UPDATED REVISED STUDY 22

DOWNSTREAM MIGRATION OF JUVENILE AMERICAN SHAD – VERNON

RELEVANT STUDY REQUESTS

FWS-06; NHDES-26; NHFG-26; VANR-09; CRWC-24; TU-09

STUDY GOALS AND OBJECTIVES

In their study requests, FWS, NHDES, NHFG, VANR, CRWC, and TU identified a potential issue related to the Vernon Project's operations on downstream passage of juvenile shad. The issue identified is whether or not project operations affect juvenile shad outmigration and production.

The study goal is to assess whether project operations affect the safe and timely passage of emigrating juvenile American shad.

The specific objectives of this study are to:

- assess project operation effects on the timing, route selection, migration rates, and survival of juvenile shad migrating past the project;
- characterize the proportion of juvenile shad using all possible passage routes at Vernon over the period of downstream migration under normal operational conditions; and
- conduct controlled turbine passage survival tests for juvenile shad passed through one of the older Francis units (Unit Nos. 1 to 4) and one of the new Kaplan units (Unit Nos. 5 to 8) to estimate the relative survival specific to those unit types.

This study, in conjunction with a previous juvenile American shad turbine survival study of Unit 10 (Normandeau, 1996), will provide the information needed to evaluate whether turbine passage adversely affects juvenile survival and to evaluate migration timing, forebay residency time, and route selection.

The Revised Study Plan has been updated herein to incorporate newly proposed study plan modifications based on:

- results of juvenile shad tagging tests conducted in 2014 to evaluate the potential use of hatchery-reared juvenile shad (Normandeau, 2014);
- stakeholder comments received on the Initial Study Report (ISR) filed on September 15, 2014 and based on the ISR meeting summary filed on October 14, 2014;

- stakeholder consultation that occurred on August 26, 2014 in conjunction with proposed Study Plan 34 – Vernon Hydroacoustics Study; and
- FERC technical meeting on November 20, 2014 (also in conjunction with proposed Study Plan 34 but related to this study as well).

RELEVANT JURISDICTIONAL AGENCY RESOURCE MANAGEMENT GOALS

In their study requests, federal and state resource agencies described various jurisdictional resource management goals for this study, as summarized below.

FWS	• Specific goals related to American shad including minimizing project effects on juvenile shad survival, production, and recruitment. Goals reference ASMFC Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC, 2010) and CRASC Management Plan for American Shad in the Connecticut River (CRASC, 1992).
	• General goals for relicensing including ensuring that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives and conserving, protecting, and enhancing habitats for fish, wildlife, and plants affected by the projects.
NHDES	• State water quality standards and designated uses for Class B waters including aquatic life, fish consumption, drinking water supply after treatment, primary and secondary contact recreation, and wildlife.
NHFG	• NHFG specific goals related to American shad including minimizing project effects on juvenile shad survival, production, and recruitment. Goals reference ASMFC (2010) and CRASC (1992).
	• General goals related to healthy ecosystems to support fish and wildlife. Goals reference the New Hampshire Fish and Game Department Strategic Plan 1998–2010 (NHFG, 1998).
VANR	• VFWD specific goals related to American shad including minimizing project effects on juvenile shad survival, production, and recruitment. Goals reference ASMFC (2010) and CRASC (1992).
	• State water quality standards for designated uses of Class B waters relative to levels of water quality that fully support aquatic biota and habitat.
	• General goals related to aquatic resources including protecting,

enhancing, and restoring habitats necessary to sustain healthy aquatic and riparian communities; providing instream flows to meet the requirements of resident fish and wildlife including invertebrates; and minimizing project effects on water quality and aquatic habitat.

- General goals for relicensing including ensuring that protection, mitigation, and enhancement measures are commensurate with project effects and help meet regional fish and wildlife objectives and conserving, protecting, and enhancing habitats for fish, wildlife, and plants affected by the projects.

- VFWD general goals related to conserving, enhancing, and restoring natural communities, habitats, species, and the ecological processes that support them and providing fish- and wildlife-based activities including viewing, harvesting, and utilization of fish, plant, and wildlife resources. Goals reference Vermont's Wildlife Action Plan (Kart et al., 2005).

- VFWD general goals related to resource conservation, fish and wildlife recreation and use, and human health and safety. Goals reference the Vermont Fish and Wildlife Strategic Plan (VFWD, 2006).

The above agency management goals were included in the original study requests filed by agencies and stakeholders in March of 2013. Additional consultation on the Revised Study Plan 22 and on the Proposed Study Plan 34 (Hydroacoustics at Vernon) occurred after FERC's study plan determination that approved Study Plan 22 without modification on February 21, 2014. During the consultation and comment process, agencies clarified their management goals for this study but that did not alter the study's overall goals and objectives. Revised study methods designed to meet the study's goals and objectives are clarified in the sections below.

