TRANSCANADA HYDRO NORTHEAST INC.

ILP Study 16
Sea Lamprey Spawning Assessment

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)

Prepared for

TransCanada Hydro Northeast Inc.
4 Park Street, Suite 402
Concord, NH 03301

Prepared by

Normandeau Associates, Inc.
25 Nashua Road
Bedford, NH 03110

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EXECUTIVE SUMMARY

The goal of this study was to assess the level of spawning activity by Sea Lamprey (*Petromyzon marinus*) in the Wilder, Bellows Falls, and Vernon project-affected areas and to determine whether project operations are affecting the success (i.e., survival to emergence) of lamprey spawning. The objectives of this study were to conduct a field study of a subset of likely Sea Lamprey spawning locations to characterize spawning habitat, identify spawning locations via radio telemetry of tagged upstream migrating individuals, confirm spawning activity via capping of identified nests, and assess the potential effects of project related water-level fluctuations in impoundments and project-related flow fluctuations in riverine reaches downstream of the project dams on spawning success.

Twenty-three sites were pre-selected using habitat-based survey data for characterization of spawning and assessment of potential project effects. Additionally, 40 Sea Lamprey were collected, radio tagged, and manually tracked, and another 18 tagged lamprey from the FirstLight study being conducted downstream were manually tracked in the study area to refine the site selection. Sea Lamprey were distributed among all study reaches, and 4 of the original 23 pre-selected sites were altered as a result of manual tracking or visual observation of spawning activity.

Potential evidence of spawning activity was recorded in all study reaches. Lamprey were associated with 17 of the 23 (74%) spawning habitat assessment sites by radio telemetry manual tracking. Visual observation of nest building / spawning behavior was made at seven sites (30%), and nests were identified at 16 sites (70% overall, 83% of riverine sites and 55% of impoundment sites). Only the sites where spawning activity was verified were considered active spawning sites in 2015. Four sites (17%) were classified as having unsuitable spawning habitat within the project-affected area and were excluded from analysis of project effects. Three of those were in impoundment reaches and one was in a riverine reach. Of the remaining 19 sites, 16 (84%) were classified as active spawning areas, and three (16%) sites were classified as having suitable habitat, but with no evidence of spawning. Of the 16 active spawning sites, 10 were in riverine reaches (83% of the 12 riverine sites) and six were in impoundment reaches (55% of the 11 impoundment sites) including two in tributaries.

Nest caps were placed on four nests at three sites after visual confirmation of spawning activity in order to monitor spawning success. Nest capping efforts were not productive; however, ammocoetes were collected in simultaneous studies (Studies 10 and 21) providing evidence of spawning success in the study area.

As part of this final report, Hydraulic Model and Operations model data (Studies 4 and 5) and 2015 water surface elevation data were analyzed in conjunction with identified nest elevations recorded for all pertinent sites to evaluate the potential for normal project operations to expose nests. In a review of nest exposure potential of the 16 sites with identified spawning activity, and based on the worst case scenario from the Operations Model (Study 5, Hatch 2016) three sites (19%)

had 'no project effects'. One of those was in riverine habitat, and two were in impoundment habitats, though they were both in tributaries. Nine sites (56%) were found to have 'moderate project effects', meaning that some nests were exposed (at any point in the analysis), but at least one nest elevation was continuously inundated. Two sites with 'moderate project effects' are located downstream of Vernon dam in the reach affected by Turners Falls project operations. The remaining four sites (25%) experienced 'project effects', meaning all nests were exposed at some point (regardless of frequency or duration). Note that a finding of project effects should not be interpreted as spawning failure. A number of mitigating factors have the potential to reduce the effect of observed or predicted nest exposure.

It is important to note that this study was inherently biased toward relatively higher elevation habitat and shallower water (usually < 3 ft) because the study and site selection was intended to ignore deeper depths that are not vulnerable to dewatering. As a result, only the most vulnerable habitats were surveyed, but it is likely that Sea Lamprey also spawned in relatively deep water, despite literature suggesting that spawning occurs at shallow depths. This was evidenced by radio telemetry locations of fish in depths greater than 8ft during the spawning season, which, when surveyed during low water periods, contained nests in approximately 2 ft depth or less.

In addition, observational depths were limited in the spring due to high flow events during June, the approximate midpoint of the expected May 15 – July 15 spawning season. Actual spawning and gestation typically occurs over a much shorter period (e.g., 2 weeks). Therefore, it is reasonable to assume that this relatively short spawning window is highly responsive to the flow and WSE conditions at the time of spawning. The model analysis does not reflect the specific conditions observed in 2015, but rather depicts more typical WSE's for the same period (e.g., June) which are generally lower than earlier in the spring. Thus, using the model and hydrologies that do not reflect the actual hydrology experienced in 2015 is very problematic in terms of assessing actual project effects.

This final report also incorporates revisions based on stakeholder comments received on the interim study report filed March 1, 2016.

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List of Abbreviations

AOQL	Average Outgoing Quality Limit
cm	Centimeter
CRWC	Connecticut River Watershed Council
°C	Degrees centigrade
DO	Dissolved oxygen
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Power Resources
FWS	U.S. Department of the Interior – Fish and Wildlife Service
mHz	Mega-Hertz
µS/cm	Micro-siemens per centimeter
mi	Mile (statute)
NHDES	New Hampshire Department of Environmental Services
NHFGD	New Hampshire Fish and Game Department
NTU	Nephelometric Turbidity Units
PVC	Polyvinylchloride
RSP	Revised Study Plan
RTK	Real Time Kinematic Unit
SGCN	Species of Greatest Conservation Need
SN	Serial number
SSR	Site Selection Report
su	Standard units
TransCanada	TransCanada Hydro Northeast Inc.
USR	Updated Study Report
VANR	Vermont Agency of Natural Resources
VDEC	Vermont Department of Environmental Conservation
WSE	Water surface elevation

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1.0 INTRODUCTION

This study report presents the final results of the 2015 Sea Lamprey Spawning Assessment Study (ILP Study 16) conducted in support of Federal Energy Regulatory Commission (FERC) relicensing efforts by TransCanada Hydro Northeast Inc. (TransCanada) for the Wilder Hydroelectric Project (FERC Project No. 1892), Bellows Falls Hydroelectric Project (FERC No. 1855) and the Vernon Hydroelectric Project (FERC No. 1904). This report updates the interim study report filed March 1, 2016 to include analysis of the Hydraulic Model Study (Study 4 [GEI, 2016]) and the Operations Model Study (Study 5 [Hatch, 2016]) output and to respond to comments provided during the Study Report meeting on March 18, 2016 and written comments received by May 2, 2016. TransCanada provided responses to those comments in a May 31, 2016 FERC filing.

Operations of the Wilder, Bellows Falls, and Vernon projects have the potential to cause direct effects on Sea Lamprey (*Petromyzon marinus*) spawning habitat and activity downstream of the projects in riverine portions of the river from water releases during routine operations. In their study requests, U.S. Department of the Interior-Fish and Wildlife Service (FWS), New Hampshire Department of Environmental Services (NHDES), New Hampshire Fish and Game Department (NHFGD), Vermont Agency of Natural Resources (VANR), and Connecticut River Watershed Council (CRWC) identified issues related to potential effects of operation of the Wilder, Bellows Falls, and Vernon Projects on Sea Lamprey spawning habitat and activity in the Connecticut River.

Among rivers where Sea Lamprey spawning stock estimates are available, the Connecticut River likely supports the largest migration (Beamish, 1980). Sea lamprey are known to spawn in the Connecticut River as far upstream as Wilder dam and in tributaries such as the West, Williams, Black, and White rivers (Kart et al., 2005). Sea Lamprey typically spawn in areas of shallow, rapid water conducive to their nests[1], but near sandy bottom, quiet water areas preferred by larvae (Bigelow and Schroeder, 1953). FWS (2010) lists the current upstream extent of Sea Lamprey range as Bellows Falls dam, noting, however, that reproduction has been documented as far north as the White River, Vermont, just downstream of Wilder dam. A summary of Sea Lamprey spawning habitat characteristics is provided in Appendix A (filed separately in Excel format).

Revised Study Plan (RSP) 16 as supported by stakeholders in 2013 and approved by FERC in its February 21, 2014 Study Plan Determination, specified that a subset of project-affected locations would be evaluated for potential effects of project-related water level fluctuations and flows on Sea Lamprey spawning. FERC modified the RSP for Study 16 to include conducting habitat-based surveys to

[1] Sea Lamprey nests are often referred to as redds; however, the term nest is used throughout this report.

identify suitable spawning habitat and nests, using data from Study 7 – Aquatic Habitat Mapping (Normandeau, 2014) to focus survey efforts on potential spawning habitat including shallow, fast-moving water with gravel/cobble substrate.

An initial site selection report was posted on TransCanada's relicensing website on December 5, 2014 and comments were received during an aquatics working group meeting held on December 17, 2014. The final sampling locations were randomly selected and presented in the Revised Site Selection Report (Revised SSR [Normandeau, 2015]) which included modifications that addressed all working group discussion and comments. The Revised SSR was filed with FERC on September 14, 2015 as Volumes II.G of TransCanada's Updated Study Report (USR), with corresponding geodata of final study site locations filed as Volume II.I of the USR.

This final study report provides results from data collected at the selected study locations during the spring and summer of 2015. This report also includes analysis based on Hydraulic and Operations Model data (Studies 4 and 5) that was not available at the time of filing of the interim report.

2.0 STUDY GOALS AND OBJECTIVES

As stated in the RSP, the goal of this study was to assess the level of spawning activity by Sea Lamprey in the project-affected areas and to determine whether project operations are affecting the success (i.e., survival to emergence) of lamprey spawning. New Hampshire and Vermont have classified Sea Lamprey as a Species of Greatest Conservation Need (SGCN), thus, as stated in Vermont's Wildlife Action Plan (Kart et al., 2005), "research and monitoring needs for SGCN include monitoring and assessing populations and habitats for current conditions and future changes, and identifying and monitoring problems for species and their habitats." New Hampshire has listed the conservation status of Sea Lamprey as "vulnerable."

Specific objectives for this study were to:

- identify areas within the Wilder, Bellows Falls, and Vernon project-affected areas and riverine reaches where suitable spawning habitat exists for Sea Lamprey;
- conduct a telemetry study of Sea Lamprey during their upstream migration period in the spring, focusing on areas of suitable spawning habitat and areas of known spawning;
- conduct spawning ground surveys to observe the use of this habitat for spawning purposes and, hence, confirm suitability;
- obtain data on nest characteristics, including location, size, substrate, depth and velocity; and

- assess whether operations at the Wilder, Bellows Falls, or Vernon Projects adversely affect these spawning areas, specifically if flow alterations cause dewatering and/or scouring of Sea Lamprey nests.

3.0 STUDY AREA

The three project riverine reaches and tributary mouths and island habitats within the Bellows Falls and Vernon impoundments were included in the study area. As stated in the RSP, Sea Lamprey are unlikely to be found upstream of Wilder dam, so the Wilder impoundment was not included in the study. The three riverine reaches total 25 miles in length, and the two impoundments total 52 miles. The Wilder riverine reach was divided into three sub reaches: sub reach 1 from Wilder Dam downstream to the White River confluence (1.5 mi); sub reach 2 from White River downstream to Sumner Falls (5.2 mi), and sub reach 3 from Sumner Falls downstream to the Bellows Falls impoundment (11.0 mi).

3.1 Study Site Selection

Sea Lamprey typically spawn in areas of shallow, rapid water with cobble/gravel substrate for their nests and require sandy/muddy bottom in quiet water for their larvae (Bigelow and Schroeder, 1953). Preliminary study sites were selected in accordance with the process described in the Revised SSR with concurrence from the aquatics working group, and summarized below. The final selection of sampling locations entailed a combination of purposive sampling in study sites observed to support actual spawning activities identified by radio-tagged adult lampreys, as well as locations reported to be utilized by spawning adults based on nest observations noted by biologists over the course of the instream flow studies in 2014 and 2015 (Study 9, Normandeau 2016a).

Preliminary site selection used habitat-based survey data collected for Study 7 – Aquatic Habitat Mapping (Normandeau, 2014), to identify potential spawning habitat including shallow, fast-moving water with gravel/cobble substrate. Areas that were not expected to provide significant spawning habitat were excluded from site selection: areas dominated by sand or silt substrate (which are utilized by rearing ammocoetes, but not by spawning adults); areas greater than 10 feet deep that are not vulnerable to normal fluctuations in water surface elevations (WSE); and areas expected to contain velocities too slow for lamprey spawning (e.g., pool habitats). Potential study sites that met the basic spawning requirements of Sea Lamprey were then selected based on several criteria, principally:

- Known presence of spawning:
    - Nest locations identified during previous studies
- Presence of required habitat characteristics, namely:
    - Riverine habitats dominated by gravel or cobble substrate with moderate to swift water velocities

  - Impoundment tributary mouths possessing these same characteristics

Because of the large extent of potential habitat containing gravel/cobble substrate and non-zero velocities in the riverine reaches, a subsampling protocol was applied to select specific sites. In the two impoundment reaches, random selection of non-purposive study sites was based on tributary size (stream order) to maximize both the number and diversity of adult spawners or nests encountered at each sampling location. Larger tributary confluences generally contain a wider and more diverse range of microhabitat attributes than would small study sites. Finally, selection of a fixed number of larger sites would yield a much greater sampling area than would a similar number of small sites, again increasing the likelihood of achieving the goals of this study.

Twelve habitat-based study sites were selected in the project-affected area to assess spawning activities and habitat for Sea Lamprey in the riverine reaches, and 11 sites were selected in the impoundment reaches (total of 23 pre-selected sites). To the extent possible, the study sites were distributed among the three riverine reaches (three sub reaches in Wilder) in proportion to the length of each reach, and between the two impounded reaches. Based on those criteria, and giving one extra study site for the short (1.5 mi) Vernon riverine reach, produced the following sample size goals:

- Wilder 1 Sub riverine reach: 2 sites
- Wilder 2 Sub riverine reach: 2 sites
- Wilder 3 Sub riverine reach: 3 sites
- Bellows Falls impoundment: 6 sites
- Bellows Falls riverine reach: 3 sites
- Vernon impoundment: 5 sites
- Vernon riverine reach: 2 sites

Selection of specific study sites began with identification of known spawning areas. Lamprey nests were observed in two locations during Study 9 (Normandeau, 2016a) in 2014: one site in the Bellows Falls riverine reach and one site in the Vernon riverine reach. The Vernon site contained multiple nests surrounding Stebbins Island, which illustrated how the complex assemblage of substrate types, meso-habitat types, and depth/velocity characteristics of island habitats are likely to provide many opportunities for lamprey spawning. Most islands in each reach possess large gravel/cobble bars at the island head with moderate velocities in riffle, run, and glide habitats that may be utilized by lamprey. In addition, fine sediments deposited in the low velocity eddies alongside and below islands may be particularly important for rearing ammocoetes after emergence from the gravel/cobble nests. Consequently, initial study sites selected for lamprey spawning were based on known observations of nest locations as well as potential spawning areas associated with primary (wooded) islands. Most islands selected for assessment of lamprey spawning habitat were also selected for assessing riverine spawning by Smallmouth Bass and Fallfish in Study 15 (Resident Fish Spawning in Riverine Sections Study [Normandeau, 2016c]).

In the two impoundment reaches, the area of potential riffle and shoal spawning habitat at tributary mouths was approximated by filtering the list of tributaries to those classified as either "large" tributaries (stream order 4, 5, or 6) or "medium" tributaries (stream order 2 or 3), prior to random selection. Medium-sized tributaries that did not possess a shallow (<5 ft) gravel/cobble dominated delta or shoal (based on Study 7 habitat mapping [Normandeau, 2014]) were excluded. Small (1st order) tributaries were also excluded due to the expectation that such tributaries would not produce sizeable shoals at the impoundment confluence, nor would they provide a significant area of spawning habitat within the stream channel due to their small size and intermittent flow characteristics. Many impoundment sites selected for assessment of lamprey spawning habitat were also selected for assessing impoundment spawning by resident fish species in Study 14 (Resident Fish Spawning in Impoundments Study [Normandeau, 2016c]).

Finally, the locations of a few study sites were modified based on tracking of radio-tagged adult Sea Lamprey released above the Vernon and Bellows Falls projects, and visual observation of adults exhibiting spawning behavior in Study 14 and 15 surveys. Figures 3.1-1 through 3.1-5 illustrate final study site locations, and Table 3.1-1 provides study site details.

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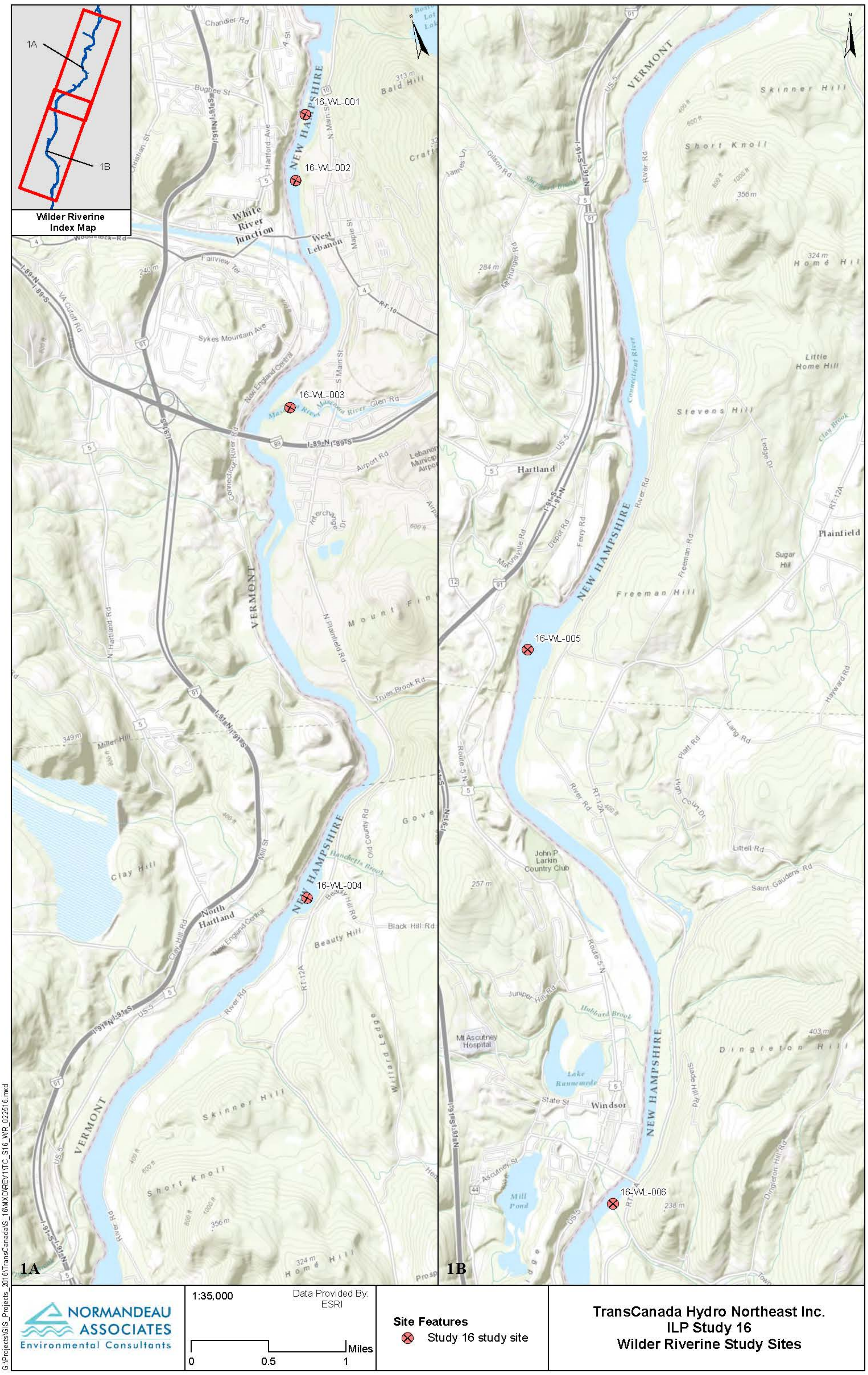

Figure 3.1-1. Sea Lamprey spawning habitat assessment sites in the Wilder riverine reach.

