

TRANSCANADA HYDRO NORTHEAST INC.

ILP Study 23
Fish Impingement, Entrainment, and Survival Study
Supplement to Final Study Report

In support of Federal Energy Regulatory Commission Relicensing of:

Wilder Hydroelectric Project (FERC Project No. 1892-026)
Bellows Falls Hydroelectric Project (FERC Project No. 1855-045)
Vernon Hydroelectric Project (FERC Project No. 1904-073)

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This supplement to the final report for ILP Study 23 - Fish Impingement, Entrainment, and Survival Study (Normandeau, 2016) provides revised analysis and data presentation related to estimates of total project survival as described in Section 7.0 of the Study 23 final report, as revised below.

Note that the final study reports for Studies 19 and 21 (Normandeau, 2017a; 2017b) with revised route selection data are being filed simultaneously to this Study 23 report supplement. The final study report for Study 22 was filed on January 17, 2017 (Normandeau, 2017c).

7.0 TOTAL PROJECT SURVIVAL

As stated in the FERC study request related to the assessment of fish impingement, entrainment, and survival, total project survival considering all passage routes was to be estimated for American Eel, Atlantic Salmon, and Sea Lamprey at Wilder, Bellows Falls and Vernon, and for American Shad and river herring at Vernon.

Total project survival rates for American Eel at each of the three project locations were estimated using data collected as part of the radio telemetry (i.e., route selection) and HI-Z tag turbine survival evaluations conducted on adult silver eels as part of Study 19 - American Eel Downstream Passage Assessment (Normandeau, 2017a). Total project survival rates for American Shad at Vernon were estimated for both the adult and juvenile life stages and relied on radio telemetry data collected as part of the radio telemetry (Study 21 - American Shad Telemetry at Vernon [Normandeau, 2017b], and Study 22 - Downstream Migration of Juvenile American Shad at Vernon [Normandeau, 2017c]) and HI-Z turbine tag survival evaluations conducted as part of Study 22 and during 1995 (Normandeau, 1996) for juvenile shad. Results from the Franke et al. (1997) survival estimates presented in Section 6.1 of the Study 23 final report are also presented in the sections below for comparison purposes with HI-Z tag and radio-telemetry survival estimates.

As reported in TransCanada's October 31, 2016 filing, telemetry data for Studies 19, 21, and 22 was re-processed and revised results of downstream passage route selection are used for this analysis and presented below.

There is no available data related to the downstream route selection or passage survival of Sea Lamprey at Wilder, Bellows Falls, or Vernon. To date, peer-reviewed literature related to passage of Sea Lamprey has focused on upstream passage. Sea Lamprey were not among the fish species evaluated as part of the EPRI (1997) turbine passage survival database. Given the lack of available data, the total project survival of emigrating Sea Lamprey at the projects is unknown at this time.

The Atlantic Salmon Connecticut River Restoration Program was discontinued in July, 2012. As of 2016, TransCanada has been granted permission by FERC to cease operation of the downstream fish passage facilities for emigrating Atlantic Salmon smolts at their Moore, Comerford, and McIndoes developments (FERC Project # 2077) on the Connecticut River upstream of the Wilder, Bellows Falls, and

Vernon project areas. Given the lack of the species presence within the project area, total station survival estimates are not provided.

As summarized in the Vernon Pre-Application Document, returns of Blueback Herring at Vernon have been low since 1981 with greater than 100 individuals recorded during only two of the 32 years summarized, and no individuals recorded since 2000. It is suspected that the total project survival for river herring would be similar to American Shad due to their similar size.

It is important to note that radio-tagged fish whether eels, adult shad, or juvenile shad were not intended to inform on project survival in Studies 19, 21, or 22. Estimates of survival based on radio telemetry are presented in the sections below to provide a broader range of estimates for general comparison purposes with calculated Franke survival estimates and HI-Z direct turbine testing and survival data from Studies 19 and 22, and to provide a proxy for survival through non-turbine passage routes. For purposes of this comparison only, survival estimates from telemetry data are calculated as the proportion of radio-tagged fish detected at the next downstream project (or at Stebbins Island for Vernon) relative to the number of radio-tagged fish detected passing the project.