ASSOCIATION WITH OTHER STUDIES

This study is not directly associated with any other studies (other than the Proposed Study 34 – Hydroacoustics at Vernon), although temperature data collected in Water Quality Monitoring (Study 6) will be used to help characterize the overall temperature conditions during juvenile shad emigration.

EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

Adult shad are counted annually as they pass above Vernon dam. Juvenile American shad production has been monitored upstream and within approximately 0.5 mile downstream of Vernon dam by Vermont Yankee as part of an annual monitoring program, using both boat electrofishing (since 1991) (Normandeau,

2012) and beach seining (since 2000) (Normandeau, 2013). A seasonal average annual index of juvenile American shad standing crop in the portion of the lower Vernon impoundment (from RM 141.9 at Vernon dam to the West River confluence at RM 149.3) has been calculated since 2000 (Normandeau, 2013). Estimates of juvenile shad growth rates have varied from 0.26 to 0.79 mm per day (Normandeau, 2013). Additionally in a study conducted in 1995 (Smith and Downey, 1995) in the Vernon reservoir and upper Turners Falls impoundment, the combined average growth rate observed was 0.75 mm per day.

Studies of American shad passage were conducted in 1991 and 1992 with tests of a high frequency sound field to guide fish to the fish pipe, the primary downstream fishway (RMC Environmental Services, Inc., 1993). Although the high-frequency sound studies were deemed inconclusive, a behavioral response by juvenile shad to the sound pulses was observed in some tests.

In 2009 following the replacement of Units 5 through 8, the feasibility of using a fixed aspect hydroacoustic array to evaluate passage routes selection by juvenile shad was studied (Normandeau, 2010). The study included the deployment of transducers on the downstream face of the trashracks, 'looking' into the turbine intakes, and a limited collection of data. The configuration of the turbine unit intake bays limited the volume that could be sampled, and there were significant amounts of entrained air that confounded juvenile shad target detection. Due to these limiting factors it was concluded that an adequate assessment of turbine entrainment (relative route selection) with this tool in this configuration was not feasible.

Passage survival of juvenile shad through Vernon's Unit 10 (a Francis turbine) was estimated in a study conducted in the fall of 1995. All recaptured fish were alive, and the immediate (1-hour after passage) estimate of relative survival was 94.73 percent. The latent survival estimate was 94.61 percent. The precision on the estimates was within $\pm$10 percent for 95 percent of the time (Normandeau, 1996).

A series of juvenile shad radio-tagging tests was conducted in the fall of 2014 to evaluate tagging effects by holding groups of tagged and untagged hatchery-reared and wild-caught juvenile shad in tanks and making formal observations on their relative behavior. Results reported by Normandeau (2014) and filed with FERC on November 26, 2014, indicated that hatchery-reared fish exhibited un-natural swimming behavior prior to tagging, and appeared sensitive to handling and tagging, using one of the types of radio-tags examined in this study. Conversely, wild-caught shad exhibited normal behavior and did appear to withstand handling and tagging, using the smaller nano-tag, for the purposes of Study 22. Accordingly, for the radio-tag portion of the 2015 Study 22, TransCanada now proposes to use wild-caught shad for radio-tagging (Normandeau, 2014). Between 1,500 – 2,000 hatchery-reared fish will still be required (if they can be raised to approximately 120 mm) for purposes of the turbine survival studies.

PROJECT NEXUS

The falls at Bellows Falls, Vermont, is recognized as the historical upstream limit of migration for American shad in the Connecticut River (Langdon et al., 2006). Spawning between Vernon dam and Bellows Falls dam is known based on the production of juvenile shad in the Vernon impoundment (e.g., Normandeau, 2013). Limited information is available regarding the overall effect of the Vernon Project on downstream migration of juvenile shad. Project operations may influence the downstream passage route selection, forebay residency time, and predation and mortality of juveniles during passage under varying flow conditions.

STUDY AREA AND STUDY SITES

The study area encompasses the Vernon Project forebay, tailrace, turbines, bypass fishways, and dam.

METHODS

Due to the configuration and specifications of the Vernon Project and the potential limitations inherent in working with juvenile American shad, no single monitoring tool will provide the necessary information for this study. Therefore, the use of multiple tools will ensure that study objectives are met.

The methods in this study include radio-telemetry, HI-Z Turb'N tag, and hydroacoustics, as requested by the agencies in their original study requests. The methods do not include the use of PIT tags or underwater video. Because the turbine units and possibly other routes, could not be set up with PIT tag antennas that would sample with high detection probabilities, the use of PIT tags would provide little additional information for determining passage route selection, survival, or overall run timing TransCanada has determined that underwater video is no longer needed with the addition of hydroacoustics.