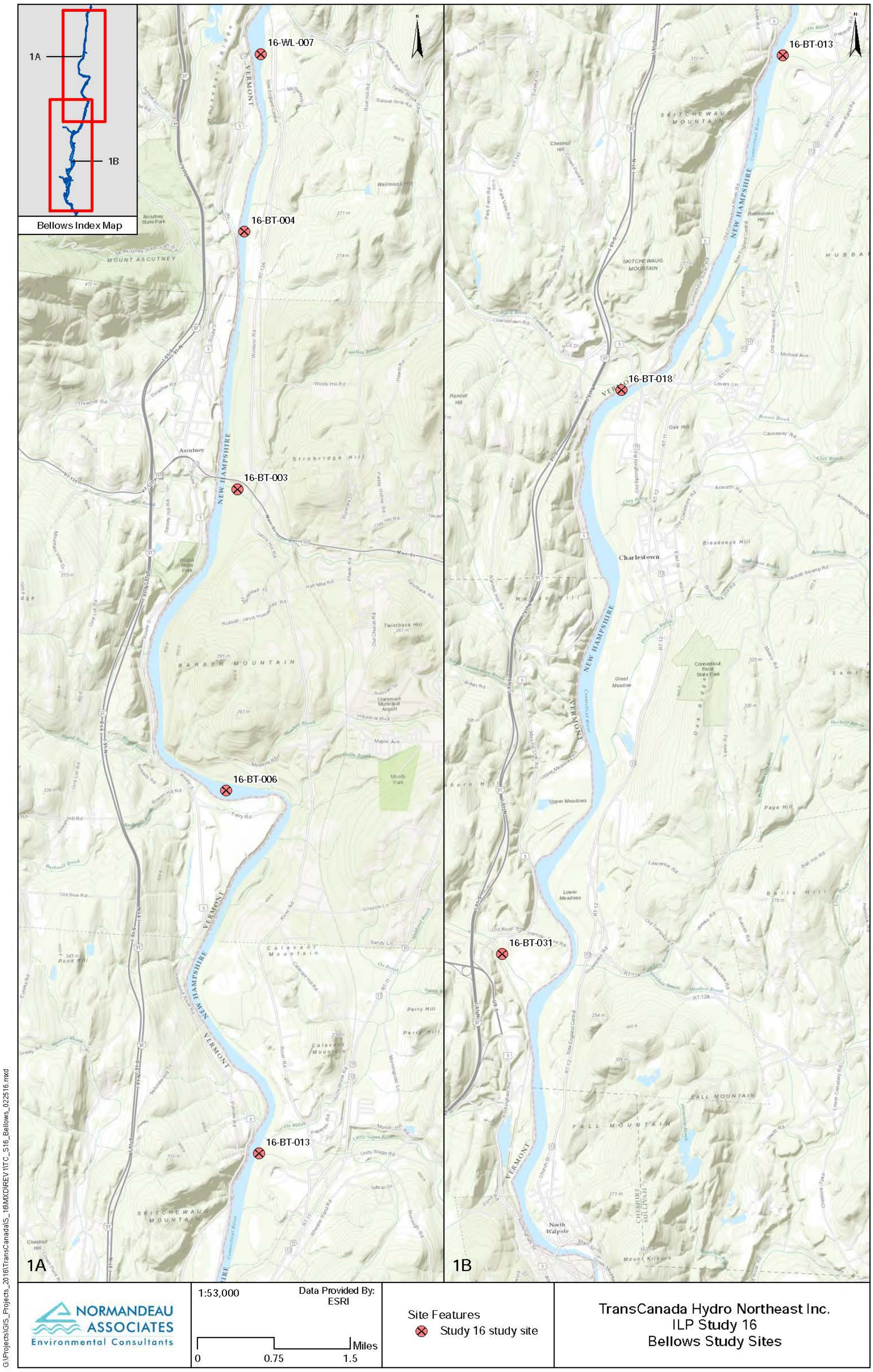

Figure 3.1-2. Sea Lamprey spawning habitat assessment sites in the Bellows Falls impoundment.

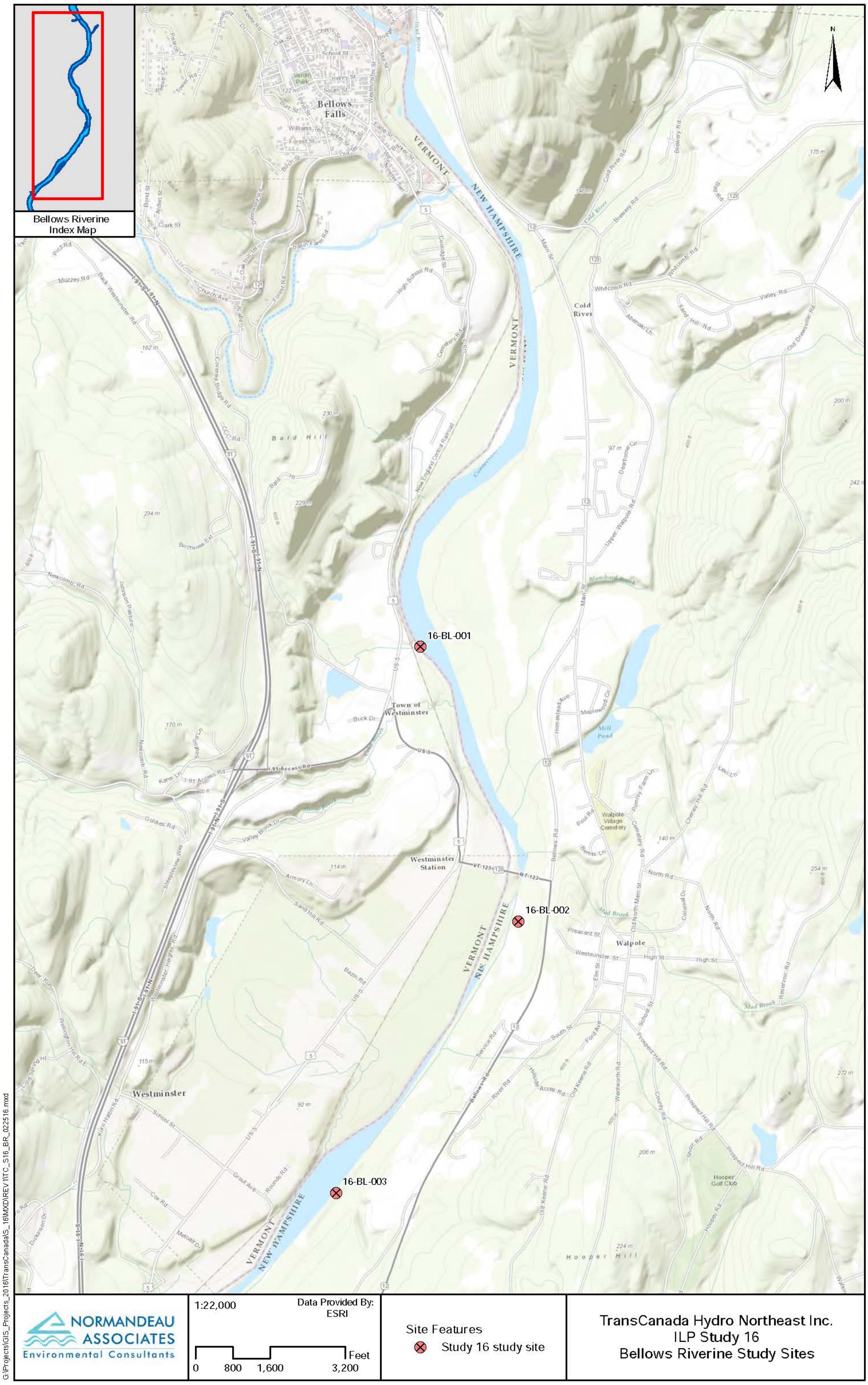

Figure 3.1-3. Sea Lamprey spawning habitat assessment sites in the Bellows Falls riverine reach.

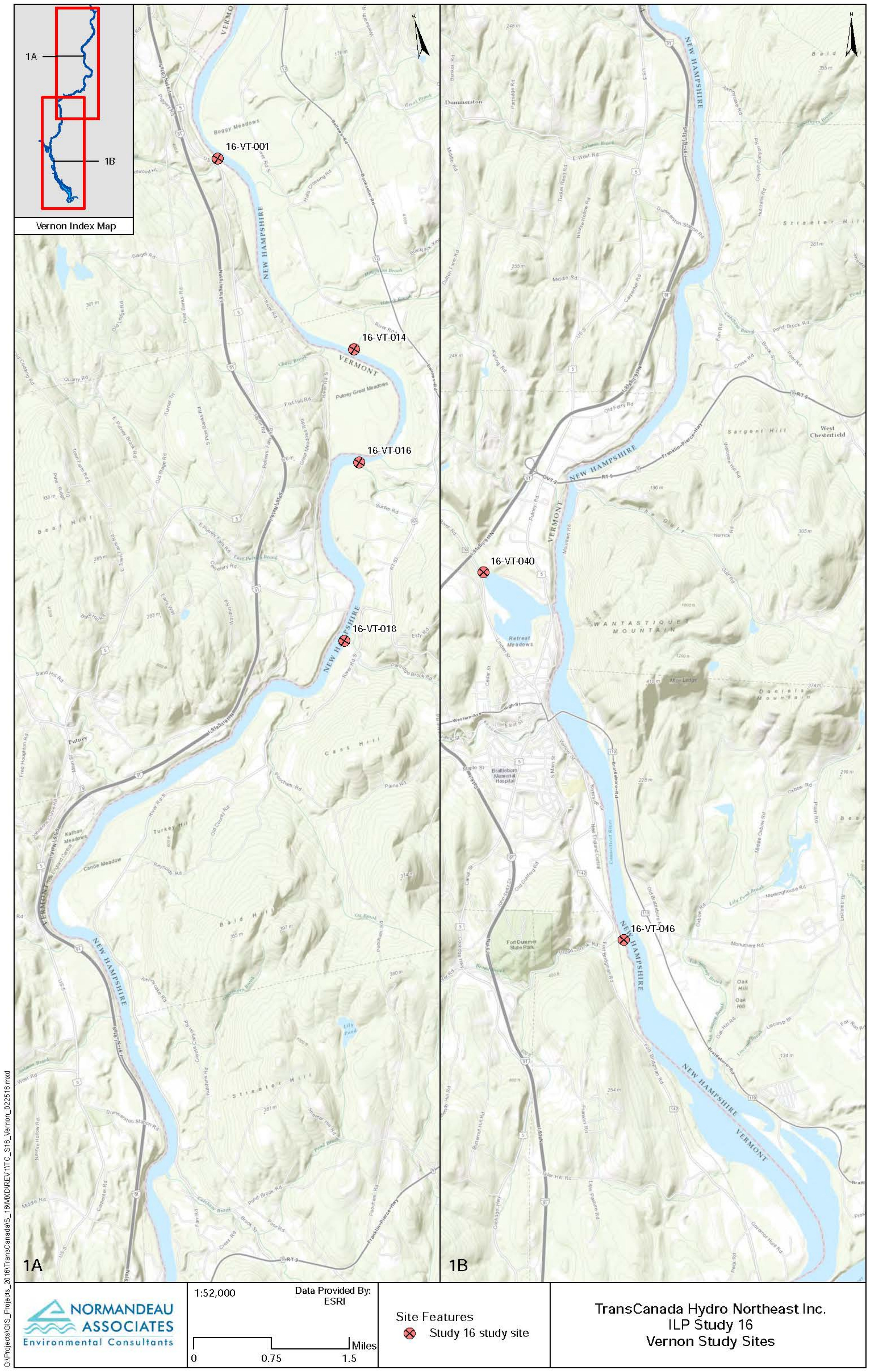

Figure 3.1-4. Sea Lamprey spawning habitat assessment sites in the Vernon impoundment.

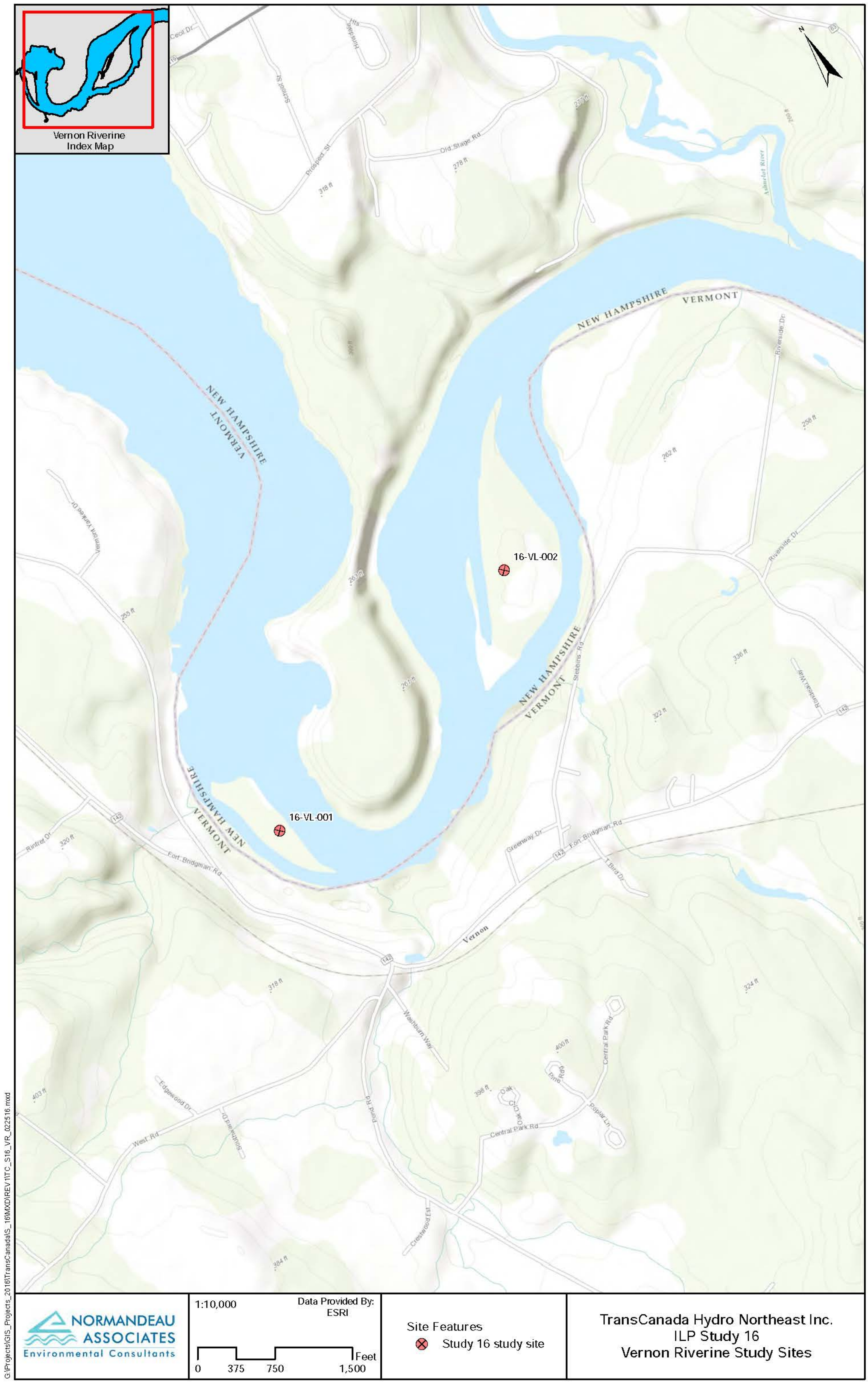

Figure 3.1-5. Sea Lamprey spawning habitat assessment sites in the Vernon riverine reach.

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Table 3.1-1. Sites selected for Sea Lamprey spawning habitat assessment in the Wilder riverine, Bellows Falls impoundment, Bellows Falls riverine, Vernon impoundment, and Vernon riverine reaches.

Reach	Habitat Type	Site ID[a]	Name	Location (DD NAD83 UTM Z18N)	
				X	Y
WR Sub 1	Riverine	16-WL-001	1st Island below Wilder Dam	-72.308651	43.661409
WR Sub 1	Riverine	16-WL-002	2nd Island below Wilder Dam	-72.312517	43.655811
~~WR Sub 2~~	~~Riverine~~	~~16-WL-003~~	~~Johnston Island~~	~~-72.329968~~	~~43.624874~~
WR Sub 2	Riverine, Tributary	16-WL-003	Mascoma River (Stream Order 5)	- 72.322653	43.635861
WR Sub 2	Riverine	16-WL-004	Burnaps Island	-72.340817	43.591786
WR Sub 3	Riverine	16-WL-005	Hart Island	-72.394997	43.523613
WR Sub 3	Riverine	16-WL-006	Bar below Cornish Bridge	-72.386233	43.471477
WR Sub 3	Riverine	16-WL-007	Chase Island	-72.390409	43.463315
BI	Impoundment, Tributary	16-BT-003	Sugar River (Stream Order 6)	-72.397636	43.401580
~~BI~~	~~Impoundment~~	~~16-BT-004~~	~~Mill Brook~~	~~-72.401287~~	~~43.401497~~
BI	Impoundment	16-BT-004	Shoal near Balloch,	-72.394678	43.438097
~~BI~~	~~Impoundment~~	~~16-BT-006~~	~~Blood Brook~~	~~-72.414300~~	~~43.364467~~
BI	Impoundment	16-BT-006	Jarvis Island	-72.401622	43.358747
BI	Impoundment, Tributary	16-BT-013	Little Sugar River (Stream Order 4)	-72.397392	43.307053
~~BI~~	~~Impoundment~~	~~16-BT-016~~	~~Beaver Brook~~	~~-72.414354~~	~~43.268448~~
BI	Impoundment, Tributary	16-BT-018	Black River (Stream Order 5)	-72.430748	43.260172
BI	Impoundment, Tributary	16-BT-031	Williams River (Stream Order 5)	-72.457251	43.180537
BR	Riverine, Tributary	16-BL-001	Cobb Brook (Stream Order 3)	-72.441668	43.098007
BR	Riverine	16-BL-002	Bar below Westminster Bridge	-72.434533	43.081773
BR	Riverine	16-BL-003	Dunshee Island	-72.449738	43.066225
VI	Impoundment, Tributary	16-VT-014	Aldrick Brook (Stream Order 3)	-72.449570	43.015160
VI	Impoundment, Tributary	16-VT-016	Mill Brook (Stream Order 4)	-72.454503	42.999753
VI	Impoundment, Tributary	16-VT-018	Partridge Brook (Stream Order 4)	-72.466343	42.976344
~~VI~~	~~Impoundment, Tributary~~	~~16-VT-024~~	~~Sackett's Brook (Stream Order 4)~~	~~-72.514282~~	~~42.963634~~
VI	Impoundment, Tributary	16-VT-040	West River (Stream Order 6)	-72.568874	42.871940

Reach	Habitat Type	Site ID[a]	Name	Location (DD NAD83 UTM Z18N)	
				X	Y
VI	Impoundment, Tributary	16-VT-046	Broad Brook (Stream Order 4)	-72.544267	42.820087
VR	Riverine	16-VL-001	1st Island below Vernon Dam	-72.514745	42.766711
VR	Riverine	16-VL-002	Stebbins Island	-72.502771	42.769141

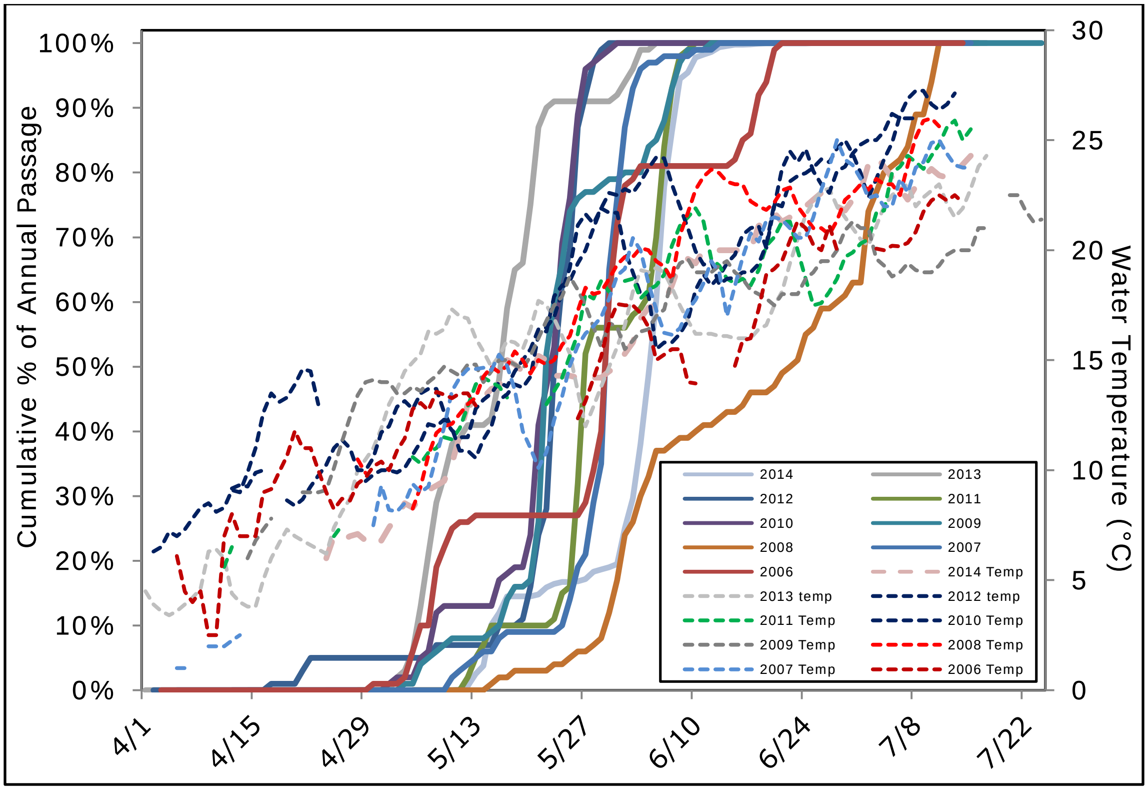
a. WR = Wilder riverine, BI = Bellows Falls impoundment, BR = Bellows Falls riverine, VI = Vernon impoundment, VR = Vernon riverine Pre-selected sites that were not used are struck-out; alternative sites are highlighted.

4.0 METHODOLOGY

4.1 Radio Telemetry

4.1.1 Fish Collection, Tagging and Release, and Tracking

Migrating adult Sea Lamprey were tagged with radio transmitters for the purpose of tracking individuals to determine specific spawning habitats. Tagging and release of up to 20 adults each upstream of both the Vernon and Bellows Falls projects was targeted with releases distributed among the projected early, mid, and late periods of the run. As stated in the RSP, if few lamprey were available at the Bellows Falls fish ladder as water temperatures approached 15°C, fish collected from the Vernon fish ladder would be tagged and transported to above Bellows Falls dam for release. Sea Lamprey passage data for Holyoke dam (river mile 86, Normandeau, 2000 - 2015), the downstream-most dam on the Connecticut River, were reviewed to aid in predicting the time of arrival of migrating Sea Lamprey at Vernon Dam (Figure 4.1-1).



Source: Normandeau (2007, 2008-2015)

Figure 4.1-1. Daily cumulative percent of annual Sea Lamprey passage at Holyoke dam with water temperature by calendar date for 2006 – 2014.

