by stations M8 and M9 and the results of Study 6 should be sufficient for staff to develop license requirements [section 5.9(b)(5)], and we do not recommend that Boott install additional receivers near the concrete weirs in the bypassed reach.

[19] The Lowell Project bypassed reach includes six concrete flow control weirs with adjustable stoplog sections to facilitate upstream fish passage. The six concrete flow control weirs are located various distances apart in an approximately 500-foot-long reach of the Merrimack River downstream of the Pawtucket Falls Dam and fish ladder entrance. The study plan indicates that six concrete flow control weirs were installed under the current license to address "the adequacy of flows for upstream fish passage at the project."

Tailrace Monitoring Station

Comments on the Study

Massachusetts DFW and FWS state that a large proportion of radio-tagged shad in previous studies conducted at the project did not enter the fish lift. Because many radio-tagged fish may aggregate in the tailrace prior to passage, the agencies state that the proposed tailrace station (station M10) may be "swamped" by multiple signals, which would result in lost data. The agencies recommend that Boott install an additional receiver along the eastern wall of the E. L. Field Powerhouse tailrace to provide data redundancy.

Discussion and Staff Recommendation

As stated by the agencies, previous studies have shown that radio-tagged fish experienced delay in the tailrace or did not enter the fish lift (Sprankle, 2005; Alden, 2011). Boott will excavate a portion of the tailrace area in 2019 in an attempt to reduce the delay observed during these studies, and Study 3 will be the first study to evaluate the upstream passage efficiency of the E. L. Field Powerhouse fish lift following the excavation. The radio tag data will be necessary to determine when dual-tagged fish enter the tailrace and whether any upstream passage delays are occurring in the tailrace. In addition, the radio tag data is necessary to estimate the attraction efficiency of the fish lift.[20]

Any data lost due to receiver malfunction will interfere with evaluating upstream passage delay and the efficiency of the fish lift. Because information about delay in the tailrace and the attraction efficiency of the fish lift will be required to develop license requirements [section 5.9(b)(5)], and because adding another receiver (approximately $2,500) would increase the likelihood that the necessary data are collected in one study season, the additional receiver would be worth the cost [section 5.9(b)(7)]. Accordingly, we recommend that Boott install an additional receiver in the tailrace area.

Tailrace Pool Telemetry Monitoring Station

Comments on the Study

To monitor the movement of tagged fish from the pool at the base of the tailrace of the E.L. Field Powerhouse to the bypassed reach, Massachusetts DFW and FWS

[20] The "attraction efficiency" of a fishway is measured as the number of fish that actually attempt to enter the fishway out of the number of fish that are available to enter a fishway.

recommend either: (1) moving the proposed location of one of the telemetry stations (station M7) farther downstream, or (2) installing an additional telemetry receiver closer to the boundary between the tailrace pool and the bypassed reach.

Discussion and Staff Recommendation

Boott proposes to place station M7 approximately 700 feet upstream of the boundary between the bypassed reach and the tailrace pool. As discussed above, Boott states in the study plan that the proposed receiver locations are approximations and that the exact placement of station M7 will be a function of site access, crew safety, and site security. However, Boott states that it will make every effort to ensure that station M7 is in proximity to the boundary between the tailrace pool and the lower bypassed reach.

Extensive bedrock ledges near the downstream end of the bypassed reach could inhibit the upstream movement of adult shad at some flows, and no previous studies have been conducted to quantify the relationship between flow in the bypassed reach and upstream migration. Because information about migration delays is needed to develop license requirements [section 5.9(b)(5)], we recommend that Boott either install station M7 so that fish movement from the tailrace pool to the bypassed reach can be adequately monitored or install an additional receive closer to the boundary of the tailrace pool and the bypassed reach.

Study 4: Fish Passage Survival Study

Applicant's Proposal

Boott proposes to conduct a study to assess the survival of adult/juvenile shad and alewife, and adult American eel that are passing downstream through the turbines located at the E.L. Field, Bridge Street, Hamilton, and John Street powerhouses. To assess the survival of migrating fish through the project turbines, Boott proposes to use a literature review in combination with a comparison of project-specific parameters, such as the proportional flow distribution between the powerhouses at the project, turbine design, site-specific intake characteristics, and intake velocities. Additionally, fish swim speeds, body dimensions, and other relevant life history information would be considered in the evaluation. The route selection information from Studies 1, 2, and 3 would also be used to assess survival through the turbines, fish bypass, and spillage.

Comments on the Study

Massachusetts DFW and FWS recommend a balloon tag analysis for adult/juvenile alosines and adult eels to evaluate injury and mortality for each potential passage route at the project.

Discussion and Staff Recommendation

A detailed rationale for why we do not recommend the balloon tag analyses for adult eels, juvenile alosines, and adult alosines is provided in the discussion and staff recommendation sections for Studies 1, 2, and 3, respectively.

Study 5: Three-Dimensional Computational Fluid Dynamics Modeling

Applicant's Proposal

Boott proposes to conduct a study to evaluate flow (*i.e.*, depth and velocity) in the vicinity of the project's fish passage facilities to determine the impacts of hydraulics on fish behavior. The study objectives include: (1) developing three-dimensional hydraulic models in the vicinity of fish passage structures (including the E.L. Field Powerhouse, the bypassed reach in the vicinity of the Pawtucket Dam fish ladder entrance, and the Pawtucket Dam fish ladder); (2) simulating project operation using each model; and (3) producing a series of color contour maps depicting flow fields relating to fishway attraction, fishway hydraulics, and the forebay and fish bypass system.

Comments on the Study

Massachusetts DFW and FWS recommend that Boott analyze flow hydraulics throughout the downstream weirs in the bypassed reach to determine the adequacy of the weir structures for fish passage and to determine if alterations are needed to increase fish passage efficiency.

Discussion and Staff Recommendation

Study 5 does not include the creation of a three-dimensional hydraulic model for the system of weirs located in the bypassed reach. However, as part of Study 6 (*Instream Flow Habitat Assessment and Zone of Passage Study in the Bypassed Reach*), Boott proposes to develop a two-dimensional hydraulic habitat model of the bypassed reach and a zone of passage study to determine an appropriate flow regime for migratory species in the bypassed reach. The habitat model and zone of passage study can be used to evaluate the availability of aquatic habitat in the bypassed reach, including the adequacy of the weir structures across a range of flows [section 5.9(b)(4)]. Accordingly, staff does not recommend that Boott develop and analyze a three-dimensional hydraulic model throughout the downstream weirs in the bypassed reach, as requested by the agencies.

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