Forebay Residence Time and Passage Route Selection

Proportional route selection and forebay residency time for juvenile shad downstream passage will be assessed by radio-tagging and systematically monitoring tagged shad movement and passage through the project. Radio-tag size has become smaller in recent years and is now suitable for juvenile American shad (Normandeau, 2014). The small radio-tags proposed for use in this study have been used with juvenile American shad in work conducted by Normandeau on the Merrimack River.

Wild juvenile shad will be collected at least twice per week via electrofishing in and above the Vernon forebay area (upstream of the log boom), and is expected to occur beginning in mid-September through mid-November to coincide with the expected natural downstream migration period. Collection of juvenile shad near the dam, together with hydroacoustic (HA) sampling will ensure that the fish are actively migrating. Collection and tagging is intended for releases of two groups of 20-tagged juvenile shad each week during the migration period for a total of up to

320 tagged fish. If juvenile shad emigration does not begin by mid-September (none captured via electrofishing), or the early-season migrants are too small for tagging, the study will be delayed until the run begins and/or the fish are large enough to tag (at least 100 mm). In most cases, it is expected that wild fish will be captured and tagged within a few days so they can be released back into the river with their migrating cohort.

Following collections, shad will be transported and retained in appropriate holding facilities in a secure location at or upstream of the Vernon Project. Wild juvenile shad will generally be held for short periods (24-48 hours) prior to tagging, but may be held for a longer period (1-2 weeks) if a large storm is forecasted in the region. Typically, large rain events trigger downstream migration and if the storm is large enough, most of the available fish near the project could move downstream very quickly. Capturing and holding a number of wild test fish prior to a rain event will ensure that fish can be tagged and released after such an event when few wild fish may be available for capture.

Juvenile shad that are at least 100 mm long will be selected for tagging. Radio transmitters for this study will be Lotek NanoTag NTQ-1 tags. The NTQ-1 tags are 5 mm wide x 3 mm high x 10 mm long in size, weigh ≤0.26 grams in air, have a calculated life of 10 days, and will propagate a signal via a flexible whip antenna. Each transmitter will contain a unique pulse code to allow for individual fish identification and digital spectrum processor (DSP) compatibility. Up to 16 groups of 20 shad will be externally radio-tagged, transported by boat, and systematically released along a river-wide transect approximately 0.5 miles upstream of Vernon dam over the course of the downstream migration season (2 releases per week). This release scenario is expected to allow for monitoring over a range of environmental and project operating conditions.

Remote telemetry monitoring will occur at the Vernon forebay, log boom and diversion boom, bypass fish pipe, turbines, tailrace, and spillway. Radio receivers and/or DSP's capable of monitoring multiple radio channels simultaneously at each location will be coupled with appropriate antennas and calibrated to ensure adequate coverage of the individual sites to be monitored while minimizing overlap between the sites. It is expected that, at a minimum, seven monitoring sites will be installed, and will be the same sites used in Study 21 – Shad Telemetry Study with the same detection coverage (see Appendix A). Data downloading from the remote telemetry monitoring stations will occur at a minimum of three times per week. Periodic manual monitoring by boat will also occur to assist in data collection and analysis.

To augment the results reported in Normandeau (2014) and to provide release-group specific information regarding post-tagging survival and behavior, control specimens tagged with dummy-tags will be maintained and observed in the holding facilities.

During the course of the study, air temperature, water temperature, turbidity, rainfall, river flow, and project operations information will be collected and reported. Lunar phase will also be noted.

Run Timing

The timing of the outmigration run of juvenile American shad will be described in fine temporal resolution by continuous hydroacoustic sampling (i.e., sonar) and verified by a time series of discrete net samples of fish within the forebay of the Vernon powerhouse. A calibrated split-beam echosounder will be used to monitor for the presence and relative magnitude of juvenile-shad-sized fish over time in the vicinity of the entrance to the downstream fish pipe (Figure A). Placement of the split-beam transducer has been selected to ensure detectability given the beam geometry and properties, current speed, fish sizes, and locations where shad are likely to occur regularly in highest abundance. A tentative location within 16 feet (5 meters) of the fish pipe opening is proposed because the fish diversion boom with its 10-foot high louver panels extending to about 16 feet below pond elevation was designed to guide surface-oriented fish such as juvenile American shad to pass through the downstream fish pipe. This location is also where Vernon personnel have historically observed great numbers of juvenile shad congregating during the outmigration season.

The entrance to the fish pipe is 7.6 feet wide x 4.0 feet high and the sill of the opening sits about 10 feet below the normal pond elevation of 220 feet. The depth layer corresponding to the fish pipe opening is 6-10 feet below normal pond elevation. A bottom-mounted 15° split-beam transducer will be mounted on the river bottom (elevation = 168 feet) and aimed vertically toward the surface to effectively sample more of the water column in this surface layer where juvenile shad naturally prefer and where they will be to pass through the fish pipe. The beam diameter at the fish pipe sill (42 feet range from transducer) is about 11.1 feet and spreads to 12.1 feet at the top of the fish pipe opening at 46 feet range from the transducer (Figure B). This configuration potentially can cover close to 100% of the fish pipe opening, but actual coverage depends on how close the transducer can be positioned to the opening without substantial acoustic interference due to echoes from infrastructure, floating debris, or entrained bubbles.