Survival estimates based on radio telemetry must be considered conservative since a lack of radio detections downstream of each project's tailrace monitoring stations does not necessarily indicate that emigrating fish were adversely affected as a result of passage through the project. Although it is possible for them to have died as a result of project passage, a lack of detection at downstream locations can also be the result of shed transmitters or a function of background mortality (i.e., natural mortality such as piscivorous fish or birds) in the intervening reach between the project and the next downstream monitoring location. Conversely, it is possible that a fish that died in passage was swept downstream yet the active tag was detected (i.e., at Vernon's Stebbins Island monitoring station) resulting in a false positive detection. A radio-telemetry study designed for the estimation of project survival would need to consider downstream placement of monitoring locations such that the distance from the project is sufficient to avoid issues with downstream drift. In addition, study components would need to be incorporated to evaluate both tag retention and background mortality and allow for adjustments to reflect losses attributable to these non-project related causes.

7.1 American Eel

7.1.1 Wilder

As determined by radio telemetry in Study 19, downstream passage route selection of eels at Wilder was distributed among the Kaplan Units 1 and 2 (70.2%), vertical Francis Unit 3 (14.9%, including the two eels that entered Unit 3 but were not later detected in the tailrace, assumed mortalities, and excluded from Table 5.1.1-1 in the Study 19 final report), the trash/ice sluice (4.3%), and unknown routes (10.6%) (Table 7.1-1).

Turbine Passage Routes

Turbine survival at Unit 2 using the HI-Z tag method was estimated at 62% (48-hour estimate) in Study 19. Turbine survival through Units 1 - 2 was also estimated using the Franke blade strike information presented in Section 6.1.1 of the Study 23 final report for body lengths of 30 inches, resulting in a predicted survival estimate of 44.6 – 90.6% at the units' typical full load discharge of 4,400 cfs.

A very conservative radio telemetry survival estimate was calculated based on radio telemetry detections for eels that passed via Units 1-2. Twenty-two of the 33 eels that passed via that route were detected at, and subsequently passed Bellows Falls (12 were also detected passing Vernon), thus the survival estimate is 66.7%, slightly higher than the HI-Z tag estimate and within the range of the calculated Franke estimates.

Turbine survival using the HI-Z tag method was not estimated for Wilder Unit 3 due to logistical difficulties with recapturing passed individuals. However, Unit 3 survival was estimated using the Franke blade strike information presented in Section 6.1.1 of the Study 23 final report for body lengths of 30 inches, resulting in a predicted survival estimate of 0.0 - 46.9% at the unit's normal discharge of 700 cfs. Seven radio-tagged eels passed via Unit 3, two were later detected at, and subsequently passed both Bellows Falls and Vernon. Therefore a very conservative radio telemetry survival estimate for Unit 3 is 28.6%, within the range of the calculated Franke estimates.

Non-Turbine Passage Routes

Based on tailrace detections of the two radio-tagged eels that passed via the trash/ice sluice, an initial radio telemetry survival estimate through this route would be 100%. One eel was later detected at, and subsequently passed Bellows Falls (and also passed Vernon) while the other had no detections downstream of the Wilder tailrace, thus a very conservative radio telemetry survival estimate is 50%.

Of the five radio-tagged eels that passed by unknown routes, all were detected in the tailrace suggesting an initial radio telemetry survival estimate of 100%; but only three eels were later detected at, and subsequently passed both Bellows Falls and Vernon. Therefore, a very conservative radio telemetry survival estimate for eels passing via unknown routes is 60%.

Total Project Survival Estimate

When the results of the Wilder radio telemetry passage route proportional distribution and estimated route survival rates based on subsequent telemetry detection at Bellows Falls are combined, total project survival for radio-tagged adult eels at Wilder is very conservatively estimated at 59.6% (Table 7.1-1). Applying both the HI-Z tag and Franke turbine survival estimates to the proportion of eels passing via turbines along with the telemetry estimates for non-turbine routes, total project survival ranges from 44.1% to 76.4% with the radio telemetry estimate slightly higher than the HI-Z estimate and in the middle of the calculated Franke estimate range.