Passage at Holyoke generally peaked when water temperatures were around 15°C, typically in the second and third week of May. Peak spawning reportedly occurs when water temperatures are 17 – 19°C, and temperatures above 18.5°C are thought to reduce migration and spawning intensity (Beamish, 1980). Therefore, tagging was expected to be done from the third week of May through early June, depending on actual occurrence of abundances sufficient for collection from the Vernon and Bellows Falls fish ladders. Although attempts were made to collect fish for tagging from the Bellows Falls fish ladder, abundances were insufficient to feasibly collect there, so all tagged specimens were collected from the Vernon fish ladder using the associated trap facility (Figure 4.1-2). Specimens were removed from the trap using dip nets and placed in a holding tank with circulating ambient river water.

Figure 4.1-2. Immigrating adult Sea Lamprey resting in the Vernon fish ladder viewing window, adjacent to the fish trap (left), and collection of trapped lamprey (right).

Sea Lamprey were tagged following established techniques (e.g., Hanson and Mathur, 2002; Moser et al., 2002; Noyes et al., 2011). Individual Sea Lamprey were anesthetized in a bath of 30 – 70 mg/l tricaine methanesulfonate (MS-222), buffered to neutral (pH = 7) with sodium bicarbonate ($NaHCO_3$) to anesthetic stage IV (total loss of muscle tone and equilibrium and slow but regular buccal pumping rate, Summerfelt and Smith, 1990). Once anesthetized, each fish was weighed, measured for total length and girth, and surgically implanted with a radio transmitter.

Tags were Sigma Eight, Inc. Model PSC—1-450 Pisces internal implantation transmitters, 41 mm long, 10 mm diameter, and 8.35 g in air. Each tag was programmed to transmit a unique identification code in a 20-millisecond burst every 2 seconds in the 150.320 mHz frequency. For tag implantation, anesthetized fish were placed in a cylindrical retention device so that the head was immersed in an anesthetic bath. Transmitters were inserted into the body cavity through an approximately 3-cm incision off the linea alba (ventral mid-line) with the posterior end of the incision in line with the origin of the first dorsal fin. The transmitter's trailing antenna was threaded through the body wall approximately 2 cm posterior to the incision using a cannula. The incision was sutured using 3 to 5 individual stitches. (Figure 4.1-3).

Figure 4.1-3. Biological data collection and transmitter implantation for adult Sea Lamprey.

Tagged lamprey were allowed to recover for approximately four hours prior to release. Immediately after tagging, lamprey were placed in a holding tank supplied with circulating ambient river water, and were then transferred to transport containers supplied with aerated and/or oxygenated river water. Releases were made mid-river after sunset at locations approximately 1.25 mi upstream of the Vernon and Bellows Falls dams. One exception was made for a partial release group released from a marina dock approximately 6 miles upstream of Vernon dam due to approaching severe electrical storm activity (see Section 5.1-1).

Manual tracking of tagged lamprey was done from road vehicle, boat, and aircraft using Lotek model SRX receivers with either a directional Yagi antenna or omnidirectional whip antenna as appropriate for the tracking vehicle and circumstance. When lamprey were relocated in suspected spawning habitat the locations were used to verify or alter the pre-selected spawning habitat assessment stations. Tracking was conducted primarily during daylight hours, multiple times per week in varying reaches of the study area. Upon relocation of a tagged lamprey, the date, time, and its position were recorded.

4.2 Habitat Assessment

As described in Section 3.1, stations were pre-selected for spawning habitat assessment, and modified based on visual observation and radio-telemetry locations. Most stations consisted of extensive areas of suitable substrate at island heads, at tributary mouths or further upstream in the tributary, and on cobble-gravel bars.

Habitat assessment included a visual survey for presence of spawning activity such as evident nests and/or presence of adults actively engaged in nest construction, substrate characterization (dominant substrate and embeddedness), depth, water velocity, and instantaneous samples of water quality variables. When lamprey nests were present, the dominant substrate and depth inside the nest were also recorded. Substrate size classifications were modified from the Wentworth (1922) scale and included: silt (<~0.06 mm) sand (<0.06-3 mm), gravel (3-64 mm), cobble (64-254 mm), and boulder (>254 mm). Substrate embeddedness was defined as the amount that coarse substrates (gravel, cobble, boulder) were embedded in fine substrates (silt, sand) and included: negligible (<5%), low (5-25%), moderate (25-50%), high (50-75%), and very high (>75%; Bain, 1995).

The area surveyed for evidence of lamprey spawning encompassed as much of the suitable habitat as practicable and generally included substrate occurring in water depths less than 2.5 ft. For stations with exceptionally large areas of suitable substrate, such as Stebbins Island below Vernon dam (16-VL-002), habitat surveyed was limited to the area that could be observed in a reasonable period, but encompassed the suitable habitat around the perimeter of the island.

Supplementary Habitat Assessment

Relatively high river flows throughout the spring and early summer hampered spawning habitat assessment due to generally high water elevations, velocities, and turbidity. In many cases, sites could not be surveyed for evidence of spawning due to unsafe or limited visibility conditions. In some cases, spawning behaviors such as nest building, nest guarding, or completed nests were observed during periods of low flows, but subsequent observation was not possible because of increased flows and WSEs. As a result, sites that could not be adequately surveyed during the spawning season (and that had not been characterized as having insufficient suitable habitat), were revisited in August or September 2015 during low flow conditions when the maximum amount of habitat was exposed or accessible to survey. The supplementary habitat assessment focused on visual surveys for presence of nests and, when identified, documentation of their elevations for use in analyses of potential project affects. Note that the supplementary habitat assessment was intentionally conducted during the summer under low river flow levels. Conditions of inundation or exposure of nests observed at that time were not necessarily representative of conditions during the spawning season.

4.3 Spawning Success / Nest Capping

Nests in a sub-set of spawning habitat identified in the habitat assessment site selection and those where spawning behavior (nest building) was observed were capped in an attempt to verify spawning success. The nest cap design was a modified form of previously reported ammocoete and emergent fry traps (Porter, 1973 [as referenced in Snyder, 1983]; Field-Dodgson, 1983; Triton, 1993; Graham et al., 2012). Nest caps consisted of a 5-ft-long x 3.25-ft-wide x 0.8-ft-high frame of steel reinforcement bar welded in a teardrop shape and funneling down to a PVC cod-end. The frame was covered with 1.5 mm mesh landscaper's heavy shade cloth, positioned over the nest with the cod-end oriented downstream, staked to the river bottom with reinforcement bar. The cod-end was terminated with a section of perforated aluminum plate to allow water flow through the nest cap from end to end. A skirt of shade cloth that extended approximately 0.5 feet beyond the frame was buried in the substrate to prevent escapement (Figure 4 .3-1)

Figure 4.3-1. Sea Lamprey nest cap: frame (left panel) and deployed in the field (right panel).

Nest caps were maintained for 2 to 6 weeks depending on whether site conditions were conducive to the technique. For example, one nest cap was removed when it was determined that the cap had significantly altered the nest meso-habitat (see Section 5.3.1). Once set, nest caps were checked daily to the extent practicable for ammocoete collection. Nest caps were not checked under conditions of high WSE, high velocities, or other unsafe conditions.

Water Surface Elevation Data Collection

For each nest cap set, an Onset HOBO water level logger was deployed. Loggers (vertical accuracy of ±0.1 in.) were programmed to collect water temperature and pressure information at 15-minute intervals and were installed adjacent to the nest to provide elevation data. During installation, the logger's position (latitude, longitude, and elevation in NAVD88 vertical datum) was recorded using a Leica GS-14 Real Time Kinematic (RTK) unit. Level loggers were maintained at their set elevations by placement inside a perforated well pipe structure affixed to a piece of ¾-inch rebar and set vertically into the bottom substrate (Figure 4.3-2). Barometric reference loggers installed at representative locations for each study reach (for Studies 14 and 15) were used in processing water level logger data. Data were downloaded and imported into HOBOware Pro Software for air pressure compensation. Sensor depths were determined and WSE calculated at each 15-minute interval based on the relationship between recorded pressure values at the in-water level logger and in-air barometric reference location. WSE was then plotted relative to nest elevations for the period of nest cap deployment.

Figure 4.3-2. Installation set-up used for HOBO water level loggers.

4.4 Data From Other Studies

Data from other TransCanada relicensing studies were used to provide additional information regarding adult Sea Lamprey abundance in the study area and/or to provide project operational information.

Study 14/15: Resident Fish Spawning in Impoundments and Riverine Reaches (Normandeau, 2016c)

- WSE data from loggers (see Section 4.3 and Study 14/15 report for detail) were used where nest capping was not done, and therefore lamprey nest specific loggers were not deployed. For most sites, elevation data were selected for stations that coincided with Sea Lamprey spawning habitat assessment sites. For some sites where study sites did not overlap, data from the nearest available logger was substituted (proxy logger). In some cases the proxy loggers were located away from the study site and WSE may vary from the survey site. WSE data were then plotted relative to nest elevations.
- Resident species spawning site survey data for coinciding stations augmented Sea Lamprey specific spawning site survey data.

Study 21: Adult American Shad Telemetry (Normandeau, 2016e)

- Sea Lamprey ammocoetes were collected incidentally in ichthyoplankton tows done to document American Shad spawning.

Study 10: Fish Species Assemblage Study (Normandeau, 2016b)

- Sea Lamprey ammocoetes were collected by electrofishing in some samples.

Study 17: Upstream Passage of Riverine Species (Normandeau, 2016d)

- Daily passage counts of Sea Lamprey were recorded for the Vernon, Bellows Falls, and Wilder fish ladders.

Study 4: Hydraulic Modeling Study (GEI, 2016)

- HEC-RAS (Hydrologic Engineering Centers River Analysis System) model results predict WSE at specific points (nodes) under an array of operational and spill discharges, and project dam WSEs.

Study 5: Operations Modeling Study (Hatch, 2016)

- Model results predict timing, duration, and frequency of WSE at specific points (nodes) based on a representative set of five annual hydrologies.

Project operations (discharge) and precipitation data provided by TransCanada Operations Department.

Anecdotal information regarding presence of Sea Lamprey ammocoetes in the Vernon fish ladder recorded during a maintenance dewatering (December 8, 2015).

4.5 Nest Dewatering Calculations

As an indication of potential project effects on Sea Lamprey nests, the incidence of nest exposure was evaluated using water level logger data (see Section 4.3) and Operations Model output. Water level logger data were specific to 2015 field conditions whereas Operations Modeling was done for five discrete historical yearly hydrologies, representing a range of river flow conditions and simulated project operations in terms of flows, impoundment elevations, and dispatch. The resulting water surface elevations reported out of the operations model were based upon the stage hydrographs produced for each cross-section in the hydraulic model.

Pursuant to the RSP, water level loggers were installed for this study at sites with nest capping. For other sites, data from water level loggers installed for Study 14/15 (Normandeau, 2016c) were available and were used to provide additional information regarding potential project effects on identified nest elevations. The period of record for water level loggers varied among sites, but generally encompassed the Sea Lamprey spawning season, defined here as May 15 – July 15, 2015. The spawning season determination was based on upstream passage (see Figure 5.1-1), water temperature, and radio telemetry locations of tagged fish. May 15 was the approximate date that lamprey first arrived at the Vernon fishway, and spawning likely occurred throughout much of June. Eggs hatch within two weeks (Piavis, 1972) and ammocoetes usually quickly emerge from the nest and move downstream into low velocity habitats where they burrow into fine substrates (Wagner and Stauffer, 1962). Therefore, emergence during the 2015 lamprey spawning season was generally expected to have occurred between mid-June and mid-July. The inclusion of a two-month period was intended to encompass the entire seasonal spawning and gestation period and is highly conservative for analysis of project effects on spawning sites. At any one site, spawning, gestation, and emergence would have occurred over a shorter period.

For each site, except those characterized with insufficient spawning habitat, 2015 water level logger data were used to calculate the observed range and mean WSE, and rate of change in WSE. For each identified nest with a recorded elevation, the range and mean occurrence and range and mean duration of exposures were also calculated. Occurrences of exposure were defined as all 15-minute water level logger observations where WSE was less than the nest elevation. Duration of exposure was defined as the period of consecutive records that WSE was less than the nest elevation and was measured in hours. In order to investigate the risk of nest exposure as a result of project operations, independent of periods of flow above normal project generation calculations were made for periods of normal project operations, and were delimited by observations of WSE within the predicted range associated with normal operations for the site (Study 4 [GEI, 2016]). It should be noted that high water operations (not normal operations) can occur as part of river flow management when TransCanada may periodically initiate "River Profile Reservoir Operations" by lowering WSE at the dams below the normal operating range in anticipation of inflows greater than maximum generating capacity at each project. This is done pursuant to high water procedures developed under Article 32 of the existing project licenses and in coordination with the US Army Corps of Engineers which operates flood control dams on several tributaries to the Connecticut River that discharge to project impoundments. These high water operations are initiated in order to maintain upstream water elevations within a range that protects specific railroad grade embankments along the river and to reduce the potential for river flows to spill outside of the normal operating ranges. These conditions and operating protocols are not considered normal project operations as they are instituted before and during spill events, but typically occur each spring during the freshet. And these relatively high river flows that resulted in periodic discharges above project generating capacity occurred during the 2015 Sea Lamprey spawning season.

Operations Model output (Study 5 [Hatch, 2016]) were used to investigate potential project effects on nest exposure under an array of hydrologic conditions, in the same manner as described above for 2015 water level logger data. For each site, except those characterized with insufficient habitat, the closest model cross section (node) was selected and the hourly model WSE output was summarized for each of five modeled years over the broadly defined spawning season of May 15 – July 15. The range and mean WSEs, and rate of change in WSEs were calculated for each site. For each identified nest with a recorded elevation, the range and mean occurrence and range and mean duration of exposures were also calculated. Occurrences of exposure were defined as all hourly observations where WSE was less than the nest elevation. Duration of exposure was defined as the period of consecutive records that WSE was less than the nest elevation. As described for 2015 water level logger data, model output was delimited by the range of WSEs within the predicted range associated with normal operations for the site (Study 4 [GEI, 2016]).

5.0 RESULTS AND DISCUSSION

5.1 Radio Telemetry

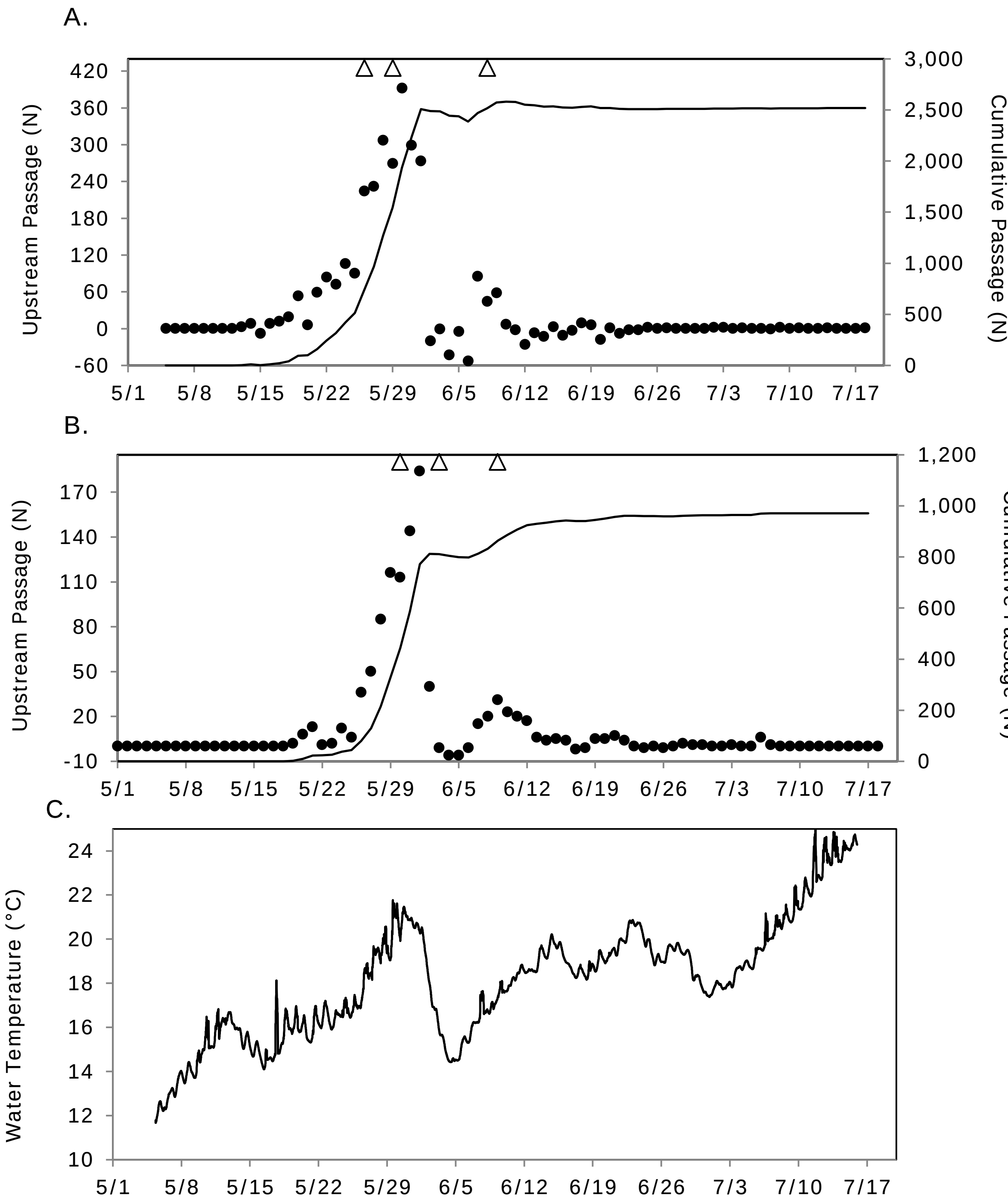
5.1.1 Fish Collection, Tagging and Release, and Tracking

Vernon fish monitoring was used to aid in selecting representative early, mid, and late run release timing. Note, however, that fish passage counts from Study 17 (Normandeau, 2016d) were made from video recordings reviewed days to weeks after passage so actual determination of passage peak was predicted based on daily fish passage counts from Holyoke dam (see Section 4.1-1), anecdotal observation of Vernon and Bellows Falls lamprey passage, and water temperatures.

As stated in the RSP, Sea Lamprey spawning has been documented to occur at water temperatures from 10°C to 20°C. If water temperatures approached 15°C, releases would be expedited to allow tagged fish to reach spawning habitat within the appropriate temperature window. Review of Sea Lamprey passage and water temperatures at Holyoke suggested that water temperatures at Vernon dam would likely be at least 15°C when immigrating lamprey first arrived in the Vernon fish ladder (see Figure 4.1-1). This suggested that the separation between early, mid, and late release groups would be short in order to ensure that tagged fish were released in the appropriate period. Actual Sea Lamprey upstream passage through the Vernon fish ladder increased from first passage to peak passage over a short period while water temperature was rapidly increasing (Figure 5.1-1).

The first lamprey passed upstream through the Vernon fish ladder on May 13 (net upstream passage = 3) when water temperature averaged 16.1°C. Collection of lamprey from the Vernon fish ladder trap was not practicable until reasonable numbers of fish began to rest in the counting window / trap area, which generally occurred when daily net upstream passage was at least 100 fish. The first date when net upstream passage was greater than 100 was May 24 (N = 106) and water temperature was 16.8°C. On May 26, net upstream passage first exceeded 200 (N = 224) and average water temperature was 17.7°C. The early run group of tagged lamprey was released to the Vernon impoundment on May 26. The mid-run group was released on May 29 and peak net upstream passage at Vernon dam occurred on May 30 (N = 392) when average water temperature was 20.9°C, and 77% of the seasonal net upstream passage (N = 2,519) had occurred. An atmospheric cold front passed just after the mid-run release and resulted in significant rainfall, increased flow, and decreased water temperatures. Water temperature fell from about 20.0°C to 14.5°C from June 1 through June 4. The late run group was released on June 6 and June 8. This group was split because on June 6 two fish were collected, tagged, and held in recovery, but after significant additional effort no more fish could be trapped. An additional four fish were trapped, tagged, and released on June 8 to complete the late run release. By June 6, 94.7% of the Vernon fish ladder net upstream passage had occurred. Tagged lamprey were released mid-river in the Vernon impoundment approximately 1.25 miles upstream of Vernon dam with one exception. The partial late run group on June 8 was released from a dock approximately 6 miles upstream of Vernon dam (Norm's Marina, Hinsdale, New Hampshire) because imminent violent electrical storm activity prevented safe boating. That site allowed for safe release near the main river channel.

The Bellows Falls early release was delayed, relative to the Vernon early release so that collection of tagging specimens from the Bellows Falls fish ladder could be made. Despite attempts, insufficient lamprey densities prevented feasible trapping there. Per the RSP, specimens for tagging and release in the Bellows Falls impoundment were collected from the Vernon fish ladder instead because of the difficult collecting from the Bellows Falls fish ladder and because water temperatures were approaching or above 15°C before lamprey had even arrived at Vernon dam. Tagged lamprey were released to the Bellows Falls impoundment mid-river approximately 1.25 miles upstream of Bellows Falls dam.



source: water temperature, Entergy Vermont Yankee (unpublished data)

Figure 5.1-1. A. Vernon fish ladder, and B. Bellows Falls fish ladder daily (closed circles), and cumulative (line) net upstream Sea Lamprey passage with radio transmitter tagged lamprey release dates (triangles); C. Vernon fish ladder water temperature.

The first lamprey passed upstream through the Bellows Falls fish ladder on May 19 (net upstream passage = 2), six days after the first passage through the Vernon fish ladder (Figure 5.1-1). The first date when net upstream passage was greater than 100 was May 27 (N = 130). The early run group of tagged lamprey was released to the Bellows Falls impoundment on May 30. Peak net upstream passage was on June 1 (N = 184), at that point 79.5% of the seasonal net upstream passage total (N = 971) had passed. The mid-run group was released on June 3 and the late run group was released on June 8. By that time, 85.8% of the Bellows Falls net upstream passage had occurred.