In addition to sampling location and coverage, this sampling configuration is capable of producing echo patterns that are easier to interpret for discriminating swimming juvenile shad from other targets. The relative acoustic size (i.e., target strength) is independent of swimming direction when fish are insonified ventrally which makes classification of juvenile shad by the target strength (-47 to -45 dB re: m^2; Love, 1977) corresponding to their size more reliable than when fish are insonified at multiple swimming directions in horizontally-aimed acoustic beams (e.g., lower target strength swimming to or away from a horizontally aimed transducer).

The split-beam echosounder system will continuously sample (24 hr/d, assuming no equipment damage or power failure) from 15 August through 15 November 2015, for a total of 93 days. The echogram data will be stored in short intervals (2-5 minutes). The HA sampling period includes approximately 2 weeks before and after the anticipated out-migration period of juvenile American shad previously described in the Connecticut River (O'Leary and Kynard, 1986) and in the lower Vernon impoundment (Normandeau, 2013). This timeframe allows for the natural baseline variability in fish echoes before and after the migration period to be assessed and for the migration periodicity to be assessed without truncation at the beginning and end of the run.

The transducer's acoustic frequency of 420 kHz is proposed because shad may detect (Mann et al., 1997) and avoid ultrasound at commonly used fishery echosounder frequencies (<200 kHz; Dunning et al., 1992; Ploskey et al., 1995), and the higher frequency and range resolution is more suitable for detecting small fish. Acoustic backscatter (i.e., sound reflected from objects) measured from the elapsed time, and received voltage response will provide time-stamped data on range, echo signal strength (relative size), and location of single echo detections within the beam. The split-beam functionality allows single echoes to be located within the beam, and over successive sound transmissions (pings) at 15 pings per second, allows for individual fish echoes to be tracked in three-dimensions (xyz axes) for describing movement.

This hydroacoustic monitoring plan to describe the temporal migratory pattern of juvenile American shad includes several important assumptions: (1) The proposed location assumes that a change in historical river bed elevations does not impact deployment or sampling coverage in a meaningful way; (2) Transducer deployment can meet all dam operation and safety requirements; (3) "Milling" behavior (multiple re-counting individuals) does not introduce bias in the relative magnitude; (4) Juvenile American shad arrive and depart (as monitored by HA) at the same time as those at other locations at the Vernon Project that are not monitored by HA; (5) The index of relative abundance derived from HA is proportional to un-monitored relative abundance; (6) Background noise and acoustic scattering contributions by other targets (e.g., macroinvertebrates, entrained surface bubbles, sediment gas bubbles, other small fish) are assumed to be either negligible, or can either be quantified or removed from analysis; and (7) The continuity of the study and the completeness of results are not compromised by natural acts beyond control of the study (e.g., hurricanes, floods, massive floating debris or debris-transducer collision) or by vandalism.

To confirm the presence of juvenile shad, visual surface observations will be made at a minimum of twice per week. In addition, a lift net, cast net, or passive trawl equipped with a flow meter will be used to sample fish in the forebay inside and outside the louver and log boom area to verify species and size composition of acoustically detected targets. Discrete net samples will be collected twice per week during site visits to maintain sonar operation and download data. A net sampling method will be selected based on preliminary performance fishing in the forebay and suitability to provide a standardized catch per unit effort to provide a coarse time series (~every 3-4 days) of an independent index of relative abundance to corroborate the larger trend in high-resolution temporal pattern observed by hydroacoustics. As stated above, the split-beam echosounder system will continuously sample (24 hr/d, assuming no equipment damage or power failure) from 15 August through 15 November 2015, for a total of 93 days.

Turbine Survival/Injury

Turbine passage survival of juvenile shad will be assessed by using mark/recapture methodology at one of each of the two un-tested unit types (the smaller Francis turbines in Units 1 through 4 and Kaplan turbines in Units 5 through 8). As discussed above, one of the two large Francis turbines (Unit 10) was previously studied for juvenile shad passage survival (Normandeau, 1996).