Table 7.1-1. Passage route distribution and associated route-specific survival estimates for adult American Eel at Wilder.

| Passage Route | No. | Proportion | Estimated and Predicted Survival Rates (%) | | |
|------------------|----------------|------------|--|---|--|
| | | | HI-Z (48-hr) | Conservative Radio Telemetry - Estimate | Franke Formula (30-inch fish) ^a |
| Unit 1 - 2 | 33 | .702 | 62.0 | 66.7 | 44.6 – 90.6 |
| Unit 3 | 7 ^b | .149 | n/a | 28.6 | 0.0 – 46.9 |
| Trash/ice sluice | 2 | .043 | n/a | 50.0 | n/a |
| Unknown | 5 | .106 | n/a | 60.0 | n/a |
| Total | 47 | 1.0 | | 59.6 | |

a. Calculated at typical full load for Units 1-2, and at minimum flow for Unit 3.

b. Includes two eels detected entering Unit 3 but not later detected and presumed mortalities.

7.1.2 Bellows Falls

As determined by radio-telemetry in Study 19, downstream passage of adult silver eels at Bellows Falls was distributed among the three vertical Francis units (80.2%), the trash/ice sluice (13.5%), and the spillway into the bypassed reach (6.3%) (Table 7.1-2).

Turbine Passage Routes

Turbine survival at Unit 2 using the HI-Z tag method was estimated at 98% (48-hour estimate). Turbine survival through Units 1 - 3 was also estimated using the Franke blade strike information presented in Section 6.1.1 of the Study 23 final study report for body lengths of 30 inches, resulting in a predicted survival estimate of 53.9 – 77.0% at the units' peak efficiency discharge of 3,175 cfs.

A very conservative radio telemetry survival estimate was calculated based on radio telemetry detections for eels that passed via Units 1-3. Fifty-eight of the 77 eels that passed via the turbines were detected at (and subsequently passed) Vernon,

resulting in a survival estimate of 75.3%, lower than the HI-Z tag estimate and within the upper range of the calculated Franke estimates.

Non-Turbine Passage Routes

All 13 radio-tagged eels passing via the trash/ice sluice were detected in the Bellows Falls tailrace for an initial survival estimate of 100%. Ten eels were later detected at Vernon, providing a very conservative radio telemetry survival estimate of 76.9%; nine of the ten also subsequently passed Vernon.

While all six radio-tagged eels that passed via the spillway were detected at the downstream end of the bypassed reach for an initial survival estimate of 100%, two remained in the bypassed reach for 17 days or more and for the purposes of this assessment were assumed to be mortalities. The remaining four were later detected at, and passed Vernon. Therefore, a conservative radio telemetry survival estimate for passage through the spillway is 66.7%.

Total Project Survival Estimate

When the results of the Bellows Falls radio telemetry passage route proportional distribution and estimated route survival rates based on subsequent telemetry detection at Vernon are combined, total project survival for radio-tagged adult eels at Bellows Falls is very conservatively estimated at 75.0% (Table 7.1-2). Applying both the HI-Z tag and Franke turbine survival estimates to the proportion of eels passing via turbines along with the telemetry estimates for non-turbine routes, total project survival ranges from 57.8% to 93.2% with the radio telemetry estimate lower than the HI-Z estimate and slightly lower than the calculated maximum Franke estimate.

Table 7.1-2. Passage route distribution and associated route-specific survival estimates for adult American Eel at Bellows Falls.

| Passage Route | No. | Proportion | Estimated and Predicted Survival Rates (%) | | |
|------------------|-----------|------------|--|---|--|
| | | | HI-Z (48-hr) | Conservative Radio Telemetry - Estimate | Franke Formula (30-inch fish) ^a |
| Units 1-3 | 77 | 0.802 | 98.0 | 75.3 | 53.9 – 77.0 |
| Trash/ice sluice | 13 | 0.135 | n/a | 76.9 | n/a |
| Spillway | 6 | 0.063 | n/a | 66.7 | n/a |
| Unknown | 0 | 0 | n/a | n/a | n/a |
| Total | 96 | 1.0 | | 75.0 | |

a. Calculated at typical full load for Units 1-3.