Overall, 20 tagged lamprey were released in both the Vernon and Bellows Falls impoundments. Total lengths ranged from 631 to 775 mm (mean = 708.55 mm), and weight ranged from 400 to 1,050 g (mean = 726.25 g). Sex was recorded when evident during the surgical tagging procedure, but when not evident no additional invasive exploration was done to determine sex. Eggs were highly evident, but testes were not always visible. Overall, 18 (45%) tagged lamprey were known female, 8 (20%) were known male, and 14 (35%) were unknown. It is likely that the majority, if not all, of those classified as unknown were male, so the sex ratio was probably nearly equal or with a slight preponderance of males, as has been suggested for established populations (Beamish, 1980). Table 5.1-1 summarizes characteristics of tagged lamprey, and Table 5.1-2 provides individual characteristics and release group specifics.

Of the 20 tagged lamprey released in the Vernon impoundment, one (5%) was never relocated. Of the remaining 19, the upstream-most reach where relocated was: 30% within the Vernon impoundment, 40% in the Bellows Falls riverine reach, 5% in the Bellows Falls impoundment, and 10% in the Wilder riverine reach. Another two fish (10%) were relocated in the West River, a tributary to the Vernon impoundment, above the project-influenced area: one at Townshend dam (~20 miles upstream of the tributary mouth) and one approximately 2.5 miles upstream of the Interstate 91 Bridge or 3.5 miles upstream of the tributary mouth (Table 5.1-3). GIS-derived elevation maps and on-site visual clues (e.g., vegetation lines) were used to identify the extent of the project-influenced tributary reach.

Of the 20 tagged lamprey released in the Bellows Falls impoundment, one (5%) was never relocated. Of the remaining 19: one (5%) dropped back and was relocated only in the Vernon impoundment; one (5%) dropped back and was relocated only in the Bellows Falls riverine reach; ten (50%) were relocated within the Bellows Falls impoundment; and seven (35%) were relocated in the Wilder riverine reach (Table 5.1-3).

Additionally, 18 Sea Lamprey tagged and released in the Connecticut River for FirstLight's Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project relicensing studies were located from one to six times each within the study area or tributaries.

Table 5.1-1. Summary characteristics of adult Sea Lamprey tagged with surgically implanted radio transmitters including number tagged and range, mean, and standard deviation of the mean of length (mm), weight (g), and girth (mm) by sex.

	N	Length (mm)			Weight (g)			Girth (mm)		
		Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Female	18	645-775	718	36.5	500-1050	768	138.5	127-165	146	10.5
Male	8	631-744	697	35.9	500-950	706	120.4	135-175	155	14.1
Unknown	14	636-732	703	25.3	400-850	684	115.6	127-166	152	10.6
Total	40	631-775	709	34.0	400-1050	726	133.0	127-175	150	11.9

Table 5.1-2. Adult Sea Lamprey tagging data including tagging date-time, release date-time, coordinates of release location, and specimen length (mm), weight (g), girth at largest point (mm), and sex.

Code	Tag Date-Time	Release Date-Time	Length (mm)	Weight (g)	Girth	Sex
Vernon, early release; Release Location: 42.787472°N, 72.516556°W						
161	05/26/2015 14:37	5/26/15 21:00	680	700	145	M
162	05/26/2015 14:50	5/26/15 21:00	752	750	135	F
163	05/26/2015 15:01	5/26/15 21:00	708	720	146	F
164	05/26/2015 15:14	5/26/15 21:00	710	680	145	.
165	05/26/2015 15:22	5/26/15 21:00	732	710	152	.
166	05/26/2015 15:38	5/26/15 21:00	716	850	162	.
167	05/26/2015 15:50	5/26/15 21:00	720	850	166	.
Vernon, mid release; Release Location: 42.787472°N, 72.516556°W						
168	05/29/2015 14:14	5/29/15 20:36	681	500	127	.
169	05/29/2015 14:25	5/29/15 20:36	715	650	142	.
170	05/29/2015 14:32	5/29/15 20:36	731	700	166	.
171	05/29/2015 14:39	5/29/15 20:36	719	650	161	.
172	05/29/2015 14:47	5/29/15 20:36	697	500	152	F
173	05/29/2015 14:57	5/29/15 20:36	725	700	162	.
174	05/29/2015 15:07	5/29/15 20:36	636	400	157	.
Bellows Falls, early; Release Location: 43.150733°N, 72.453200°W						
175	05/29/2015 15:25	5/30/15 21:03	771	1050	155	F
176	05/29/2015 15:42	5/30/15 21:03	700	690	147	.
177	05/29/2015 15:57	5/30/15 21:03	695	800	152	.
178	05/29/2015 16:07	5/30/15 21:03	672	700	137	F
179	05/29/2015 16:17	5/30/15 21:03	645	650	138	F
180	05/29/2015 16:29	5/30/15 21:03	680	700	146	.
181	05/29/2015 16:43	5/30/15 21:03	683	700	145	.
Bellows Falls, mid; Release Location: 43.153050°N, 72.450917°W						
182	06/03/2015 14:28	6/3/15 20:35	671	600	137	M
183	06/03/2015 14:28	6/3/15 20:35	631	500	135	M
184	06/03/2015 14:28	6/3/15 20:35	718	725	147	F
185	06/03/2015 14:28	6/3/15 20:35	766	1000	165	F
186	06/03/2015 14:28	6/3/15 20:35	682	725	151	M
187	06/03/2015 14:28	6/3/15 20:35	732	850	146	F
188	06/03/2015 14:28	6/3/15 20:35	733	850	144	F
Vernon, late; Release Location: 43.153050°N, 72.450917°W (* indicates different Release Location: 42.848856°N, 72.549181°W)						
189	06/06/2015 15:28	6/6/15 20:25	727	825	161	F
190	06/06/2015 15:43	6/6/15 20:25	744	950	175	M
191	06/08/2015 17:18*	6/8/15 18:49	694	625	134	F

Code	Tag Date-Time	Release Date-Time	Length (mm)	Weight (g)	Girth	Sex
192	06/08/2015 17:32*	6/8/15 18:49	775	975	165	F
193	06/08/2015 17:44*	6/8/15 18:49	731	750	171	M
194	06/08/2015 17:59*	6/8/15 18:49	696	700	143	F
Bellows Falls, late; Release Location: 43.152317°N, 72.452603°W						
195	06/09/2015 15:06	6/9/15 20:56	707	675	136	F
196	06/09/2015 15:22	6/9/15 20:56	655	625	127	F
197	06/09/2015 15:36	6/9/15 20:56	706	700	159	M
198	06/09/2015 18:00	6/9/15 20:56	733	725	164	M
199	06/09/2015 18:15	6/9/15 20:56	728	775	147	F
200	06/09/2015 18:27	6/9/15 20:56	745	825	153	F

Table 5.1-3. Sea Lamprey radio telemetry manual tracking results summarizing tagged lamprey not relocated, the upstream-most river reach where relocated, and relocated in tributaries above the project-affected area by release group.

Release Group	Not Relocated	Upstream-most Reach					Tributary	Total
		Vernon Riverine	Vernon Impound-ment	Bellows Falls Riverine	Bellows Falls Impound-ment	Wilder Riverine		
Vernon, early	0	0	2	3	1	1	0	7
Vernon, mid	0	0	2	4	0	1	0	7
Vernon, late	1	0	2	1	0	0	2	6
Bellows Falls, early	0	0	1	0	2	4	0	7
Bellows Falls, mid	0	0	0	1	5	1	0	7
Bellows Falls, late	1	0	0	0	3	2	0	6
Total (N)	**2**	**0**	**7**	**9**	**11**	**9**	**2**	**40**
% Vernon Releases	5	0	30	40	5	10	10	100
% Bellows Falls Releases	5	0	5	5	50	35	0	100

A summary of individual tagged fish locations including upstream distribution and locations pertaining to spawning habitat assessment site selection is contained in Tables 5.1-4 and 5.1-5. Manual tracking relocation events are represented in Figures 5.1-2 – 5.1-8. Appendix B (filed separately in Excel format) contains tables of manual tracking notes. Sea Lamprey behavior as indicated by manual tracking varied and included movements out of the study area, to large distances upstream, to relatively short distances to suitable spawning habitat, locations in the vicinity of more than one spawning habitat assessment station, probable post-spawn moribund movement/locations, and locations with verified mortality, presumably post—spawn.

Adult Sea Lamprey are known to migrate long distances to reach suitable spawning habitat (Kircheis, 2004). Tagged lamprey in this study migrated to a maximum of at least 222 miles from the mouth of the Connecticut River to reach spawning habitat as far upstream as the White River. Three fish moved up tributaries well above the project-influenced reach. Two moved to the West River (code 194, at least 3.4 miles upstream, code 190 approximately 20 miles upstream to Townshend dam); and one to the White River (code 60, at least 7.4 miles upstream). One fish (code 167) was relocated in the West River upstream of the project-influenced reach in an area of suitable spawning habitat for several days, but then returned to the Connecticut River and moved approximately 11 miles upstream to Partridge Brook (habitat station 16-VT-18), a site with evidence of relatively high spawning density.

The observation of that lamprey migrating up one tributary before returning to the mainstem and continuing upstream to another tributary was not consistent with the published understanding of migratory behavior and spawning, and suggested potential scouting or serial spawning. No references to serial spawning were found in a literature review, however. Overall, eight-tagged lamprey were associated with more than one habitat assessment station. Some of the locations may have simply been circumstantial records of a fish that happened to be in the vicinity of suitable habitat during a tracking event, which is reasonable because suitable habitat is distributed throughout much of the study area.

Table 5.1-4. Sea Lamprey radio telemetry manual tracking results summarizing individual tagged fish including number of relocations, the upstream-most river reach where relocated, spawning habitat assessment stations where relocated, and specific comments.

Code	Release Group	Number of Relocations	Upstream Most Reach	Habitat Assessment Station	Comments
161	Vernon, early	5	Vernon impoundment	VT-018	post-spawn mortality, tag recovered
162	Vernon, early	5	Bellows Falls impoundment	BT-003	
163	Vernon, early	2	Wilder Riverine	WL-003	passed BF and reached WL-003 within 10 d
164	Vernon, early	3	Bellows Falls riverine	NA	BF bypassed reach fish barrier dam
165	Vernon, early	3	Bellows Falls riverine	BL-003	up to BFBR then back to BL-003
166	Vernon, early	2	Bellows Falls riverine	NA	located twice near bar, ~0.4 mi downstream of Cold River mouth
167	Vernon, early	5	Vernon impoundment	BT-003	entered West River for several days, then reached VT-018; post-spawn mortality, tag recovered
168	Vernon, mid	6	Vernon impoundment	NA	various locations in Vernon impoundment
169	Vernon, mid	4	Bellows Falls riverine	BL-003	
170	Vernon, mid	4	Bellows Falls riverine	BL-003, VT-014	to BL-003 then back to VT-014
171	Vernon, mid	6	Wilder riverine	BT-004, WL-007	a few days in vicinity of BT-004 then up to WL-007, later found in Bellows Falls riverine
172	Vernon, mid	3	Bellows Falls riverine	NA	BF bypassed reach fish barrier dam
173	Vernon, mid	3	Bellows Falls riverine	VT-016	up to near Bellows Falls then back to VT-016
174	Vernon, mid	8	Vernon impoundment	NA	Old Ferry - West Chesterfield, Vernon impoundment

Code	Release Group	Number of Relocations	Upstream Most Reach	Habitat Assessment Station	Comments
175	BF, early	3	Wilder riverine	VT-016	to above Sumner Falls then late in season found in Vernon impoundment (post-spawn?)
176	BF, early	4	Vernon impoundment	VT-016	dropped back to VT-016
177	BF, early	7	Bellows Falls impoundment	BT-006	moved rapidly to vicinity of BT-006 and remained
178	BF, early	1	Bellows Falls impoundment	BT-006	only one relocation
179	BF, early	2	Wilder riverine	WL-004	
180	BF, early	7	Wilder riverine	BT-004, BT-013	several days near BT-004, then up to lower Wilder riverine reach, then back to vicinity of BT-013
181	BF, early	5	Wilder riverine	WL-007, BT-004	several days in vicinity of BT-004, then up to WL-007
182	BF, mid	4	Bellows Falls riverine	NA	dropped back to BF bypassed reach
183	BF, mid	4	Bellows Falls impoundment	BT-013	
184	BF, mid	5	Bellows Falls impoundment	BT-006	up to vicinity of BT-006, later found further downstream
185	BF, mid	5	Bellows Falls impoundment	NA	various locations in BF impoundment
186	BF, mid	5	Wilder riverine	WL-006, BT-006	to upstream of WL-006 with location at BT-006
187	BF, mid	2	Bellows Falls impoundment	BT-018	to intensive spawning habitat in Black River
188	BF, mid	4	Bellows Falls impoundment	BT-06	
189	Vernon, Late	1	Vernon impoundment	VT-014	only one relocation
190	Vernon, Late	2	Tributary	NA	West River upstream of project-affected area; Townshend Dam, ~20 miles upstream of mouth within 2 days

Code	Release Group	Number of Relocations	Upstream Most Reach	Habitat Assessment Station	Comments
191	Vernon, Late	2	Vernon impoundment	VT-016	
192	Vernon, Late	1	Bellows Falls riverine	BL-002	one relocation
193	Vernon, Late	0	NA	NA	not relocated
194	Vernon, Late	2	Tributary	NA	West River, ~3.5 mi upstream of mouth
195	BF, late	1	Wilder riverine	WL-004	one relocation
196	BF, late	2	Bellows Falls impoundment	BT-006	
197	BF, late	3	Bellows Falls impoundment	BT-004	
198	BF, late	2	Bellows Falls impoundment	NA	two locations in BF impoundment
199	BF, late	0	NA	NA	not relocated
200	BF, late	2	Wilder riverine	WL-001	

Table 5.1-5. Sea Lamprey radio telemetry manual tracking summary of tagged fish from FirstLight studies that were relocated in the TransCanada study area.

Code	Number of Relocations	Upstream Most Reach Located	Habitat Assessment Station	Comments
46	5	Vernon impoundment	VT-016	
51	1	Vernon riverine	VL-001	
52	4	Wilder riverine	WL-003	
55	5	Bellows Falls riverine	BL-002, BL-003	
56	2	Vernon riverine	VL-002	
57	1	Bellows Falls riverine	NA	BF bypassed reach fish barrier dam
59	4	Wilder riverine	WL-006	
60	2	Tributary	NA	White River, upstream of project-affected area
62	4	Vernon riverine	VL-001, VL-002	
63	2	Bellows Falls riverine	NA	BF bypassed reach fish barrier dam
102	6	Vernon riverine	VL-001, VL-002	
110	4	Vernon impoundment	BL-003	
111	2	Bellows Falls riverine	NA	BF bypassed reach fish barrier dam
112	2	Vernon riverine	VL-001	
114	1	Vernon impoundment	VT-016	
115	3	Vernon riverine	VL-001	
116	2	Vernon riverine	VL-001	
117	2	Vernon riverine	VL-001	

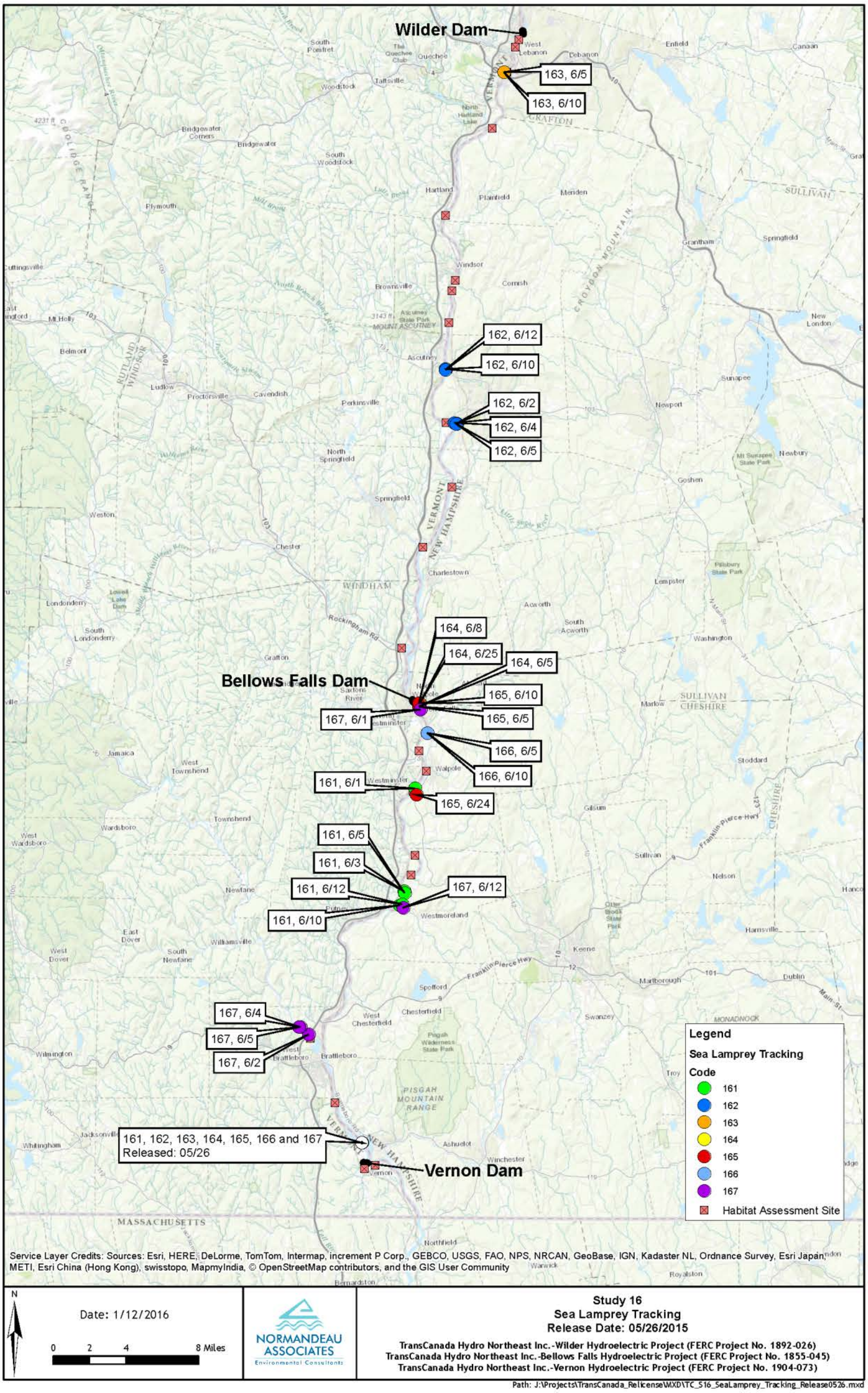


Figure 5.1-2. Sea Lamprey radio telemetry relocations for Vernon impoundment early run release group (released May 26, 2015).

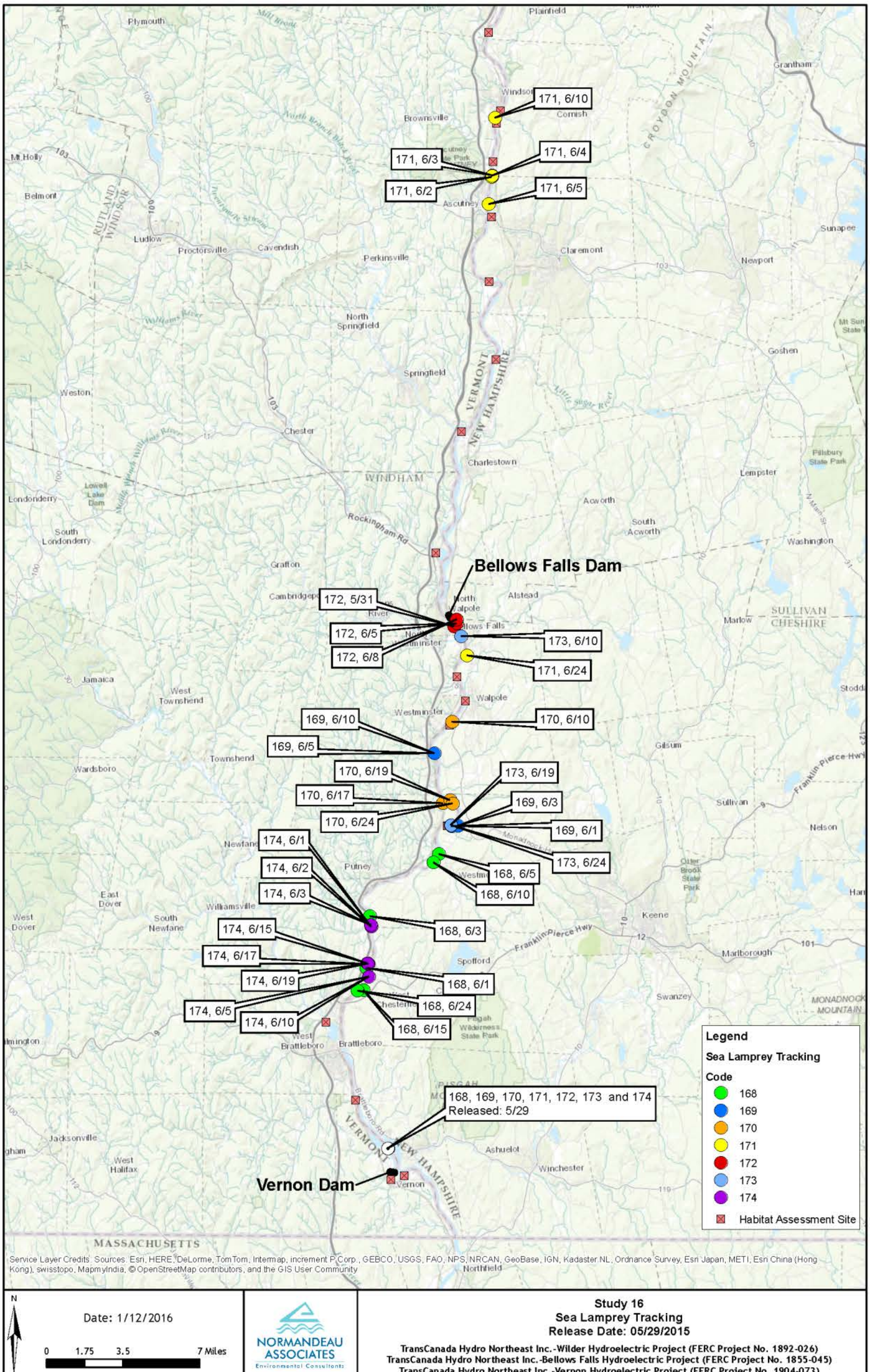


Figure 5.1-3. Sea Lamprey radio telemetry relocations for Vernon impoundment mid-run release group (released May 29, 2015).