Selection of the test turbine units will be based in part on historic operations being prepared as part of Study 5, Operations Model and on an evaluation of the turbine specifications and priority of operation. An evaluation of unit-loading conditions will be shared with the aquatics working group for comment prior to making final unit loading determination(s) for each set of released fish. As described in the Vernon PAD, Units 1 through 4 are single runner, vertical Francis turbines rated at 4,190 horsepower (HP) at 35 feet of head and 133.3 rpm with a maximum hydraulic capacity of 1,465 cfs. The new units, No. 5 through 8, are vertical axial flow Kaplan turbines with a 3.1-meter diameter runner rated at 5,898 HP at 32 feet of head, and 144 rpm with a maximum hydraulic capacity of 1,800 cfs. Units No. 9 and 10 are vertical single runner Francis turbines rated at 6,000 HP at 34 feet of head with a maximum hydraulic capacity of 2,035 cfs. The turbine intake trashracks are 2-inch on center for Units 1 through 8, and 4-inch on center for Units 9 and 10. During fish ladder operation, unit priority is Unit 10, followed by 8, 7, 9, 6, 5, 4, 3, 2, and 1. Outside of the fish ladder operating season unit priority is Units 5 through 8 first, followed by Units 9 and 10, followed by Units 1 through 4.

The HI-Z Turb'N tag methodology (Heisey et al., 1996) is the most effective approach to estimate the direct survival of fishes that pass through hydro turbines or spill structures. The methodology was developed in the early 1990s in large part to evaluate turbine passage survival of juvenile American shad at Susquehanna River projects. Due to the relatively large size of the river and the hydro projects, no other conventional tool was effective at the time for juvenile American shad (due to their small size and fragile nature).

A minimum of 150 HI-Z Turb'N tagged hatchery-reared juvenile shad (minimum length of 120 mm) will be released into one of the small Francis units and 150 into one of the Kaplan units. An additional 150 HI-Z Turb'N tagged shad will be released into the tailrace to serve as the control group for the turbine survival tests. Based on assumptions of 93 percent control group survival, 93 percent live recapture of fish, a sample size of 150 treatment group fish per test unit and 150 control group fish should yield a survival estimate with a precision of $\leq$+10 percent, 95 percent of the time. Survival tests will be conducted by injecting tagged shad into a turbine at or near full generation. Following release of treatment and control group fish, they will be recovered from the tailrace, examined for injuries, and held for 48 hours for observation and latent mortality. Unrecovered tagged shad will be censored from the data set.

ANALYSIS

Forebay Residence Time and Route Selection

The radio-telemetry data will be analyzed to determine the number and timing of shad using each monitored downstream passage route at the Vernon Project. A comparative analysis of passage routes with operations and environmental variables that occur during the study period will then be conducted. The analysis will include 2-D maps of movement and passage for example shad along with summarized data in tabular form. Forebay residency time by release group and for all release groups combined will be reported.

Run Timing

Both the relative index of volume backscattering strength and acoustic estimate of fish passage can provide sufficient temporal resolution for estimating the timing, duration, and relative magnitude of juvenile shad in the vicinity of the upstream fish pipe opening. However, it provides no direct measure of absolute or relative abundance of the whole-river outmigration, exit route selection or the residency time of individuals within the forebay. The split-beam transducer will collect information necessary for determining relative fish size, position within the beam, direction and rate of movement through the beam, and volume backscattering strength proportional to fish density (Foote, 1983; Simmonds and MacLennan, 2005). Echo integration, echo counting, or both would be considered for deriving fish density depending on their observed distributions. Like other clupeids (Dunning and Gurshin, 2012; Gurshin et al., 2014), juvenile shad may form dense schools during the day that make echo counting difficult, but scatter as individuals during the night. The fish flux (number per unit area [vertical plane] and time) will be determined by the acoustic fish density estimate, and the rate of movement downstream in direction of fish pipe opening. The fish flux then can be used as index of relative abundance.

Turbine Survival / Injury

Immediate (1 hour) and latent (24 hour) relative survival and classification of injuries will be estimated for each of the turbine types tested at the project using generally accepted practices (Normandeau, 1996). The results will be assessed in conjunction with the physical, environmental, and operating conditions that occur during the study.

An estimate of passage survival for the project in total will be calculated using proportional route selection data collected during the radio-telemetry portion of this study, and survival data from this study and the previous study of juvenile shad turbine survival through Unit 10 (Normandeau, 1996). In addition, the assessment will also take into account the unit preference and operating frequency or likelihood of unit operation.

CONSISTENCY WITH GENERALLY ACCEPTED SCIENTIFIC PRACTICE

The study methodology, data collection, and analysis techniques to complete the study objectives are consistent with generally accepted practices for radio-telemetry (Normandeau, 1996; Normandeau and Gomez and Sullivan, 2012) and hydroacoustics (Ehrenberg and Torkelson 1996; Mulligan and Kieser 1996; Nestler et al. 1999; Enzenhofer and Cronkite 2000; Simmonds and MacLennan 2005; Rudstam et al. 2009; Gurshin et al. 2014) with emphasis on monitoring migratory clupeids.