7.1.3 Vernon

As determined by radio-telemetry in Study 19, downstream passage of silver eels at Vernon was primarily distributed among the vertical Kaplan Units 5-8 (47.3%), vertical Francis Units 9-10 (23.2%), and vertical Francis Units 1-4 (12.5%) (Table

7.1-3). At this time, FirstLight's eel telemetry data is not available so the radio telemetry survival estimates provided below are based only on detections at Stebbins Island.

Turbine Passage Routes

At Vernon, the HI-Z tag 48-hour turbine survival estimates for adult silver American Eels were:

- 93.5% at Unit 4,
- 80.8% (mean result for the two different discharges) at Unit 8, and
- 97.9% at Unit 9.

Turbine survival was also estimated using the Franke blade strike information presented in Section 6.1.1 of the Study 23 final report for body lengths of 30 inches, resulting in predicted survival estimates of:

- 24.4 – 65.1% at Units 1-4 peak efficiency (and maximum) discharge of 1,092 cfs,
- 17.4 – 82.4% at Units 5-8 peak efficiency discharge of 1,178 cfs, and
- 53.8 – 76.9% at Units 9-10 minimum flow discharge of 1,600 cfs.

All 14 radio-tagged eels that passed via Units 1-4 were detected at Stebbins Island but one had a tailrace residency of 43 days and for the purposes of this assessment was assumed to be a mortality. Therefore, an initial radio telemetry survival estimate would be 92.9%, slightly lower than the HI-Z tag estimate and much higher than the calculated maximum Franke value. Forty-five of the 53 radio-tagged eels that passed via Units 5-8 were detected at Stebbins Island yielding a conservative radio telemetry survival estimate of 84.9%, somewhat higher than the HI-Z tag estimate and slightly higher than the calculated maximum Franke value. All 26 radio-tagged eels that passed via Units 9-10 were detected at Stebbins Island, although two eels had tailrace residencies of more than 76 days, and for the purposes of this assessment both were assumed to be mortalities. Therefore, the conservative radio telemetry survival estimate is 92.3%, somewhat lower than the HI-Z tag estimate but much higher than the calculated maximum Franke value.

Non-Turbine Passage Routes

Passage survival of radio-tagged silver eels passing via the fish pipe, fish tube, trash/ice sluice, and fish ladder were not directly assessed. Based on downstream detections at Stebbins Island, a conservative radio telemetry survival estimate of radio-tagged eels that passed via the fish pipe, fish tube, trash/ice sluice, and fish ladder is 100% for each route. While all 11 radio-tagged eels that passed via unknown routes were later detected at Stebbins Island, one of those remained in the tailrace for nearly 28 days and for the purposes of this assessment was

assumed to be a mortality. Therefore, survival through unknown routes was conservatively estimated at 90.9%.

Total Project Survival Estimate

When the results of the Vernon radio telemetry passage route proportional distribution and estimated route survival rates based on telemetry detection at Stebbins Island are combined, total project survival for radio-tagged adult eels at Vernon is very conservatively estimated at 89.3% (Table 7.1-3). Applying both the HI-Z tag and Franke turbine survival estimates to the proportion of eels passing via turbines along with the telemetry estimates for non-turbine routes, total project survival ranges from 39.9% to 88.7% with the telemetry estimate slightly higher than the HI-Z tag estimate and higher than the calculated maximum Franke estimate.