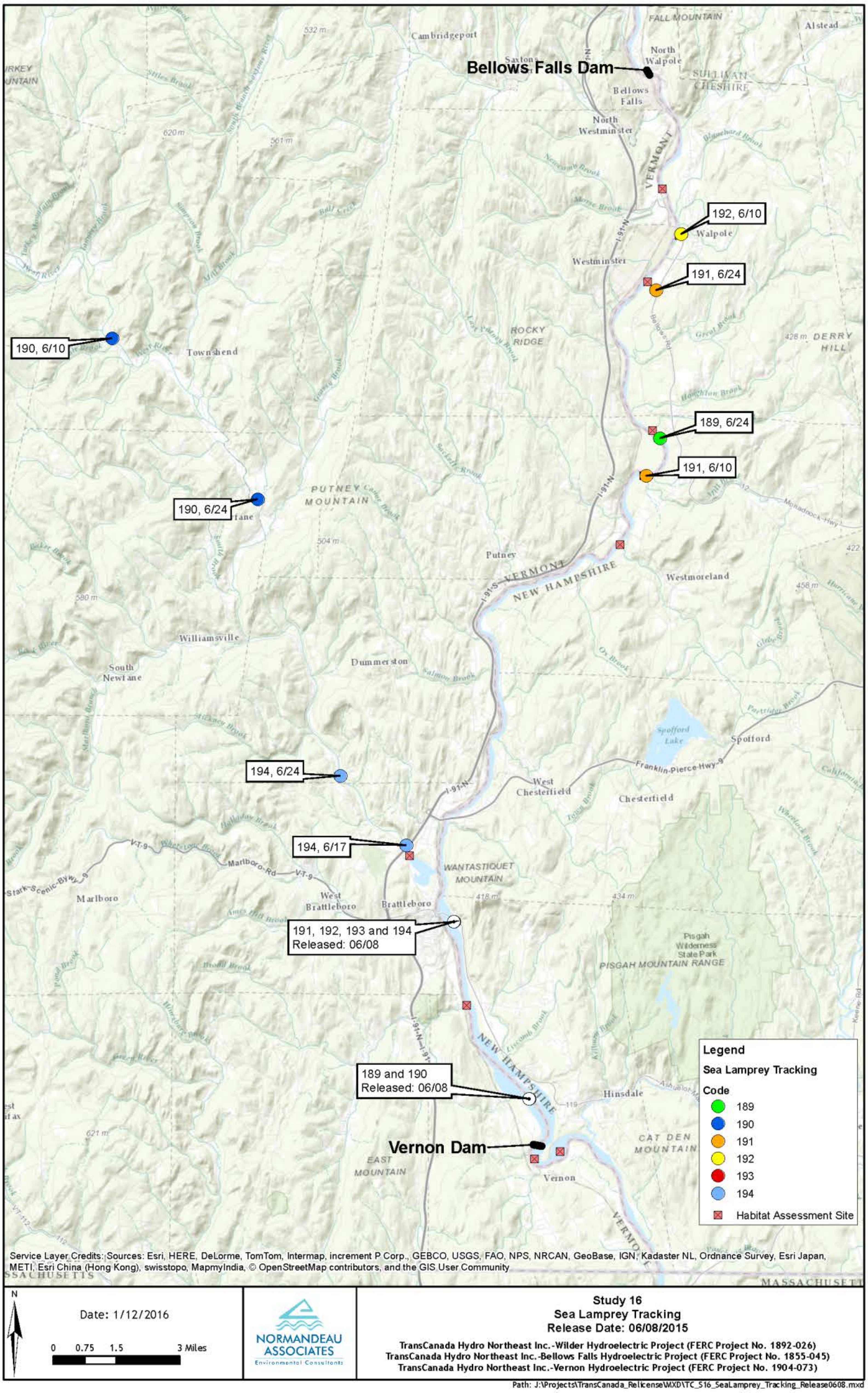


Figure 5.1-4. Sea Lamprey radio telemetry relocations for Vernon impoundment late-run release group (released June 8, 2015).

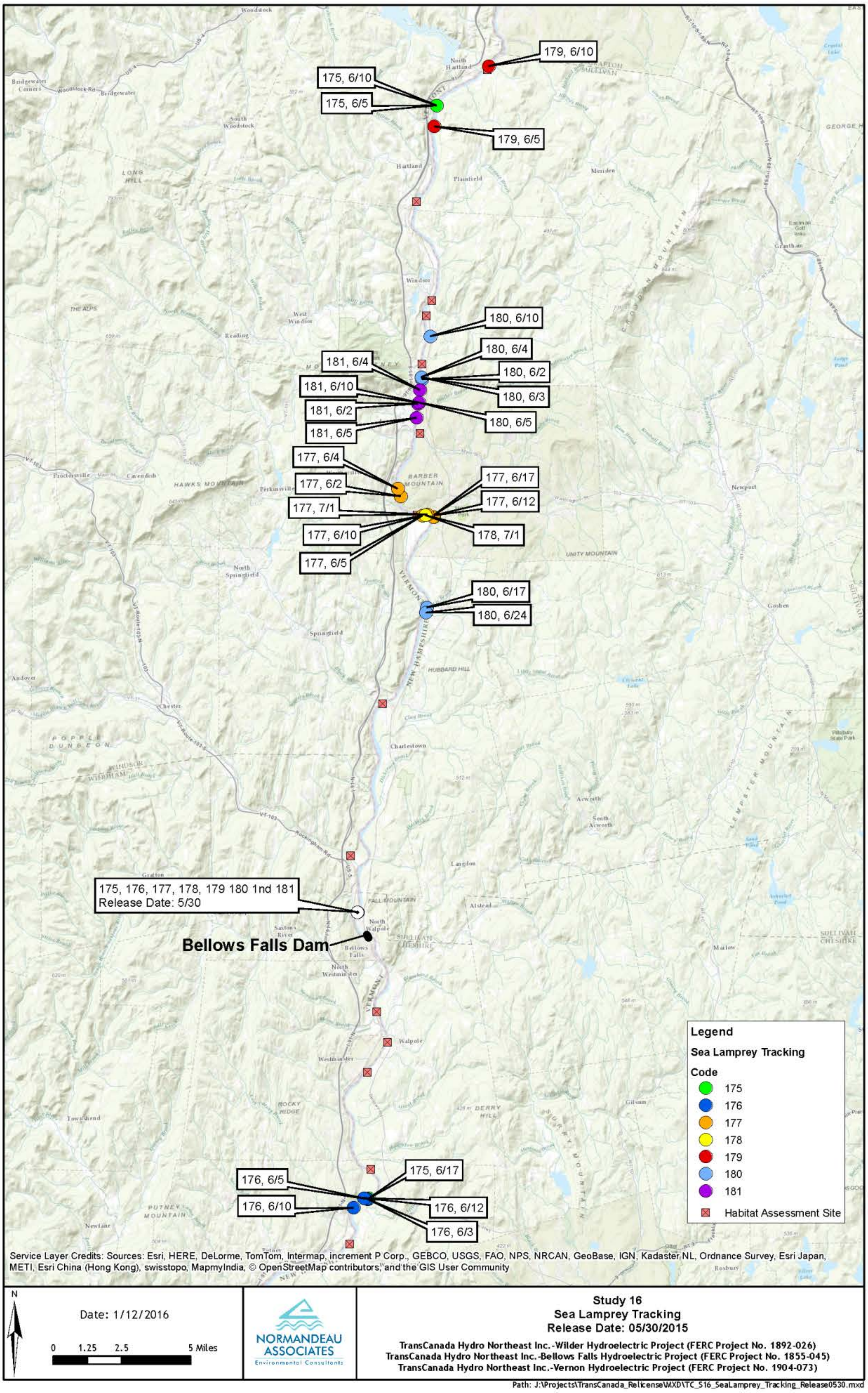


Figure 5.1-5. Sea Lamprey radio telemetry relocations for Bellows Falls impoundment early run release group (released May 30, 2015).

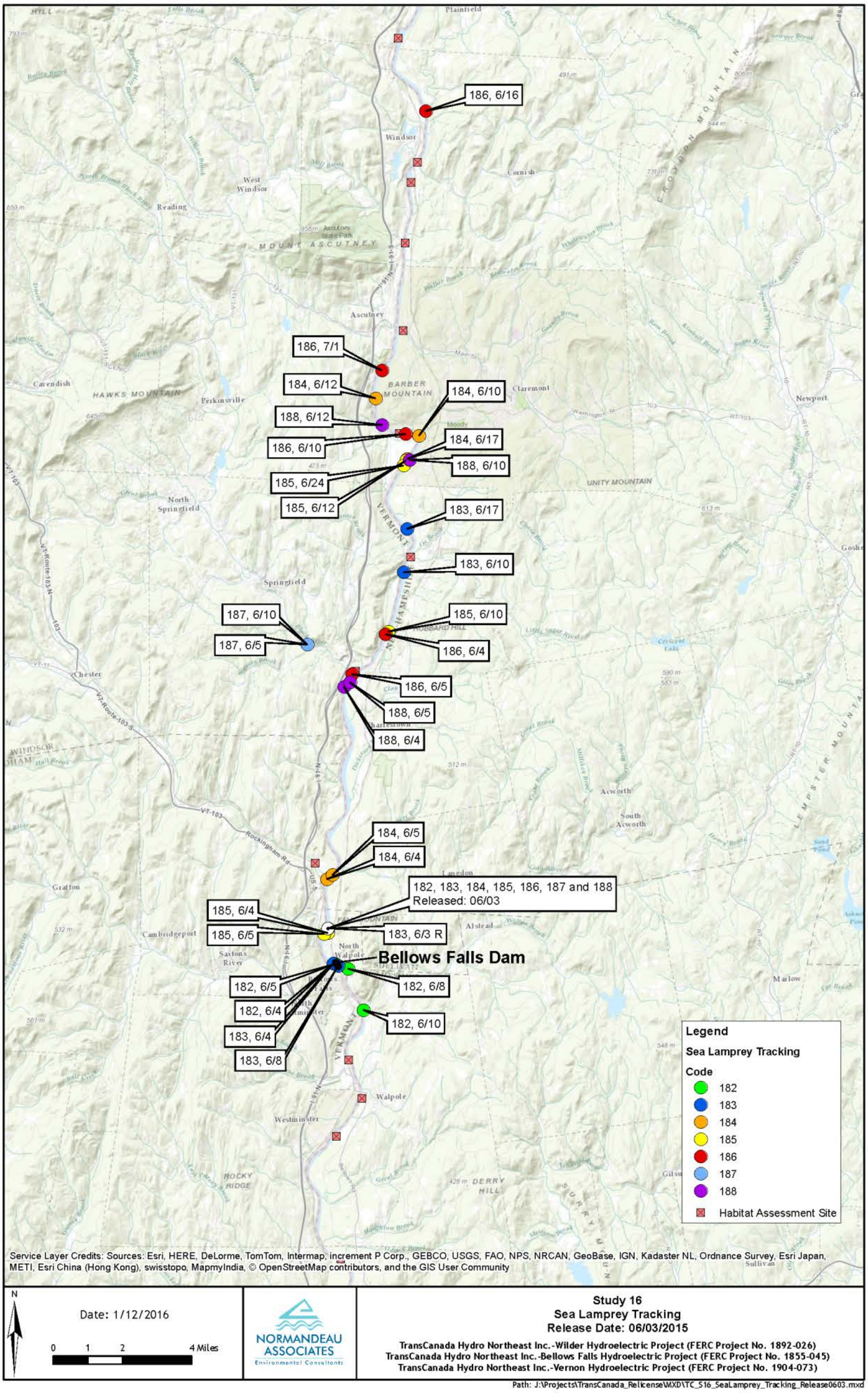


Figure 5.1-6. Sea Lamprey radio telemetry relocations for Bellows Falls impoundment mid-run release group (released June 3, 2015).

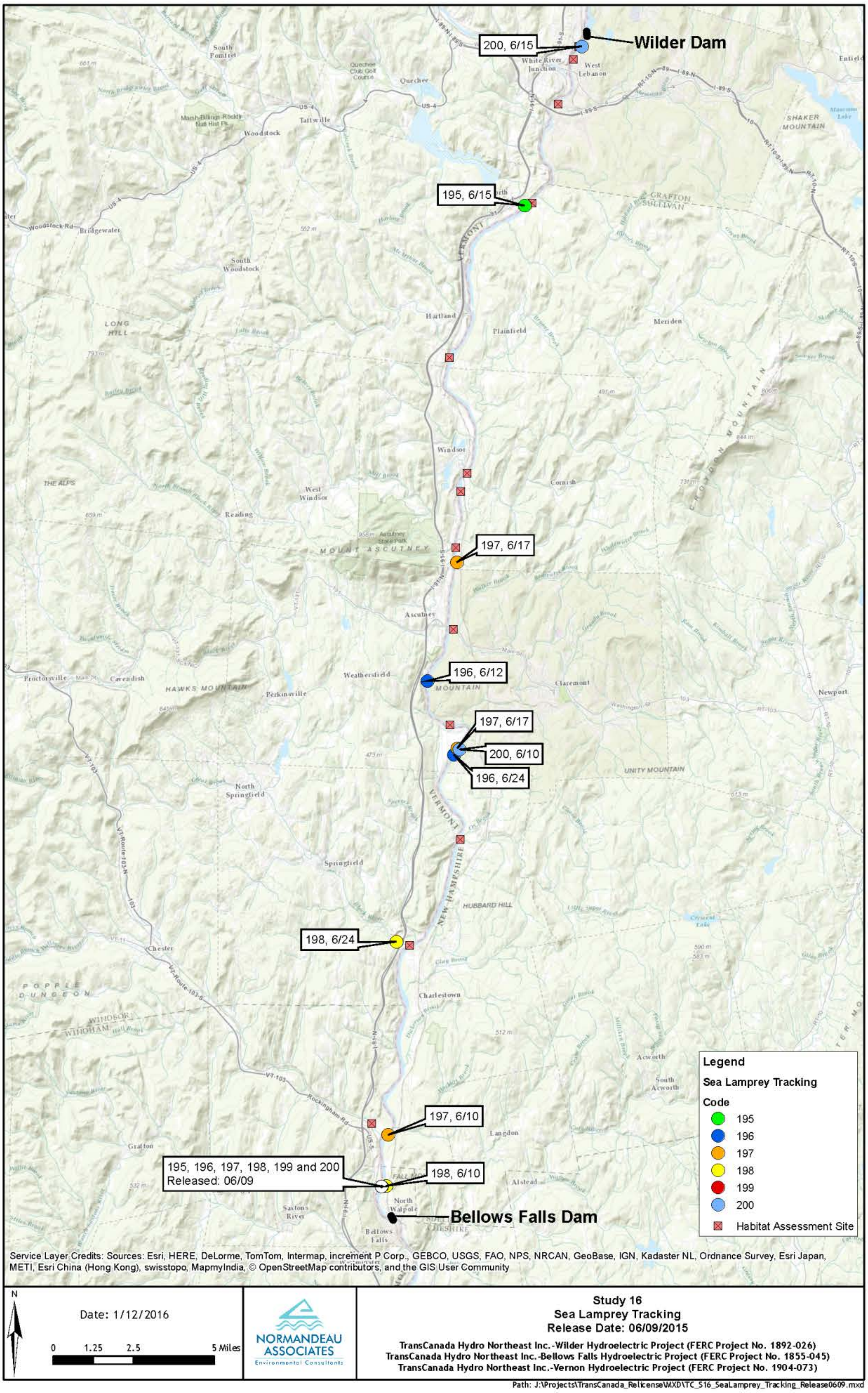


Figure 5.1-7. Sea Lamprey radio telemetry relocations for Bellows Falls impoundment late-run release group (released June 9, 2015).

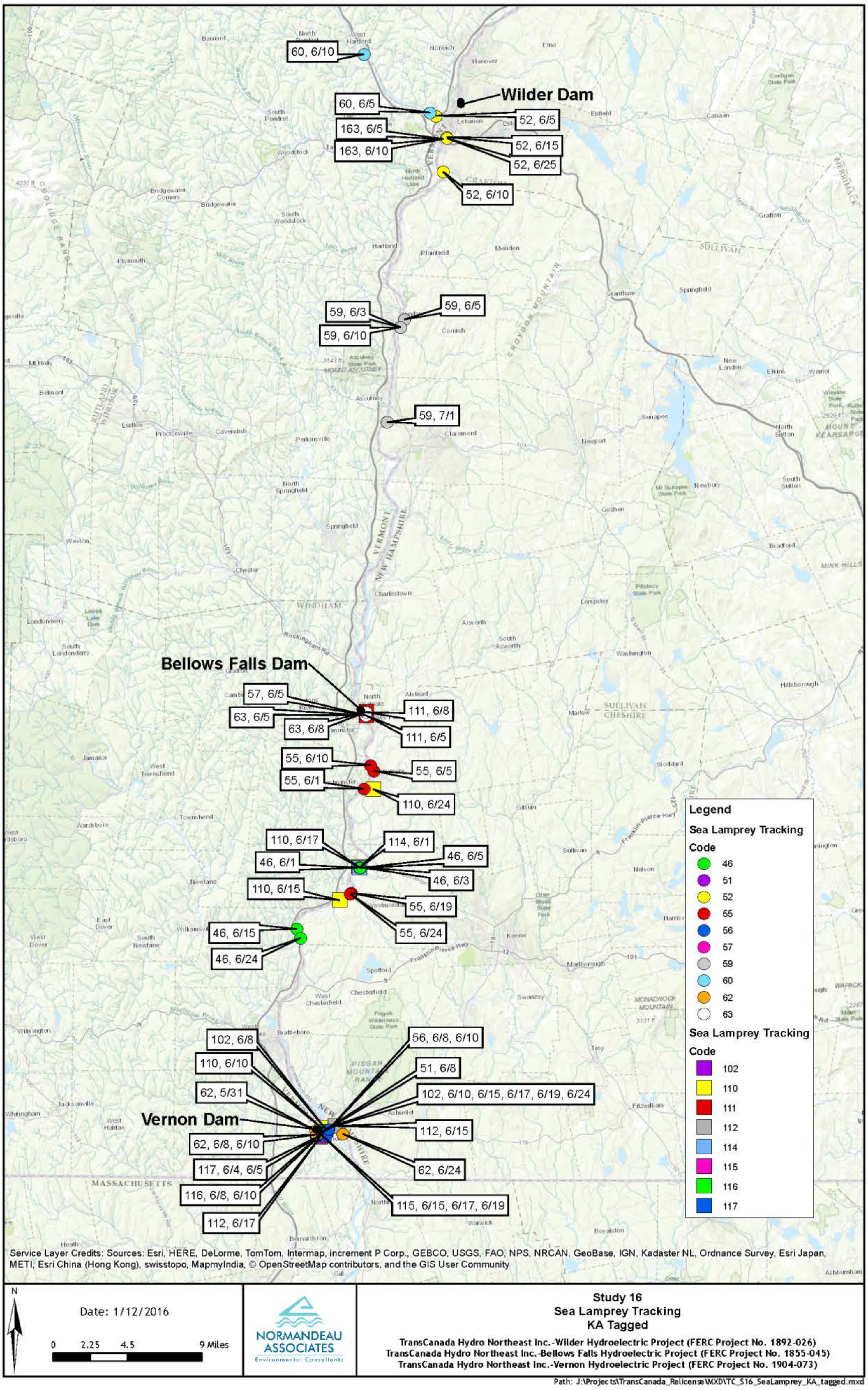


Figure 5.1-8. Sea Lamprey radio telemetry relocations for tagged fish from FirstLight studies that were relocated in the TransCanada study area.

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In several cases, radio telemetry supported the finding that lamprey die soon after spawning. In Partridge Brook (16-VT-018), two tagged lamprey (codes 161 and 167) and a third untagged lamprey were located dead, presumably post-spawn (Figure 5.1-9). In another case (code 176), the bare transmitter was recovered from the riverbank adjacent to Mill Brook (16-VT-016), suggesting predation or scavenging of a post-spawn mortality. Additionally, apparent post-spawned moribund fish were observed drifting downstream in Partridge Brook (16-VT-018) and in the West River upstream of the Interstate 91 Bridge. This suggested that post-spawned fish may drift for several days before dying. Therefore, locations made later in the season in areas of unsuitable habitat and usually downstream of a previous location in suitable habitat were disregarded in interpreting spawning habitat use.

Figure 5.1-9. Post-spawned Sea Lamprey mortality, Partridge Brook, spawning habitat assessment site 16-VT-018.