DELIVERABLES

A report will be prepared that presents methods, analysis, and results of the study. A draft final study report will be provided after the study analysis is complete and the results are available. A report appendix will include all the relevant data for each individual fish. The report will be prepared for stakeholder review and comment. Stakeholder comments on the draft final report will be included in the final report with an explanation of any stakeholder comments not incorporated.

Results and conclusions will be reported in either the PLP or draft license application for the projects. Exhibit E of the final license application will include modified results and conclusions, as appropriate, in response to stakeholder comments on the PLP or draft license application.

SCHEDULE

This study will be conducted in the fall of the second study year (2015), as specified in FERC's February 21, 2014 Study Plan Determination (SPD). The study report will be prepared after all field work and data analyses are completed. The final study report is due to be filed with FERC by March 1, 2016 in accordance with the SPD.

LEVEL OF EFFORT AND COST

The preliminary estimated cost range for this updated, revised study is $627,000 - $687,000 and is dependent in part on the effort required to obtain test specimens, based on the year-class success. This represents almost a 100% increase in cost of the previously proposed study plan, largely due to an increase in the number of radio-tagged fish and an increase in the cost of the HA equipment deployment and monitoring period.

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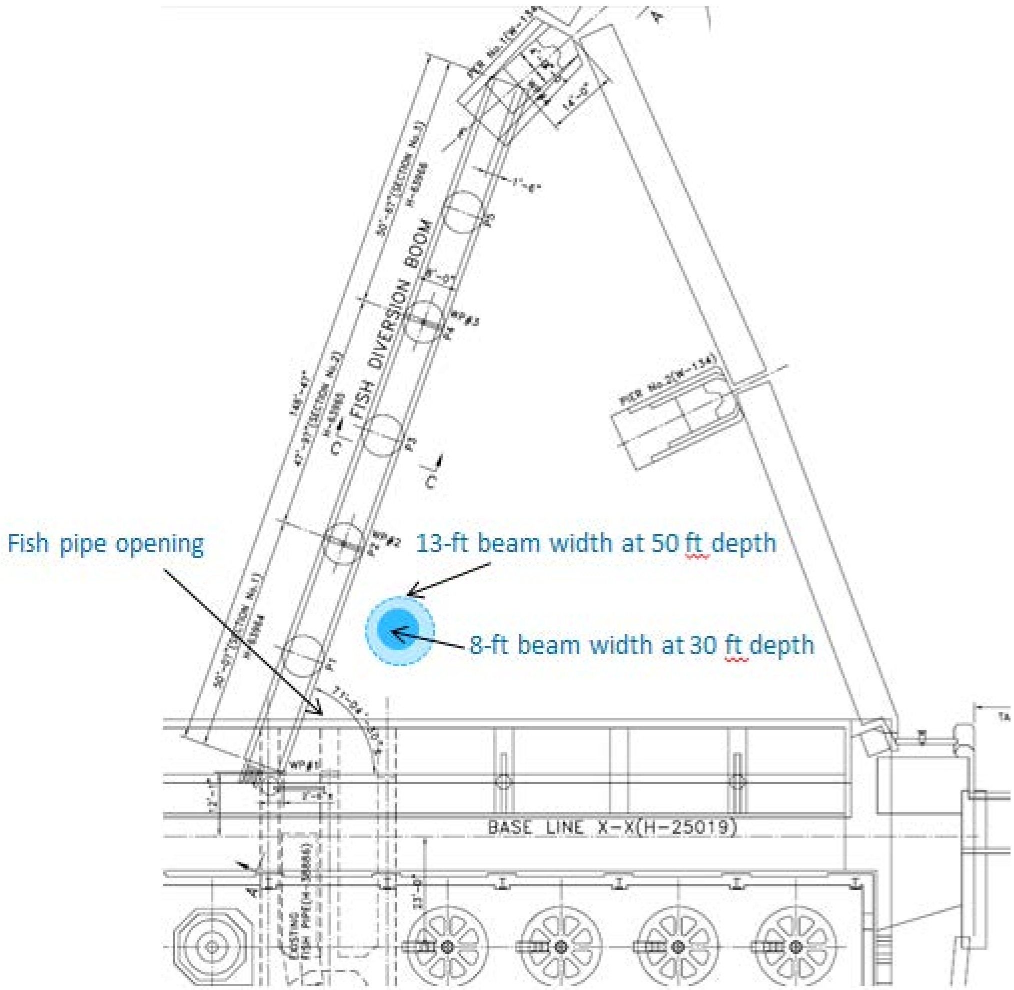

Figure A. Top view of fish diversion louver and entrance to downstream fish pipe. An upward-looking 15° 420-kHz split-beam transducer will monitor surface-oriented fish passing through the acoustic beam. The half-power beam width at surface ranges from 8 feet in diameter in 30 feet of water (solid blue circle) to 13 feet (light outlined blue circle) in 50 feet.