Table 7.1-3. Passage route distribution and associated route-specific survival estimates for adult American Eel at Vernon.

| Passage Route | No. | Proportion | Estimated and Predicted Survival Rates (%) | | |
|------------------|-----------|------------|--|---|--|
| | | | HI-Z (48-hr) | Conservative Radio Telemetry - Estimate | Franke Formula (30-inch fish) ^a |
| Units 1-4 | 14 | .125 | 93.5 | 92.9 | 24.4 – 65.1 |
| Units 5-8 | 53 | .473 | 80.8 | 84.9 | 17.4 – 82.4 |
| Units 9-10 | 26 | .232 | 97.9 | 92.3 | 53.8 – 76.9 |
| Fish pipe | 4 | .036 | n/a | 100.0 | n/a |
| Fish tube | 1 | .009 | n/a | 100.0 | n/a |
| Trash/ice sluice | 2 | .018 | n/a | 100.0 | n/a |
| Fish ladder | 1 | .009 | n/a | 100.0 | n/a |
| Unknown | 11 | .098 | n/a | 90.9 | n/a |
| Total | 43 | 1.0 | | 89.3 | |

a. Calculated at peak efficiency for Units 1-4 and Units 5-8, and at minimum flow for Units 9-10.

7.2 American Shad

7.2.1 Adult Shad

As determined by radio-telemetry in Study 21, downstream passage of adult American Shad at Vernon was distributed among passage routes as follows: spillway (35.7%), unknown routes (33.3%), fish pipe (19%), vertical Kaplan units 5-8 (7.1%), and vertical Francis units 9-10 (4.8%) (Table 7.2-1).

The conservative radio telemetry survival estimate for radio-tagged adult shad based on passage distribution and downstream detections at Stebbins Island is 78.6% (Table 7.2-1). Farther downstream from Vernon, project survival declines overall (but not for shad that passed via turbine units). Uncertainty about potential project-related survival increases with distance from Vernon due to potential tag

loss and mortality due to non-project effects (i.e., predation). Based on detections at Northfield Mountain (~15 river miles downstream) survival is very conservatively estimated at 59.5%, and 54.8% at Turners Falls (~22 river miles downstream) (Table 7.2-1). Applying Franke turbine survival estimates to the proportion of adult shad passing via turbines along with telemetry estimates for non-turbine routes, total project survival is 79.3 to 82.2% at Stebbins Island, 60.2 to 63.1% at Northfield Mountain, and 55.5 to 58.3% at Turners Falls, all slightly higher than the corresponding telemetry based estimates.

Table 7.2-1. Passage route distribution, detections, and survival estimates for adult American Shad at Vernon based on radio telemetry detections at Stebbins Island, Northfield Mountain, and Turners Falls.

| Passage Route | No. | Proportion | Estimated and Predicted Survival Rates | | | | | | |
|---------------|-----------|------------|--|-----------------|-------------------|---------------------|-------------------|---------------|-------------------|
| | | | Franke Formula (15-inch fish) ^a | Stebbins Island | | Northfield Mountain | | Turners Falls | |
| | | | | No. | Survival Rate (%) | No. | Survival Rate (%) | No. | Survival Rate (%) |
| Units 1-4 | 0 | 0 | 62.2–82.6 | 0 | n/a | 0 | n/a | 0 | n/a |
| Units 5-8 | 3 | 0.071 | 58.7-91.2 | 1 | 33.3% | 1 | 33.3% | 1 | 33.3% |
| Units 9-10 | 2 | 0.048 | 76.9-88.5 | 2 | 100% | 2 | 100.0% | 2 | 100.0% |
| Fish Pipe | 8 | 0.190 | n/a | 7 | 87.5% | 6 | 75.0% | 6 | 75.0% |
| Spill | 15 | 0.357 | n/a | 14 | 93.3% | 10 | 66.7% | 9 | 60.0% |
| Unknown | 14 | 0.333 | n/a | 9 | 64.3% | 6 | 42.9% | 5 | 35.7% |
| Total | 42 | 1.0 | n/a | 33 | 78.6% | 25 | 59.5% | 23 | 54.8% |

a. Calculated at peak efficiency for Units 1-4 and Units 5-8, and at minimum flow for Units 9-10.