Telemetry relocations in areas of suitable habitat were considered to be verification of pre-selected sites for spawning habitat assessment, and in a few cases, rationale for altering the site selection (see Section 3.1). Manual tracking locations were reviewed to make those associations considering several factors including potential post-spawn moribund drift as noted above, and locations in deep water (>10 ft) which prevented determination of spawning activity as well as habitat assessment. Many locations in the mainstem were made in water that was too deep and / or turbid to visually verify spawning behavior, an occurrence that was likely exacerbated by conditions of generally high flows during the spawning season. As a result, unless spawning behavior was verified, such as by observation of nest construction or identification of nests, telemetry locations were considered supplemental verification of the use of pre-selected sites and were not used to alter site selection for habitat assessment. In many cases, the verification of nest construction was not able to be made until after the spawning season due to lack of visibility, so were made during summertime lower flow periods. All locations where tagged lamprey were observed exhibiting spawning behavior were included in the habitat assessment and no locations where spawning behavior was observed were excluded from habitat assessment.

Monthly precipitation data collected by TransCanada at the projects (Table 5.1-6) indicates that the month of June was wetter than the 10-year average at Wilder and Bellows Falls and drier than average at Vernon. Numerous rain events resulted in periods of spill throughout the month at all three projects (Figure 5.1-10

Table 5.1-6. Monthly precipitation at Wilder, Bellows Falls, and Vernon: 2015 and 10-year average.

Wilder	**May**	**June**	**July**
2015	2.69	8.05	2.53
2015 YTD	9.05	17.10	19.63
10 Yr Avg.	3.27	3.98	4.98
10 Yr Avg. YTD	13.07	17.05	22.04
% 10YR Avg. MOS	0.82	2.02	0.51
% 10YR Avg. YTD	0.69	1.0	0.89
Bellows Falls	**May**	**June**	**July**
2015	1.87	5.96	2.23
2015 YTD	8.58	14.54	16.77
10 Yr Avg.	3.16	4.35	4.48
10 Yr Avg. YTD	13.11	17.46	21.93
% 10YR Avg. MOS	0.59	1.37	0.50
% 10YR Avg. YTD	0.65	0.83	0.76
VERNON	**May**	**June**	**July**
2015	1.04	3.88	1.93
2015 YTD	8.97	12.85	14.78
10 Yr Avg.	3.68	5.50	4.22
10 Yr Avg. YTD	15.86	21.36	25.58
% 10YR Avg. MOS	0.28	0.71	0.46
% 10YR Avg. YTD	0.57	0.60	0.58

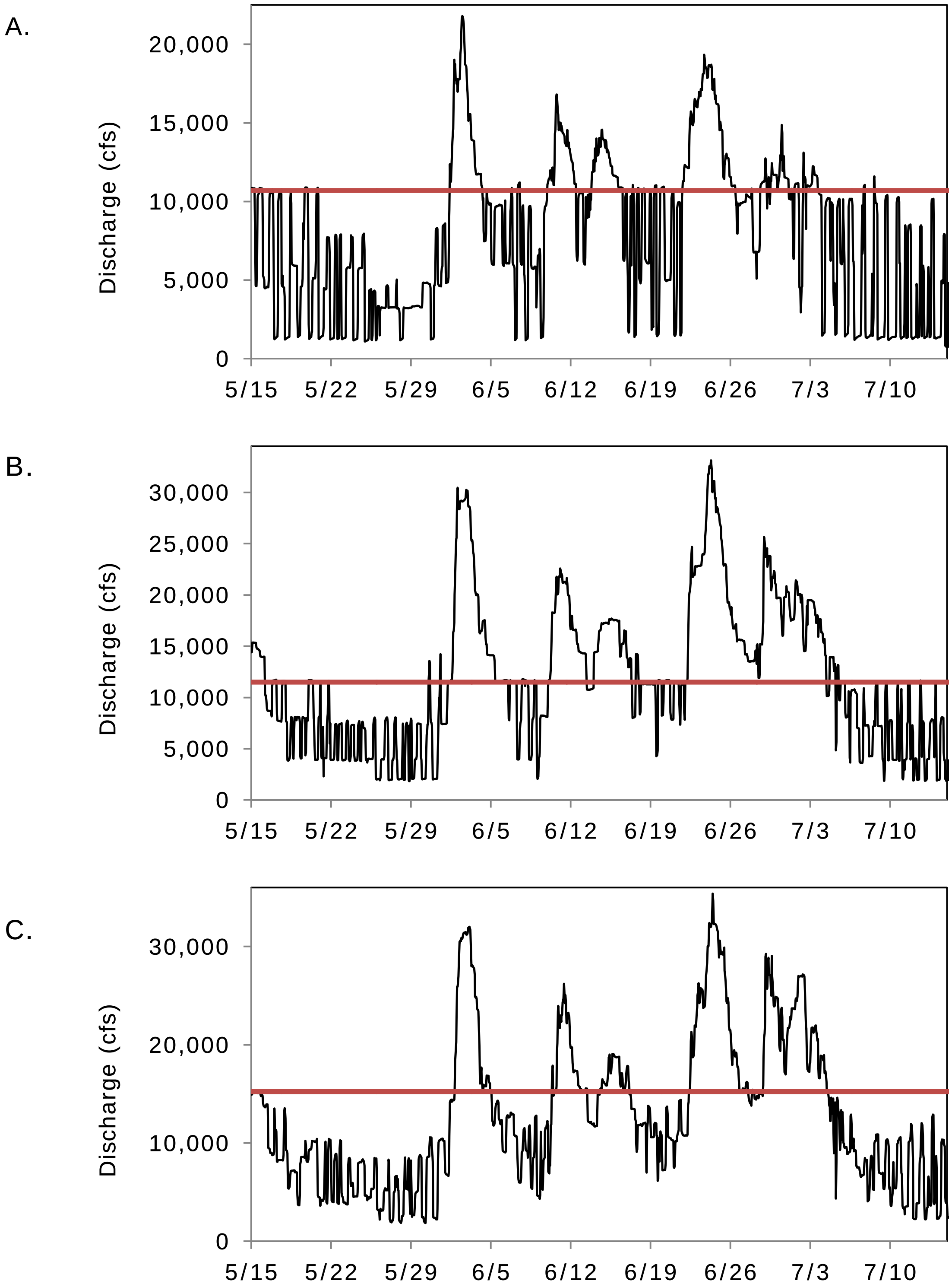

Figure 5.1-10. Hourly average total project discharge for: A. Wilder, B. Bellows Falls, and C. Vernon. The horizontal line indicates full station generating capacity.

5.2 Habitat Assessment

As described in Section 4.2, 23 sites were selected for Sea Lamprey spawning habitat assessment. During the spawning season, assessments consisted of surveys for evidence of spawning activity, including visual or radio telemetry confirmation of the presence of adults and visual survey for nests and spawning activity. Sea Lamprey nests are described as elongated nests of gravel and cobble excavated in riffles that are 25 to 50 cm (0.82 to 1.64 ft) deep. Nests are constructed by both males and females and more than one female may share a nest. Sea lamprey excavate nests by lifting stones with their mouths and using body motions to clear fine sediments (Leim and Scott, 1966; Scott and Scott, 1988 [in Kircheis, 2004]). Before the end of May, not more than 1,000 adult Sea Lamprey were available to the reaches above Vernon Dam. By the beginning of June, when appreciable spawning activity likely was occurring, all three projects were in spill, and spill or high generation discharge conditions persisted through much of the spawning season (see Figure 5.1-10) resulting in limited accessibility of some sites. As a result, 17 sites were revisited during post-spawning low water conditions in August and September to supplement habitat assessment data collected during the spawning season and document nests and their elevations. The remaining six study sites were determined to have been adequately surveyed during the spawning season.

Potential for lamprey spawning was recorded throughout the study area, but not at all sites surveyed. Overall, lamprey were associated with 17 of the 23 (74%) spawning habitat assessment sites via radio telemetry manual tracking. Visual observation of nest building / spawning behavior was made at seven sites (30%), and nests were identified at 16 sites (70% overall, 83% of riverine sites and 54% of impoundment sites). Since visual observations were subject to conditions encountered during the observations, the record of nest presence included the supplemental low-water surveys to provide the most comprehensive evidence of spawning behavior. Observations of spawning activity are summarized in Table 5.2-1.

Only three sites showed no indication of potential spawning activity as evidenced collectively by radio telemetry, visual observation, and/or presence of nests (16-BT-031, 16-VT-040, 16-VT-046); however, spawning activity was not verified at seven sites: two sites in the Wilder riverine reach (16-WL-003, 16-WL-004), two sites in the Bellows Falls impoundment (16-BT-006, 16-BT-031), and three sites in the Vernon impoundment (16-VT-014, 16-VT-040, 16-VT-046). Telemetry locations were made in association with four of those seven sites where spawning activity could not be verified by identification of nests, and those sites were characterized as either having insufficient habitat (16-WL-003) or as having suitable habitat, but no nests identified either during the spawning season or in the post-spawning supplementary assessment (16-WL-004, 16-BT-006, 16-VT-014). Of the three sites with no indication of potential spawning activity, all were characterized as having insufficient spawning habitat (see Section 5.2-1). Two of those sites were tributaries where telemetry or visual observation suggested that lamprey spawned further upstream outside of the project-influenced tributary reach (16-WL-003, 16-VT-040, see Section 5.2.1).

Spawning activity was most concentrated at sites below Vernon dam (sties 16-VL-001, 16-VL-002), and the Black River, a tributary to the Bellows Falls impoundment (16-BT-018). Other concentrations occurred at an island below the Wilder project in the Wilder riverine reach (16-WL-002), on a bar at the mouth of Cobb Brook in the Bellows Falls riverine reach (16-BL-002), and in Partridge Brook, a tributary to the Vernon impoundment (16-VT-018).

Substrate classifications are summarized in Table 5.2-2. Dominant substrate for sites with identified nests ranged from sand to cobble, with gravel being most frequently dominant. Substrate embeddedness ranged from negligible to high, but note that sites recorded as highly embedded were embedded in sand rather than silt. The dominant substrate inside of identified nests ranged from gravel to cobble with gravel most frequently dominant. Embeddedness of substrate inside nests ranged from low to high. As for general substrate characterization, fine sediments were sand rather than silt. One exception was noted where dominant substrate inside of a nest was silt and embeddedness was characterized as very high (BT-003). That site was in a tributary. More suitable habitat was present further upstream in the tributary but outside of the project-influenced area.

Per the RSP, water level loggers were installed at sites where nest caps were installed (N=3). For most of the remaining sites, level loggers were deployed either on site or nearby in the course of study 14/15, and data collected from those loggers (for N=19 sites) were used to supplement the analysis. The period of record for level loggers varied among sites, but generally encompassed the Sea Lamprey spawning season, defined here as May 15 – July 15, 2015. Based on upstream passage (see Figure 5.1-1), water temperatures, and radio telemetry locations of tagged fish, spawning likely occurred throughout much of June. Eggs hatch within two weeks (Piavis, 1972) and ammocoetes usually quickly emerge from the nest and move downstream into lower velocity habitats where they burrow into fine substrates (Wagner and Stauffer, 1962). Therefore, emergence during the 2015 Sea Lamprey spawning season was expected to have occurred between mid-June and mid-July. The inclusion of a two-month period was intended to encompass the entire seasonal spawning and gestation and is highly conservative for analysis of project effects on spawning sites. At any one site, spawning, gestation, and emergence would occur over a shorter period.

Table 5.2-3 summarizes the number, and mean duration of occurrences of Sea Lamprey nest elevations by site during normal project operations from May 15 – July 15 for 2015 level logger data and for operations model output for five years representing a range of hydrologic conditions. Note that nest locations recorded during 2015 may not be representative of nest locations in years with different conditions. For example, habitat that is inundated and therefore available for spawning during high flow / spilling conditions may not be inundated during a drier year and nests would not be constructed at those elevations. In 2015, the frequency and duration of nest exposure was greatest at Wilder riverine reach sites, particularly those closest to the dam where WSE fluctuations were the greatest. For example, the highest elevation nest at site 16-WL-001 experienced 53 exposure events with an average duration of 11 hours during periods of normal project operations. However, some spawning habitat remained inundated at that site as indicated by no exposure events occurring at the lowest nest elevation recorded. Those observations were similar to the model data for a relatively wetter year (1989) while drier model years yielded slightly more occurrences of exposure. In all model years, however, some habitat always remained inundated. Nests at Wilder riverine sites further downstream generally experienced fewer occurrences of exposure than those close to the dam and all had nest elevations that were never exposed. Water level logger data for one site, 16-WL-005 suggested no to relatively few exposure events while model data suggested frequent exposure. Sites in the Bellows Falls riverine reach experienced no exposure in analysis of either 2015 water level logger data or model data across all years (16-BL-003) or had some habitat that was always inundated or relatively infrequently exposed. Sites in the Vernon riverine reach had habitat that was always inundated in 2015 and in all model years, and shallower habitat that was infrequently exposed, depending on the model year.

Impoundment sites experienced varying levels of exposure. For example, site 16-BT-013 had two nests, and 2015 data indicated that they were never exposed while model data suggested that the deeper habitat was never exposed, but the shallower habitat was frequently exposed. Nest elevations are presented graphically with time series plots of WSE and water temperature in Appendix C (filed separately in Excel format). Water surface elevations, rates of WSE change, and exposure occurrence and durations for each nest elevation based on 2015 water level logger data are included in Appendix E (filed separately in Excel format). Predicted WSE, rates of WSE change, and exposure occurrence and duration for each nest elevation recorded in 2015 and based on model output for five different years are included in Appendix F (filed separately in Excel format).

Table 5.2-1. Summary of potential and verified Sea Lamprey spawning activity observed by study site.

Habitat Type	Reach	Site ID	Potential Activity	Verified Activity[a]		Number of Visits[b]	Date Range
			Telemetry	Visual	Nests		
	Wilder Riverine Reach						
Riverine	WL Sub 1	16-WL-001	Y	N	Y	4	6/5-8/12
Riverine	WL Sub 1	16-WL-002	N	N	Y	3	6/5-8/12
Riverine/Tributary	WL Sub 2	16-WL-003	Y	N	N	3	6/18-8/12
Riverine	WL Sub 2	16-WL-004	Y	N	N	4	6/5-8/12
Riverine	WL Sub 3	16-WL-005	N	N	Y	3	6/5-8/13
Riverine	WL Sub 3	16-WL-006	Y	N	Y	2	6/18-8/19
Riverine	WL Sub 3	16-WL-007	Y	N	Y	3	6/5-8/19
	Percent of sites		**71%**	**0%**	**71%**		
	Bellows Falls impoundment						
Impoundment	BT	16-BT-004	Y	N	Y	3	6/17-8/18
Impoundment	BT	16-BT-003	Y	N	Y	3	6/8-8/18
Impoundment	BT	16-BT-006	Y	N	N	6	6/8-8/19
Impoundment	BT	16-BT-013	Y	Y	Y	6	6/3-9/1
Impoundment/Tributary	BT	16-BT-018	Y	Y	Y	21	6/3-7/15
Impoundment	BT	16-BT-031	N	N	N	5	6/3-8/12
	Percent of sites		**83%**	**33%**	**67%**		
	Bellows Falls Riverine Reach						
Riverine	BL	16-BL-001	N	N	Y	3	6/12-9/1
Riverine	BL	16-BL-002	Y	N	Y	4	6/10-9/1
Riverine	BL	16-BL-003	Y	Y	Y	3	6/12-9/1
	Percent of sites		**67%**	**33%**	**100%**		
	Vernon Impoundment						
Impoundment	VT	16-VT-014	Y	N	N	9	6/5-6/26
Impoundment	VT	16-VT-016	Y	Y	Y	21	6/5-7/27
Impoundment/Tributary	VT	16-VT-018	Y	Y	Y	26	6/10-7/27
Impoundment/Tributary	VT	16-VT-040	N	N	N	8	6/8-6/26
Impoundment Tributary	VT	16-VT-046	N	N	N	9	6/8-6/29
	Percent of Sites		**60%**	**40%**	**40%**		

Habitat Type	Reach	Site ID	Potential Activity	Verified Activity[a]		Number of Visits[b]	Date Range
			Telemetry	Visual	Nests		
	Vernon Riverine						
Riverine	VL	16-VL-001	Y	Y	Y	9	6/8-8/17
Riverine	VL	16-VL-002	Y	Y	Y	9	6/8-8/17
	Percent of sites		**100%**	**100%**	**100%**		
	Overall						
	Percent of sites		**74%**	**30%**	**70%**		
	By Habitat Type						
Riverine	**Percent of sites**		**75%**	**25%**	**83%**		
Impoundment	**Percent of sites**		**73%**	**36%**	**55%**		

a. Radio telemetry locations in close proximity to site were considered potential spawning activity, but visual observation of nest building or other spawning behavior (Visual), and / or observation of constructed nests (Nests) including those observed in post-spawning season low-water surveys were required for verification of spawning activity.

b. The number of visits per site included nest cap checks (sites 16-BT-018, 16-VT-016, 16-VT-018).

Table 5.2-2. Summary of dominant substrate and substrate embeddedness inside and outside of nests.

Site ID	Nest(N)	Inside Nest		Site	
		Dominant Substrate[a]	Embeddedness[b]	Dominant Substrate[a]	Embeddedness[b]
16-WL-001	3	gravel-cobble	negligible-high	gravel-cobble	moderate
16-WL-002	5	gravel-cobble	negligible-high	gravel-cobble	moderate
16-WL-003	0	NA	NA	sand-cobble	low
16-WL-004	0	NA	NA	gravel-cobble	moderate
16-WL-005	3	gravel-cobble	negligible-high	gravel	negligible-low
16-WL-006	3	gravel-cobble	negligible-high	gravel	low-moderate
16-WL-007	4	gravel-cobble	negligible-high	gravel	negligible-low
16-BT-004	1	gravel	high	gravel	moderate
16-BT-003	1	silt	very high	gravel	high
16-BT-006	0	NA	NA	gravel	low-moderate
16-BT-013	2	gravel	low	gravel-cobble	low-moderate
16-BT-018	10	sand-gravel	negligible-high	sand-cobble	negligible-high
16-BT-031	0	NA	NA	gravel	low-moderate
16-BL-001	6	gravel-cobble	low-moderate	gravel-cobble	negligible-moderate
16-BL-002	3	gravel	low	gravel-cobble	negligible-low
16-BL-003	4	gravel	negligible-low	gravel-cobble	low-high
16-VT-014	0	NA	NA	gravel	moderate
16-VT-016	4	sand-gravel	negligible-moderate	cobble	negligible-low
16-VT-018	4	sand-gravel	negligible-low	gravel-cobble	negligible-low
16-VT-040	0	NA	NA	gravel	high
16-VT-046	0	NA	NA	gravel	high
16-VL-001	6	gravel-cobble	negligible-high	gravel	negligible-high
16-VL-002	11[c]	gravel-cobble	negligible-high	gravel	negligible-high

a. Substrate size classifications: sand <3 mm, gravel = 3-64 mm, cobble = 64-254 mm, boulder >254 mm.

b. Substrate embeddedness classifications (embeddedness of coarse substrates in fine substrates including sand where dominant substrate is more coarse): negligible = <5%, low = 5-25%, moderate = 25-50%, high = 50-75%, very high =>75%.

c. Includes clusters with multiple nests in areas <100 ft^2. At least 28 individual nests were identified.

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Table 5.2-3. Number and mean duration (hours) of Sea Lamprey nest exposure events[a] during periods of normal project operations over two months (May 15 - July 15)[b] by site and nest elevation (in increasing order / decreasing depth) for 2015 level logger observations[c], and for operations model output for five model years[d].

					← Drier						Wetter →			
		2015 Level Logger Observations			Model Year 1992		Model Year 1994		Model Year 2007		Model Year 1989		Model Year 1990	
Site	Nest[e]	Logger Site	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)
16-WL-001	1	15-WR-002	0	.	0	.	0	.	0	.	0	.	0	.
16-WL-001	2	15-WR-002	48	6.9	85	11.6	64	9.4	69	11.0	59	9.5	71	7.1
16-WL-001	3	15-WR-002	53	11.0	80	12.9	67	9.7	77	10.8	64	9.6	72	7.9
16-WL-002	1	15-WR-002 (proxy, +0.6 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-WL-002	2	15-WR-002 (proxy, +0.6 mi)	33	6.8	84	11.5	66	9.0	68	11.1	54	10.1	69	7.2
16-WL-002	3	15-WR-002 (proxy, +0.6 mi)	36	6.6	84	11.5	66	9.0	68	11.1	54	10.1	69	7.2
16-WL-002	4	15-WR-002 (proxy, +0.6 mi)	36	6.6	84	11.5	65	9.2	68	11.2	54	10.1	70	7.1
16-WL-002	5	15-WR-002 (proxy, +0.6 mi)	49	8.2	85	11.9	64	9.5	72	10.9	59	9.7	71	7.2
16-WL-003	0	insufficient habitat												
16-WL-004	0	15-WI-003	no nests observed											
16-WL-005	1	15-WI-005	0	.	45	14.8	41	10.3	32	15.9	30	11.2	30	7.7
16-WL-005	2	15-WI-005	0	.	55	14.2	47	10.5	42	14.5	41	10.5	40	8.6
16-WL-005	3	15-WI-005	19	7.4	62	16.8	60	11.0	60	13.8	51	11.4	58	9.1
16-WL-006	1	15-WI-006	0	.	0	.	0	.	0	.	0	.	0	.
16-WL-006	2	15-WI-006	0	.	16	9.4	17	5.0	6	11.5	0	.	3	7.7
16-WL-006	3	15-WI-006	0	.	30	13.3	26	8.0	20	13.3	8	8.9	10	7.0
16-WL-007	1	15-WI-006 (proxy, +0.7 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-WL-007	2	15-WI-006 (proxy, +0.7 mi)	0	.	27	10.5	22	6.1	11	13.0	0	.	8	6.1
16-WL-007	3	15-WI-006 (proxy, +0.7 mi)	0	.	29	15.0	27	9.3	21	16.3	13	12.3	17	6.7
16-WL-007	4	15-WI-006 (proxy, +0.7 mi)	0	.	46	14.6	41	10.3	34	15.1	30	11.1	33	7.6
16-BT-004	1	14-BT-002 (proxy, -2.5 mi)	17	4.1	47	13.9	44	9.2	35	14.5	28	11.4	31	6.6
16-BT-003	1	14-BT-002	0	.	77	35.0	19	12.0	60	26.0	40	15.0	5	5.0
16-BT-006	0	16-BT-006	no nests observed											
16-BT-013	1	14-BT-013	0	.	0	.	0	.	0	.	0	.	0	.
16-BT-013	2	14-BT-013	0	.	43	11.0	37	11.0	35	13.2	30	9.6	31	9.7
16-BT-018	1	16-BT-018	0	.	tributary site, no model data									
16-BT-018	2	16-BT-018	0	.										
16-BT-018	3	16-BT-018	0	.										
16-BT-018	4	16-BT-018	0	.										
16-BT-018	5	16-BT-018	0	.										
16-BT-018	6	16-BT-018	0	.										
16-BT-018	7	16-BT-018	0	.										