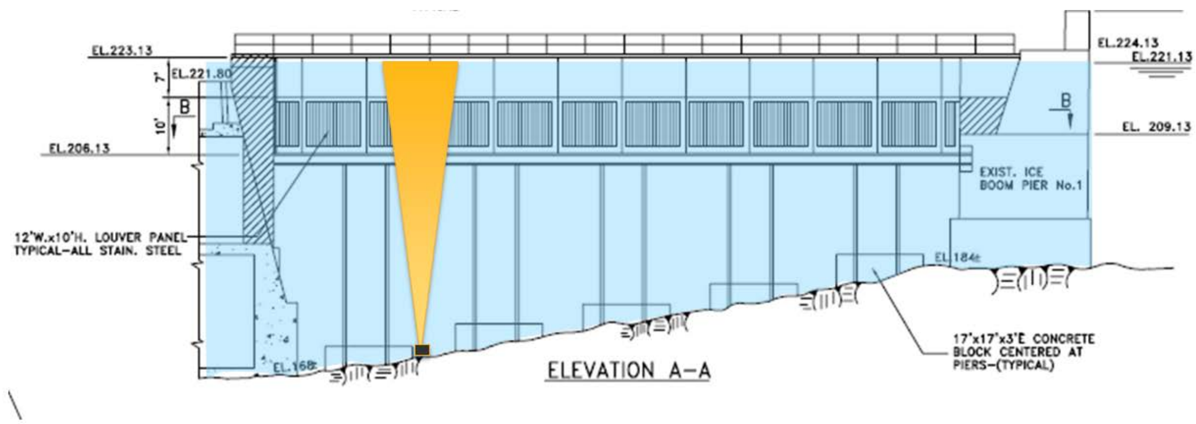

Figure B. Side view of fish diversion boom and louver. An upward-looking 15° 420-kHz split-beam transducer will monitor surface-oriented fish passing through the acoustic beam (orange). The half-power beam width at the 6 to 10-ft depth layer of fish pipe opening is about 11 to 12 feet wide.

APPENDIX A

Study 21 – American Shad Telemetry Study – Vernon Radio Telemetry Detection Zones