7.2.2 Juvenile Shad

As determined by radio-telemetry in Study 22, downstream passage of juvenile shad at Vernon was primarily distributed among the vertical Kaplan Units 5-8 (39.8%), vertical Francis Units 9-10 (15.5%), and vertical Francis Units 1-4 (9.7%) with smaller numbers passing via the non-turbine routes (Table 7.2-2).

Turbine Passage Routes

The HI-Z tag one-hour turbine survival rates for juvenile shad were estimated at:

- 91.7% at Unit 4 (Study 22),
- 95.2% at Unit 8 (Study 22), and
- 94.7% at Unit 10 (Normandeau, 1996).

As discussed in the Study 22 final report the HI-Z tag 48-hour direct turbine survival estimate was deemed unreliable due to the high number of control mortalities during the delayed assessment period.

Turbine survival was also estimated using the Franke blade strike information presented in Section 6.1.1 of the Study 23 final report for body lengths of 4 inches, resulting in predicted survival estimates of:

- 89.9 – 95.4% at Units 1-4 peak efficiency (and maximum) discharge of 1,092 cfs,
- 89.0 – 97.7% at Units 5-8 peak efficiency discharge of 1,178 cfs, and
- 93.8 – 96.9% at Units 9-10 minimum flow discharge of 1,600 cfs.

For the reasons stated above, survival estimates based on downstream radio telemetry detections carry a high degree of uncertainty but are conservatively estimated at 59.1% for Units 1-4, 75.6% for Units 5-8, and 65.7% for Units 9-10, much lower than both the HI-Z tag and Franke estimates for each turbine type.

Non-Turbine Passage Routes

Passage survival of juvenile shad passing via the fish pipe, fish tube, trash/ice sluice, spill, or the fish ladder was not directly assessed. Based on the downstream detections of radio-tagged juvenile shad at the Stebbins Island monitoring station, conservative estimates of passage survival for those routes are presented in Table 7.2-2.

Total Project Survival Estimate

In addition to the limitations stated in the sections above about using radio-telemetry results to estimate survival, in the case of juvenile shad the retention of the externally mounted transmitters (i.e., dorsal fish hook) on fish passing via turbulent passage routes is unknown, thus making radio telemetry survival estimates even more uncertain.

However, given these limitations, when the results of the Vernon radio telemetry passage route proportional distribution and estimated route survival rates based on telemetry detection at Stebbins Island are combined, total project survival for radio-tagged juvenile shad at Vernon is very conservatively estimated at 70.4% (Table 7.2-2).

Applying both the HI-Z tag and Franke turbine survival estimates to the proportion of juvenile shad passing via turbines along with telemetry estimates for non-turbine routes, total project survival ranges from 83.1% to 87.5%, higher than the radio telemetry estimate.

Table 7.2-2. Passage route distribution and associated route-specific survival estimates for juvenile American Shad at Vernon.

| Passage Route | No. | Proportion | Estimated and Predicted Survival Rates (%) | | |
|------------------|------------|--------------|--|---|---|
| | | | HI-Z (1-hr) | Conservative Radio Telemetry - Estimate | Franke Formula (4-inch fish) ^a |
| Units 1-4 | 22 | 0.097 | 91.7 | 59.1 | 89.9 – 95.4 |
| Units 5-8 | 90 | 0.398 | 95.2 | 75.6 | 89.0 – 97.7 |
| Units 9-10 | 35 | 0.155 | 94.7 | 65.7 | 93.8 – 96.9 |
| Fish Pipe | 17 | 0.075 | n/a | 82.4 | n/a |
| Fish Tube | 1 | 0.004 | n/a | 100 | n/a |
| Trash/Ice Sluice | 2 | 0.009 | n/a | 0 | n/a |
| Fish Ladder | 2 | 0.009 | n/a | 0 | n/a |
| Spill | 1 | 0.004 | n/a | 100 | n/a |
| Unknown | 56 | 0.248 | n/a | 69.6 | n/a |
| Total | 226 | 1.000 | | 70.4 | |

a. Calculated at peak efficiency for Units 1-4 and Units 5-8, and at minimum flow for Units 9-10.

8.0 LITERATURE CITED

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