					← Drier						Wetter		→	
		2015 Level Logger Observations			Model Year 1992		Model Year 1994		Model Year 2007		Model Year 1989		Model Year 1990	
Site	Nest[e]	Logger Site	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)
16-BT-018	8	16-BT-018	0	.										
16-BT-018	9	16-BT-018	0	.										
16-BT-018	10	16-BT-018	0	.										
16-BT-031	0	insufficient habitat												
16-BL-001	1	15-BL-002 (proxy, -1.2 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-BL-001	2	15-BL-002 (proxy, -1.2 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-BL-001	3	15-BL-002 (proxy, -1.2 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-BL-001	4	15-BL-002 (proxy, -1.2 mi)	0	.	6	1.3	0	.	0	.	0	.	0	.
16-BL-001	5	15-BL-002 (proxy, -1.2 mi)	0	.	36	5.3	22	1.8	28	4.0	19	2.9	0	.
16-BL-001	6	15-BL-002 (proxy, -1.2 mi)	7	7.0	65	12.3	48	9.5	42	13.0	35	9.7	0	.
16-BL-002	1	15-BL-002	0	.	5	11.6	1	4.0	4	5.3	1	3.0	0	.
16-BL-002	2	15-BL-002	0	.	13	7.9	1	6.0	9	7.7	3	5.3	0	.
16-BL-002	3	15-BL-002	0	.	13	7.9	1	6.0	9	7.7	3	5.3	0	.
16-BL-003	1	15-BL-003 (proxy, +1.1 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-BL-003	2	15-BL-003 (proxy, +1.1 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-BL-003	3	15-BL-003 (proxy, +1.1 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-BL-003	4	15-BL-003 (proxy, +1.1 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-VT-014	0	14-VT-014	no nests observed											
16-VT-016	1	16-VT-016	0	.	0	.	0	.	0	.	0	.	0	.
16-VT-016	2	16-VT-016	0	.	45	18.4	62	9.4	42	15.9	34	12.2	72	5.0
16-VT-016	3	16-VT-016	0	.	45	18.4	62	9.4	42	15.9	34	12.2	72	5.0
16-VT-016	4	16-VT-016	0	.	45	18.4	62	9.4	42	15.9	34	12.2	72	5.0
16-VT-018	1	16-VT-018	0	.	tributary site, no model data									
16-VT-018	2	16-VT-018	0	.										
16-VT-018	3	16-VT-018	0	.										
16-VT-018	4	16-VT-018	0	.										
16-VT-040	0	insufficient habitat												
16-VT-046	0	insufficient habitat												
16-VL-01	1	15-VI-002 (proxy, -0.6 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-01	2	15-VI-002 (proxy, -0.6 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-01	3	15-VI-002 (proxy, -0.6 mi)	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-01	4	15-VI-002 (proxy, -0.6 mi)	11	7.0	51	5.5	40	3.6	39	4.9	27	4.4	28	2.8
16-VL-01	5	15-VI-002 (proxy, -0.6 mi)	10	7.6	51	5.5	40	3.6	39	4.9	27	4.4	28	2.7
16-VL-01	6	15-VI-002 (proxy, -0.6 mi)	18	9.2	120	5.3	94	4.0	87	5.0	58	4.7	79	3.4

					← Drier						Wetter →			
		2015 Level Logger Observations			Model Year 1992		Model Year 1994		Model Year 2007		Model Year 1989		Model Year 1990	
Site	Nest[e]	Logger Site	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)	N Events	Mean Duration (hr)
16-VL-02	1	15-VI-002	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-02	2	15-VI-002	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-02	3	15-VI-002	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-02	4	15-VI-002	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-02	5	15-VI-002	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-02	6	15-VI-002	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-02	7	15-VI-002	0	.	0	.	0	.	0	.	0	.	0	.
16-VL-02	8	15-VI-002	1	5.5	9	4.2	8	3.6	7	6.3	4	4.3	3	4.0
16-VL-02	9	15-VI-002	7	7.8	21	6.7	11	4.0	18	5.4	9	4.3	4	3.5
16-VL-02	10	15-VI-002	9	6.5	30	6.1	22	4.2	25	5.7	12	4.8	7	3.4
16-VL-02	17	15-VI-002	9	7.0	43	5.9	32	4.0	34	5.1	23	4.8	20	3.5

a. An exposure event is defined as an uninterrupted period that observed (2015) or modeled (1992, 1994, 1989, 2007, 1990) water surface elevation was less than nest elevation. Exposure events are based on nest elevations observed in 2015, which may not be representative of nest elevations in different years.

b. A two-month period was selected to encompass the entire spawning and gestation season, but is a highly conservative period for analysis of project effects.

c. See Appendix C for graphical representation of nest elevations; See Appendix E for summaries of logged water surface elevation range and rate of change for each site and occurrence and duration of exposure by nest elevation for each site.

d. See Appendix F for summaries of modeled water surface elevation range and rate of change for each site and occurrence and duration of exposure by nest elevation for each site.

e. Note that not all identified nests were included in the analysis because elevations were redundant. For example, at least 28 individual nests were identified at site 16-VL-02, but only 11 nest elevations are included for analysis.

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5.2.1 Summary of Spawning Habitat

The following sections contain brief narratives of spawning habitat assessment by site. Appendix C contains water level logger data and nest elevation figures for each site as described below. The period of record for water level loggers varied among sites, but generally encompassed the Sea Lamprey spawning season, defined here as May 15 – July 15, 2015. Appendix E contains summarized WSE data collected from water level loggers during 2015, and Appendix F contains summarized modeled WSE data including: range and mean WSE, range and mean change of WSE, and range and mean rate of change of WSE for all sites with suitable habitat; and summary of occurrence of exposure, and mean and range of duration of exposure for all recorded nest elevations. Appendix G contains maps of spawning habitat assessment sites with nest locations and meso-habitat type (riverine habitats) or substrate type (impoundment habitats).

16-WL-001

Site WL-001 was associated with an island approximately 0.2 miles downstream of Wilder dam. No nests were observed during the spawning season, largely due to flow conditions, but in the late summer supplementary low-water survey, three nests were identified around the head of the island in an area that was classified as moderately embedded gravel-cobble substrate (Table 5.2-2). Water level logger recorded elevations indicated that the nests were exposed from 0 – 38% of the time (by ascending nest elevation), and 0 – 55% of normal operations periods for the logger period of record, May 15 – July 14, (Appendix C, Figure C-1, Appendix E). Operations model output indicated potential exposure from 0 – 72% of operational control periods, depending on nest elevation and water year conditions (Appendix F). The lowest nest elevation was never exposed (Table 5.2-3).

This was a dynamic site with frequent exposure of some habitat, but also with continuously inundated habitat. Additionally, suitable substrate was evident in deeper water in the channel adjacent to the island, though in areas that were too deep to survey. Therefore, despite notable potential project effects on some habitat, at higher elevations suitable deeper habitat exists that would remain watered.

16-WL-002

Site WL-002 (Figure 5.2-1) was associated with an island approximately 0.8 miles downstream of Wilder dam No nests were observed during the spawning season, largely due to flow conditions, but in the supplementary low-water survey, five nests were identified in an area that was classified as moderately embedded gravel-cobble substrate (Table 5.2-2). Water level logger recorded elevations indicated that the nests were exposed from 0 – 25% of the time (by ascending nest elevation), and 0 – 36% of normal operations periods for the logger period of record, June 5 – July 14 (Appendix C, Figure C-2, Appendix E). Operations model output indicated potential exposure from 0 – 69% of normal operations periods, depending on nest elevation and water year conditions (Appendix F). The lowest observed nest elevation was never exposed (Table 5.2-3).

This was a dynamic site with frequent exposure of some habitat, but also with continuously inundated habitat. Additionally, suitable substrate was evident in deeper water in the channel adjacent to the island, though in areas that were too deep to survey. Therefore, despite notable potential project effects of some habitat, at higher elevations, suitable deeper habitat exists that would remain watered.

Figure 5.2-1. Sea Lamprey (site 16-WL-002) exposed nest in gravel-cobble substrate.

16-WL-003

Site WL-003 was associated with the mouth of the Mascoma River, approximately 2.5 miles downstream of Wilder dam. The bar at the tributary mouth was composed of fine sediments and contained no evident suitable habitat (Figure 5.2-2), though telemetry locations of tagged fish suggested activity in the area, and habitat in deeper water of the main channel that could not be observed may have been used. A limited bar of suitable habitat ranging from sand to cobble with low embeddedness in sand (Table 5.2-2) occurred approximately 0.25 miles upstream of the tributary mouth. No nests were identified in that area, and within about 0.4 miles from its mouth, the tributary transitioned to a higher gradient rapids characterized by boulder substrate that did not appear to be suitable habitat. A dead, presumably post-spawned lamprey was located just downstream of this gradient and near the upstream extent of the project-influenced area on June 18. It was assumed that the fish had spawned further upstream since no nests were evident. Therefore, this site was determined to be unsuitable for Sea Lamprey spawning within the project-influenced tributary reach.

Figure 5.2-2. Sea Lamprey spawning survey site with poor habitat composed of fine substrate (16-WL-003).

16-WL-004

Site WL-004 was associated with the head of Burnaps Island, approximately 6 miles downstream of Wilder dam. Despite suitable habitat of moderately embedded gravel-cobble substrate (Table 5.2-2) around the upstream half of the island, particularly to the eastern side and in the eastern channel, with more dominant cobble in the western channel, no lamprey nests were identified either during the spawning season or in the supplementary low-water survey. Water level logger data are presented in Appendix C (Figure C-3). Observed WSE analyses were summarized in Appendix E and modeled WSE analyses were summarized in Appendix F.

This site is highly dynamic, though less than other sites closer to Wilder. Suitable spawning habitat exists, but no nests were identified to verify spawning activity. Nests may have been constructed in deeper water that was not surveyed. It is possible that habitat in deeper water was available and used for spawning or would be available under different conditions experienced year to year.

16-WL-005

Site WL-005 was associated with Hart Island, approximately 12 miles downstream of Wilder dam, and 2.5 miles downstream of Sumner Falls. No nests were observed during the spawning season, but in the supplementary low-water survey, three nests were identified in habitat that was classified as negligible to low embedded gravel substrate (Table 5.2-2). Water level logger recorded elevations indicated that the nests were exposed from 0–16% of the time (by ascending nest elevation), and 0 – 34% of normal operations periods for the logger period of record, June 5 – July 14 (Appendix C, Figure C-4, Appendix E). Operations model output indicated potential exposure from 21 – 74% of normal operations periods, depending on nest elevation and water year conditions (Appendix F). The lowest observed nest elevation was never exposed based on 2015 WSE observations, but model output predicted exposure in 30 – 45 events with mean duration of 7.7 – 14.8 h, depending on model year (Table 5.2-3).

This site had a less dynamic WSE range relative to more upstream sites in the Wilder riverine reach. Frequent exposure of all recorded nest elevations was predicted in operations model output, but not observed in 2015 WSE observations. It is also possible that habitat in deeper water would be available under different conditions experienced year to year.

16-WL-006

Site WL-006 was associated with a gravel bar / shoal area approximately 16 miles downstream of Wilder dam and 0.1 miles downstream of the Cornish-Windsor Covered Bridge (Figure 5.2-3). No nests were observed during the spawning season, but in the supplementary low-water survey, three nests were identified in habitat that was classified as low to moderately embedded gravel substrate (Table 5.2-2). Limited level logger data were available; however, those indicated 0.0% exposure during the logger period of record, May 27 – June 5 (Appendix C, Figure C-5, Appendix E). Operations model output indicated potential exposure from 0 – 23% of the normal operations periods, depending on nest elevation and water year conditions (Appendix F). The lowest observed nest elevation was never exposed, and shallower elevations were infrequently exposed, depending on water year (Table 5.2-3). This site had a less dynamic WSE range relative to more upstream sites in the Wilder riverine reach. Some habitat was observed to be and predicted by the operations model to be continually watered while higher elevation (shallower) habitat may experience relatively infrequent exposure except in lower flow years. It is also possible that habitat in deeper water would be available under different conditions experienced year to year.

Figure 5.2-3. Sea Lamprey spawning survey site with submerged gravel bar / shoal habitat (16-WL-006).

16-WL-007

Site WL-007 was associated with Chase Island, approximately 16.5 miles downstream of Wilder dam. The upstream quarter of the island head was described as suitable habitat with negligible to low embedded gravel substrate (Table 5.2-2) and swift currents. Deeper channel habitat on both sides of the upper island also supported suitable habitat, but it was too deep to survey. No nests were observed during the spawning season, but in the supplementary low-water survey, four nests were identified. Limited level logger data were available from a proxy level logger located 0.7 mi upstream. Those indicated 0.0% exposure of all nest elevations during the logger period of record, May 27 – June 5 (Appendix C, Figure C-6, Appendix E). Because of the level logger location, WSE could be biased to indicate less exposure. Operations model output indicated potential exposure from 0 – 43% of normal operations periods, depending on nest elevation and water year conditions (Appendix F). The lowest observed nest elevation was predicted to be continuously submerged across all water years (Table 5.2-3).

This site was the downstream most of the Wilder riverine reach site and somewhat transitional to Bellows Falls impoundment habitat. Some observed habitat was continuously inundated and suitable habitat was also evident in deeper water that was not surveyed.

16-BT-004

Site BT-004 was associated with a large bar / shoal area near Balloch, New Hampshire, 18.5 miles downstream of Wilder dam. The dominant substrate was characterized as moderately embedded gravel (Table 5.2-2). No nests were observed during the spawning season, but in the supplementary low-water survey, one nest was identified. Water level logger recorded elevations indicated that the nest was exposed 8% of the time, and 13% of normal operations l periods, in brief intervals during the logger period of record, May 26 – July 13 (Appendix C, Figure C-7, Appendix E). Note that the level logger was approximately 2.5 miles downstream of the site, so WSE could be biased to indicate greater exposure than actual. Operations model output indicated potential exposure from 14 - 42% of normal operations periods, depending on water year conditions (Appendix F). The recorded nest elevation was dewatered in 17 events with a mean duration of 4.1h (Table 5.2-3).

Based on modeled hydrologies, habitat at this site experienced project-related exposure; however, only one nest elevation was identified. Suitable substrate was also available in deeper water that likely remains continuously inundated.

16-BT-003

Site BT-003 was associated with a bar at the mouth of the Sugar River, 21 miles downstream of Wilder dam. The dominant substrate was characterized as gravel that was highly embedded in sand (Table 5.2-2). No nests were observed during the spawning season, but in the supplementary low-water survey, one nest was identified. Water level logger recorded elevations indicated that the nest was exposed 0% of the time for the logger period of record, May 26 – July 13 (Appendix

C, Figure C-8, Appendix E). Operations model output indicated potential exposure from 0 – 5% during normal operations periods, depending on water year conditions (Appendix F). The recorded nest elevation was not exposed in 2015 WSE observations, but was exposed in 5 to 77 modeled events with mean durations of 5 – 35 hours (Table 5.2-3).

Model output suggested that the identified nest elevation may be impacted by project effects to varying degrees depending on water year. Only one nest was identified, however, and it is possible that habitat in deeper water was available and used for spawning or would be available under different conditions experienced year to year.

16-BT-006

Site BT-006 was associated with Jarvis Island, 24.5 miles downstream of Wilder dam. The dominant substrate was characterized as low to moderately embedded gravel (Table 5.2-2), but in a relatively small area at the island head with sand as dominant substrate in much of the surrounding area. No lamprey nests were identified at this site during the spawning season or in the supplemental assessment. Manual telemetry locations indicated possible use of habitat in 15.5 feet of water adjacent to the island. Observed WSE analyses for the level logger period of record, May 26 – July 12 were summarized in Appendix E and modeled WSE analyses were summarized in appendix F.

Suitable habitat was available at this site, though no nests were identified. Additionally, suitable habitat was available in deeper water that was not surveyed. Radio telemetry locations suggested that deeper habitat was potentially used by lamprey, though that was not confirmed.

16-BT-013

Site BT-013 was associated with a bar just upstream of the mouth of the Little Sugar River, 29 miles downstream of Wilder dam. Confirmation of nest building and spawning activity at this site was made by visual observation of spawners building / tending a nest on June 17 in a depth of 3.3 ft. The dominant substrate was characterized as low to moderately embedded gravel-cobble (Table 5.2-2) on a bar that dropped off to relatively deep water toward the main river channel. Two nests were identified; the nest with visual confirmation was too deep to deploy a nest cap during the spawning season. Water level logger recorded elevations indicated that the nests were exposed 0% of the time for the logger period of record, May 28 – July 13, and nests were sometimes submerged by more than 6 feet (Appendix C, Figure C-10, Appendix E). Operations model output indicated potential nest exposure from 0 – 26% of normal operations periods, depending on nest elevation and water year conditions (Appendix F). The lowest observed nest elevation was never exposed across all model years (Table 5.2-3).

This site was adjacent to a tributary, but was located in the mainstem. Some habitat with verified spawning activity was continuously submerged both in 2015 observations and in all model years.

16-BT-018

Site BT-018 was within the Black River, approximately 33 miles downstream of Wilder dam. No suitable habitat was evident near the mouth of the Black River, but an area of good habitat was located approximately 1.5 miles upstream near the head of the project-influenced area, and just below a natural falls. This site was a highly active spawning area with ten nests identified. Confirmation of nest building and spawning activity was made by multiple visual observations of nest construction or tending (Figure 5.2-4), including June 15 in a depth of 1.1 feet, June 19 in a depth of 0.8 feet, and June 20 in a depth of 0.5 feet. A nest cap was also set at this site (see Section 5.3). The dominant substrate of the nest areas were characterized as ranging from sand to cobble with negligible to high embeddedness (Table 5.2-2). Although falling within the project-influenced area, WSE and turbidity were largely controlled by discharge from upstream in the tributary, particularly in response to rain events. Water level logger recorded elevations indicated that no nests were exposed for the logger period of record, June 15 – July 15 (Appendix C, Figure C-11, Appendix E). Because of the distance upstream in the tributary, the hydraulic and operations models were not applicable for this site.

The site was one of the most active spawning areas observed in this study, and no nests experienced exposure based on level logger data (Table 5.2-3). Because of the distance upstream in the tributary, project effects are unlikely.

Figure 5.2-4. Sea Lamprey engaged in nest construction in the Black River, Vermont (16-BT-018).

16-BT-031

Site BT-031 was within the Williams River, approximately 40 miles downstream of Wilder dam. No suitable habitat was evident near the mouth of the Williams River, and little habitat was evident within the project-influenced area. A small area of potentially suitable habitat was located approximately 1 mile upstream and 0.1 mile above the Interstate 91 bridge. That area was investigated and characterized with a dominant substrate of low to moderately embedded gravel (Table 5.2-2), but was very small and appeared to be subject to continuous exposure during low tributary flow periods. One possible nest was identified in the supplemental low-water surveys, but consensus of identification couldn't be reached and it was therefore disregarded. Due to the lack of suitable habitat downstream of the I-91 bridge and the relatively small area of marginal habitat in an area that appeared to be above the project-influenced area, this site was determined to be unsuitable for Sea Lamprey spawning.

16-BL-001

Site BL-001 was a gravel-cobble bar at the mouth of Cobb Brook, approximately 2.6 miles downstream of the Bellows Falls tailrace. The dominant substrate was characterized as negligible to moderately embedded gravel to cobble (Table 5.2-2). No nests were observed during the spawning season, but six nests were identified during low-flow surveys. Water level logger recorded elevations indicated that five of the nest elevations were not exposed and the sixth was exposed only 6% of the time, and 9% of normal operations periods for the logger period of record, May 29 – July 7 (Appendix C, Figure C-13, Appendix E). Note that a proxy level logger site, 1.2 miles downstream was used. Since the site was downstream, it was assumed that results would be biased toward more periods of exposure than actual. Operations model output indicated that most of the habitat was predicted to be continuously submerged with potential exposure from 0 – 53% of the time, depending on nest elevation and water year conditions (Appendix F). The highest elevation nest recorded was predicted to experience 65 exposure events averaging 12.3 h during a dry year, but to be continuously inundated during a wet year (Table 5.2-3). This riverine site was highly dynamic; however, a substantial proportion of the identified habitat was continuously submerged.

16-BL-002

Site BL-002 was a large gravel-cobble bar/island approximately 3.8 miles downstream of the Bellows Falls tailrace, and just below the New Hampshire Route 123 Bridge (Westminster Bridge). The dominant substrate was characterized as negligible to low embedded gravel to cobble (Table 5.2-2). Three nests were identified at similar elevations Water level logger recorded elevations indicated that the nests were exposed 0% of the time for the logger period of record, May 29 – July 7 (Appendix C, Figure C-14, Appendix E). Operations model output indicated potential exposure from 0 – 4% of normal operations periods, depending on water year conditions (Appendix F). In the driest model year, the shallowest nest elevation was predicted to experience relatively few (13) exposure events with an average duration of 8 hours (Table 5.2-3).