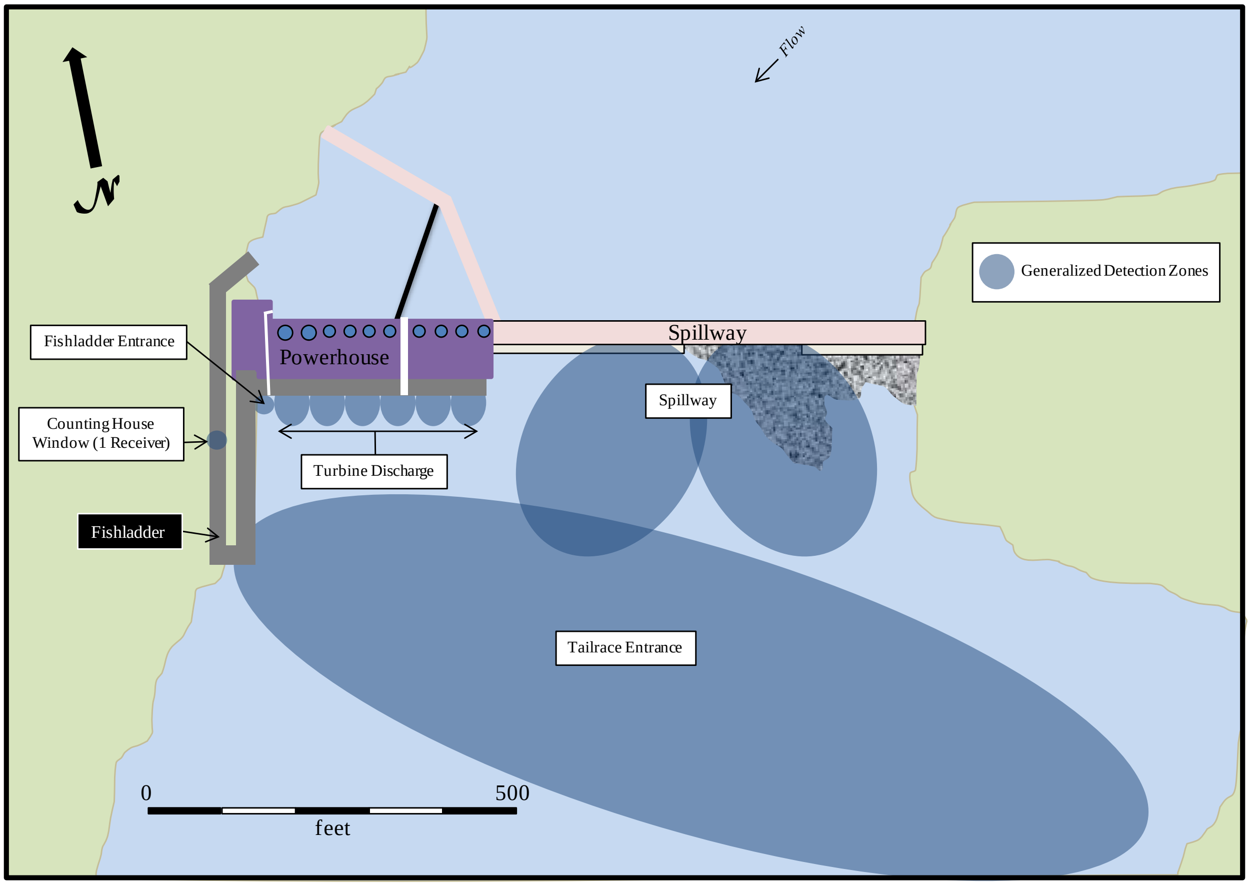

Figure A-1. Detection zones for monitoring stations used to evaluate downstream movement of radio-tagged juvenile shad at the Vernon project.

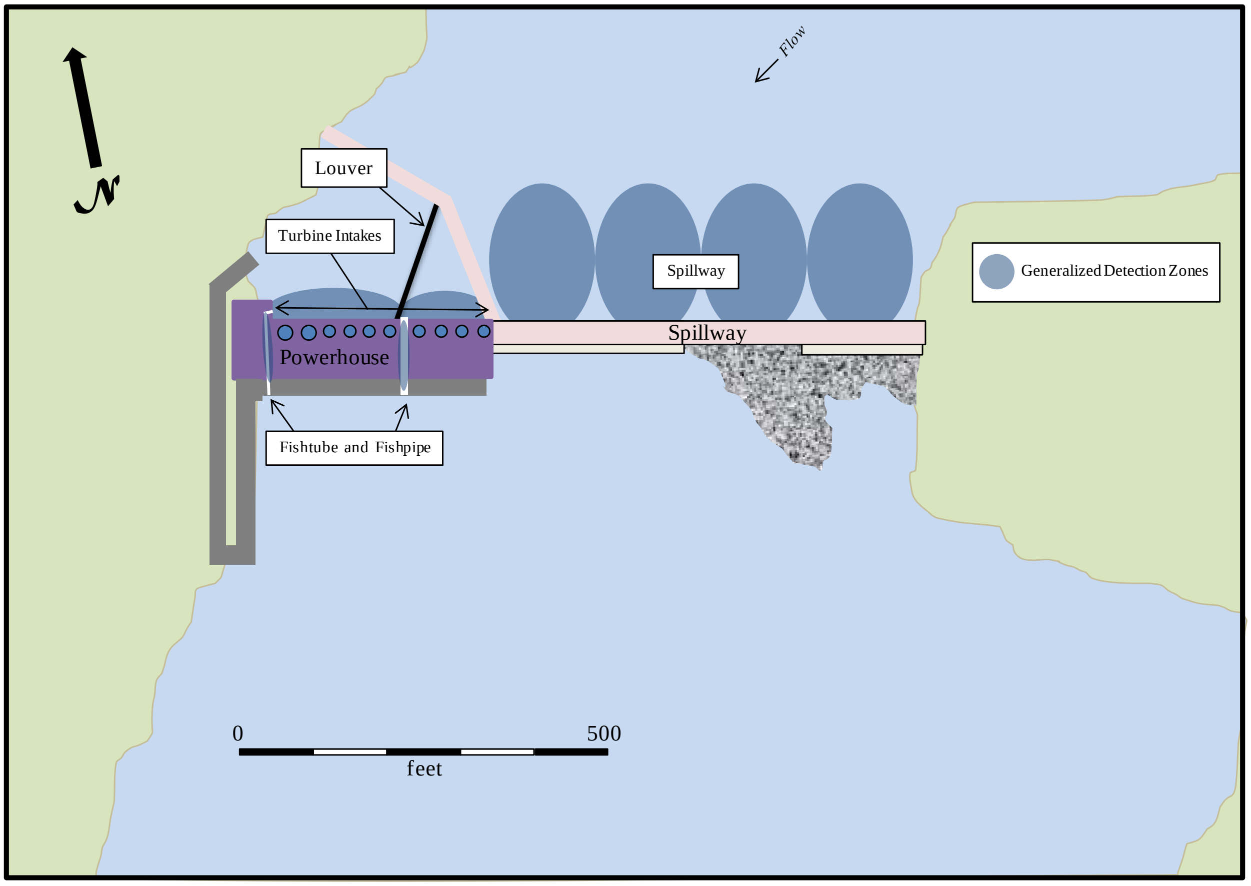

Figure A-2. Detection zones for monitoring stations used to evaluate downstream movement of radio-tagged shad at the Vernon Project.