A substantial amount of suitable habitat was available at this site, and level logger data indicate that it was continuously submerged during 2015, while modeled hydrologies suggest generally low probability of exposure and mostly of relatively brief durations. It is also possible that habitat in deeper water was available and used for spawning or would be available under different conditions experienced year to year.

16-BL-003

Site BL-003 was associated with Dunshee Island, approximately 5 miles downstream of the Bellows Falls tailrace. Spawning activity was confirmed at this site by visual observation of two lamprey constructing/tending a nest in a depth of 2.7 ft. The dominant substrate was characterized as low to highly embedded gravel to cobble (Table 5.2-2). Four nests were identified in the supplemental low-flow survey. Water level logger recorded elevations indicated that the nests were exposed 0.0% of the time for the logger period of record, May 29 – July 7 (Appendix C, Figure C-15, Appendix E). Operations model output indicated no potential exposure during normal operations periods in any modeled water year (Appendix F, Table 5.2-3).

As with the other two Bellows Falls riverine reach sites, spawning activity was verified, and all recorded nest elevations were continually submerged.

16-VT-014

Site VT-014 was a gravel bar at the mouth of Aldrick Brook, approximately 9.5 miles downstream of the Bellows Falls tailrace. The dominant substrate was characterized as moderately embedded gravel (Table 5.2-2). Despite suitable habitat, no nests were identified on the bar. Additional searching within the tributary revealed that the majority of the tributary baseline flow was subterranean as it approached the mouth so no spawning habitat was available within the tributary except during periods of run-off flows. It is possible that suitable habitat exists in deeper water in the mainstem off of the bar, but due to the lack of evidence of spawning in a large area of accessible habitat this site was not included in low-water surveys. Level logger data are included in Appendix C (Figure C-16). Observed WSE analyses for the level logger period of record, May 25 – July 13 were summarized in Appendix E and modeled WSE analyses were summarized in appendix F.

This impoundment site included suitable habitat, but spawning activity was not verified. Additional suitable habitat was available in deeper water that was not included in the surveys. It is also possible that habitat in deeper water would be available under different conditions experienced year to year.

16-VT-016

Site VT-016 was a bar at the mouth of Mill Brook, approximately 11 miles downstream of the Bellows Falls tailrace. Confirmation of nest building and spawning activity was made by visual observation of nest construction (Figure 5.2-5). Additionally, a bare radio tag was located on the adjacent bank on June 12, suggesting either predation or scavenging of a post-spawned mortality. A nest cap was also set at this site (see Section 5.3). The dominant substrate was characterized as negligible to low embedded cobble (Table 5.2-2). Four nests were identified overall. Although the period of record, June 19 – July 15, was relatively short, water level logger recorded elevations (June 19 – July 15) indicated that the nests were never exposed (Appendix C, Figure C-17, Appendix E. Operations model output indicated potential exposure from 0 – 52% of normal operations periods, depending on nest elevation and water year conditions (Appendix F).

While the deepest nest elevation was predicted to be continuously submerged, the shallowest identified nest elevation was predicted to be exposed for 34 – 72 events averaging 5.0 – 18.4 hours, depending on model year (Table 5.2-3). It is also possible that habitat in deeper water would be available under different conditions experienced year to year.

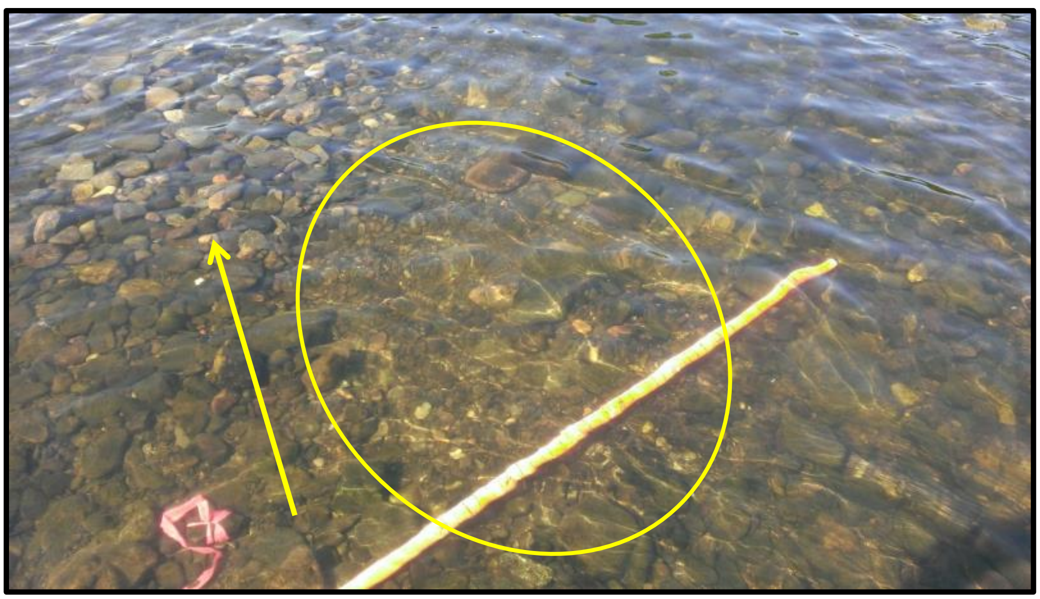

Figure 5.2-5. Sea Lamprey nest with cobble tailings at downstream end (site 16-VT-016).

16-VT-018

Site VT-018 was within Partridge Brook, approximately 13 miles downstream of the Bellows Falls tailrace. No suitable habitat was evident near the mouth of the brook, but suitable habitat was located approximately 0.3 miles upstream near the head of the project-influenced area, and just below the River Road Bridge. This site was an active spawning area with confirmation of nest building and spawning activity made by visual observation of nest construction on June 12 in depth of 0.3 feet, and location of dead post-spawned lamprey on June 10 and June 12. Two nest caps were set at this site (see Section 5.3). Additional spawning activity further upstream of the project-influenced area was indicated by observation of moribund post-spawned lamprey drifting downstream on June 13. The dominant substrate of the nest areas were characterized as ranging from negligible to low embedded gravel to coble (Figure 5.2-6, Table 5.2-2). Four nests were identified within the project-influenced area. Water level logger recorded elevations indicated that the nests were exposed 0.0% of the time for the logger period of record, June 15 – July 15 (Appendix C, Figure C-18, Appendix E). Because of the distance upstream in the tributary, the operations models were not applicable for this site.

The site was an active spawning area, and no nests experienced exposure based on level logger data (Table 5.2-3). Because of the distance upstream in the tributary, project effects were minimal.

Figure 5.2-6. Sea Lamprey nest (site 16-VT-018).

16-VT-040

Site VT-040 was within the West River, approximately 24 miles downstream of the Bellows Falls tailrace. Most of the lower one mile of the West River and the mouth was dominated by fine substrates, so little to no suitable habitat was available within the project-influenced area. Preferred habitat occurred further upstream as evidenced by radio telemetry positions of tagged lamprey and visual observations of a dead, presumably post-spawned, lamprey drifting downstream from above the project-influenced area on June 13 and June 19. Coarse substrate was available beginning in the vicinity approximately one mile upstream of the mouth of the West River in the vicinity of the Interstate 91 Bridge. That habitat was characterized as highly embedded gravel (Table 5.2-2). No nests were identified at this site. Level logger data are included in Appendix C (Figure C-19). Although Sea Lamprey use of the West River was documented through telemetry locations, those were in habitat upstream of the project-influenced reach where the tributary transitioned to higher gradient and swifter velocities. Because no suitable habitat was available in the lower reach of the tributary, this site was determined to be unsuitable for Sea Lamprey spawning.

16-VT-046

Site VT-046 was within Broad Brook, approximately 27 miles downstream of the Bellows Falls tailrace. Similar to site 16-VT-040, most of the lower 0.2 miles and mouth of the brook were dominated by fine sediments. A small bar characterized as highly embedded gravel (Figure 5.2-7, Table 5.2-2) occurred just downstream of the Vermont Highway 142 Bridge, however no evidence of Sea Lamprey spawning was identified there. Above the project-influenced area (above the bridge), the brook gradient rapidly increased and substrate transitioned to cobble and boulder dominant. Water level logger data for the mouth of the brook are included in Appendix C (Figure C-20). Because the mouth and lower reach of the tributary supported no suitable habitat, and the area of suitable substrate was shallow, highly embedded, and evidently characterized with swift currents only during run-off periods, this site was determined to be unsuitable for Sea Lamprey spawning.

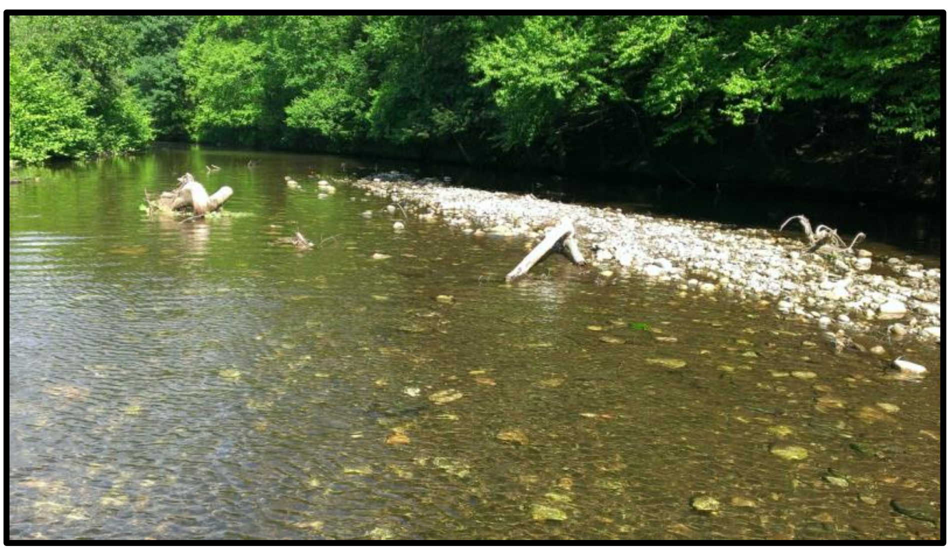

Figure 5.2-7. Highly embedded gravel bar with dispersed cobble (site 16-VT-046).

16-VL-001

Site VL-001 was an island immediately (0.2 miles) downstream of Vernon dam. This site was characterized as gravel that was negligibly to highly embedded in sand (Table 5.2-2). Coarse substrate extended the full length of the island on both the east / main channel, and west / back channel sides. This site was often inaccessible during the spawning season, but spawning activity was confirmed with visual observations of a Sea Lamprey tending a nest on June 19 in a depth of 3.1 feet During the spawning season, a cluster of six nests was identified, and in the post-spawning season low-water survey, seven nests were identified along both the main channel and the back channel. Water level logger recorded elevations indicated that the nests were exposed from 0.0 – 17% of the time (by ascending nest elevation), and 0 – 19% of normal operations periods, for the logger period of record, May 27 – July 14 (Appendix C, Figure C-21, Appendix E). Operations model output indicated potential nest exposure from 0 – 36% of normal operations periods, depending on nest elevation and water year conditions (Appendix F). This site is located downstream of Vernon dam and subject to WSEs based on Turners Falls operations. Three of six recorded nest elevations were never exposed. The shallowest nest elevation was exposed in 18 events with an average duration of 9.2 hours (Table 5.2-3).

This site was a very active spawning site and a substantial proportion of available habitat was never exposed. Additional suitable substrate was available in the main river channel but was too deep to survey. It is also possible that habitat in deeper water would be available under different conditions experienced year to year.

16-VL-002

Site VL-002, Stebbins Island, was approximately 0.85 miles downstream of Vernon dam. Stebbins Island has large areas of excellent habitat at the head of the island, along the entire eastern side and into the main channel, lower end of the island and in the western channel - particularly the lower half of the island. Stebbins Island is a known active spawning habitat, and radio telemetry locations indicated significant use of habitat by tagged lamprey. Spawning activity was confirmed by visual observation of a lamprey tending a nest in a depth of 2.3 feet on June 19, a dead lamprey on a nest in a depth 3.6 feet on June 19, and a live lamprey tending a nest in a depth of 1.8 feet on July 7. Multiple clusters of up to 10 nests in areas of <100 ft^2 accounted for at least 28 identified nests recorded. Note that it is likely that dozens of nests existed at this site, but due to logistical limitations of surveys, representatives of the suite of available elevations and positions around the island were selected for characterization. During post-spawning season low-water surveys, eleven nests or nest clusters representing the range of observed elevations were characterized. Dominant substrate ranged from gravel to cobble that was negligibly to highly embedded in sand (Table 5.2-2). Water level logger recorded elevations indicated that the nests were exposed from 0 – 5% of the time (by ascending nest elevation), and 0 - 2% of normal operations periods for the logger period of record, May 27 – July 14 (Appendix C, Figure C-22, Appendix E). This site is located downstream of Vernon dam and subject to WSEs based on

Turners Falls operations. Operations model output indicated potential nest exposure from 0 – 5% of normal operations periods, depending on nest elevation and water year conditions (Appendix F). The highest elevation nest was exposed in 9 events with an average duration of 7.0 hours during 2015. Model output suggested that in the driest year, the same nest would experience 43 exposure events averaging 7.0 hours (Table 5.2-3).

This was the most active spawning site surveyed, based on all measures used. In part, that is likely due to a higher abundance of Sea Lamprey, but substantial habitat was available, and nest dewatering was minimal in 2015. It is also possible that habitat in deeper water would be available under different conditions experienced year to year.

5.2.2 Water Quality

Water quality parameters were collected at each study site to better reflect project area conditions. Water quality data included temperature (°C), pH (standard units or su), conductivity (µS/cm), turbidity (NTU), and DO (mg/l). All measurements were taken with handheld field meters and data represent instantaneous readings. The study included collection and reporting of limited grab samples of water quality data during visits to each of the study sites. As a result, the data should not be used to characterize general site conditions or trends. Study 6 (Water Quality Monitoring Study [Louis Berger Group and Normandeau, 2016]) data provides the best data on overall water quality within the project-affected area.

Both New Hampshire and Vermont have numeric water quality standards for pH and DO, but only narrative criteria for the other parameters measured. Results of water quality sampling are summarized below. Appendix D (filed separately in Excel format) presents water quality sampling data from each documented spawning site on each survey date (excluding post-spawning season low-water surveys). Tables 5.3-1 to 5.3-3 in Section 5.3.1 provide detailed water quality data for nest cap sites.

Temperature among all sites ranged from 14.3 to 25.3°C over the course of the study (early June to late July). Temperatures were lowest in the last week of June and highest in the middle of July. All pH measurements taken in the mainstem during the study were within the New Hampshire and Vermont state standards from 6.5 and 8.0 su (8.5 su for Vermont) for Class B waters. Two sites (16-BT-018 Black River, and 16-VL-002 Stebbins Island) each had a single low pH measurement below state standards. Site 16-BT-018 also had numerous pH measurements above the New Hampshire standard, but within the Vermont standard. Conductivity measurements across all sites and sampling rounds ranged from 79 to 294 µS/cm. Several tributaries had consistently higher readings than the mainstem, likely due to increased tributary runoff as a result of rain events and high water, especially during June. Turbidity measurements across all sites ranged from 0 to 36.2 NTU, with all measurements above 10 NTU at tributary sites primarily during June, again likely associated with increased tributary runoff due to rain events. Sites 16-VT-016 (Mill Brook) and 16-VT-018 (Partridge Brook) had turbidity measurements consistently greater than 10 NTU. Dissolved oxygen remained above the New Hampshire 5.0 mg/l instantaneous standard and the Vermont 6.0 mg/l standard for class B waters at all sites throughout the study period.

5.3 Spawning Success

5.3.1 Nest Capping

The assessment of Sea Lamprey spawning success was limited to sites where spawning behavior was observed and that provided safe and reliable access across a range of river discharge levels. Nest caps were placed on four nests at three sites after visual confirmation of spawning activity and adults were no longer present on the nests.

Nest Cap Site 16-BT-018, Black River

A nest cap was set on one nest in the Black River (site 16-BT-018) on June 15 after visual confirmation of adult activity on that nest (Figure 5.3-1). The nest was 2.25 feet long by 2 feet wide and 0.46 feet deep at elevation 289.5 (NAVD88) in a water depth of 1.9 feet at the time of first set. Dominant substrate inside the nest was negligibly embedded gravel and outside of the nest was negligibly embedded cobble. The nest cap was checked on sixteen dates from June 16 through July 6. No ammocoetes were collected, though one crayfish, a predator of lamprey eggs (Paradis, 1996; Smith and Marsden, 2009) was removed from the cod-end on June 22. During high flow events, fine sand, with small enough grain to penetrate the nest cap mesh, was suspended in the Black River. The nest cap itself allowed sand to be trapped and the nest to be buried, ultimately to a depth of about 1 ft. As a result of the effect of the nest cap on the meso-habitat of the nest, the cap was removed on July 6. Instantaneous water quality records associated with the nest cap are included in Table 5.3-1. A time series of WSE and water temperature is included in Appendix C (Figure C-11).

Figure 5.3-1. Sea Lamprey nest cap, Black River (site 16-BT-018).

Table 5.3-1. Sea Lamprey nest cap monitoring, Black River (site 16-BT-018).

Date Set	Time Set	Date Pull	Time Pull	Water Temp (°C)	DO (mg/l)	Cond. (µS/cm)	pH	Turbidity (NTU)	Velocity (ft/s)
6/15/2015	1630	6/16/2015	1235	17.4	10.1	207	7.9	3.3	2.00
6/16/2015	1235	6/17/2015	1410	19.2	10.1	201	7.6	2.5	4.50
6/17/2015	1410	6/18/2015	1620	19.2	10.1	201	7.6	2.5	4.00
6/18/2015	1620	6/19/2015	1300	20.9	10.4	215	7.9	1.8	4.40
6/19/2015	1300	6/20/2015	1225	20.3	10.3	214	8	1.5	2.50
6/20/2015	1225	6/21/2015	0814	19.1	10.0	226	7.6	8.2	3.50
6/21/2015	0814	6/22/2015	1225	22	10.0	216	7.9	2.8	3.50
6/22/2015	1225	6/23/2015	1410	21.6	10.1	200	7.0	5.3	3.80
6/23/2015	1410	6/25/2015	1515	23.3	8.1	203	8.1	0.8	2.60
6/25/2015	1515	6/26/2015	1627	23.6	8.9	217	8.1	0.5	1.60
6/26/2015	1627	6/27/2015	1220	21.6	9.5	219	8.0	0.7	4.00
6/27/2015	1220	6/28/2015	1135	17.5	9.9	208	8.1	27.3	3.30
6/28/2015	1135	6/29/2015	1025	15.1	14.5	82	6.8	no data	2.00
6/29/2015	1025	6/30/2015	1036	17.6	10.1	102	6.2	4.1	4.52
6/30/2015	1036	7/1/2015	1230	17.5	10.0	177	7.8	7.0	3.50
7/1/2015	1230	7/6/2015	1645	23.2	9.3	215	8.1	no data	2.50

Nest Cap Site 16-VT-016, Mill Brook

A nest cap was set on one nest on the bar at the mouth of Mill Brook (site 16-VT-016) on June 19 after visual confirmation of adult activity on that nest. The nest was 3.5 feet long by 2.75 feet wide and 0.5 feet deep at elevation 218.2 (NAVD88) in a water depth of 2.5 feet at the time of first set. Dominant substrate inside the nest was negligibly embedded gravel, but with a small boulder exposed in the bottom of the nest. The dominant substrate outside of the nest was negligibly embedded cobble. The nest cap was checked on fifteen dates from June 20 through July 29. No ammocoetes were collected. The cap was removed on July 29 following an agency consultation conference call on July 27, 2015 that resulted in concurrence to terminate the effort. Instantaneous water quality records associated with the nest cap are included in Table 5.3-2. A time series of WSE and water temperature is included in Appendix C (Figure C-17).

Nest Cap Site 16-VT-018, Partridge Brook

Two nest caps were set in Partridge Brook (16-VT-018) on June 13 after visual confirmation of adult activity on the nests. The first nest was 3 feet long by 2 feet wide and 0.3 feet deep at elevation 220.41 (NAVD88) in a water depth of 0.75 feet at the time of first set. Dominant substrate was negligibly embedded gravel inside the nest, and negligibly embedded cobble outside of the nest. The second nest was 1.8 feet long by 1.6 feet wide and 0.6 feet deep at elevation 220.72 (NAVD88) in a water depth of 1.0 feet at the time of first set (Figure 5.3-2). Dominant substrate was negligibly embedded gravel inside the nest, and negligibly embedded cobble outside of the nest. The nest caps were checked on 24 dates from June 24 through July 29. No ammocoetes were collected. The caps were removed on July 29 following an agency consultation conference call on July 27, 2015 that resulted in concurrence to terminate the effort. Instantaneous water quality records associated with the nest cap are included in Table 5.3-2. A time series of WSE and water temperature is included in Appendix C (Figure C-18).

Figure 5.3-2. Sea Lamprey nest cap, Partridge Brook (site 16-VT-018-B).

Table 5.3-2. Sea Lamprey nest cap monitoring, Mill Brook (site 16-VT-016).

Date Set	Time Set	Date Pull	Time Pull	Water Temp (°C)	DO (mg/l)	Cond. (µS/cm)	pH	Turbidity (NTU)	Velocity (ft/s)
6/19/2015	1700	6/20/2015	1445	19.3	10.2	166	7.7	1.3	2.00
6/20/2015	1445	6/21/2015	0952	19.2	9.6	178	7.7	2.5	1.90
6/21/2015	0952	6/22/2015	1445	20.3	10.1	182	7.7	4.5	2.00
6/22/2015	1445	6/26/2015	1743	19.7	9.9	154	7.8	4.2	1.30
6/26/2015	1743	6/27/2015	1315	19.7	9.6	154	7.6	4.1	2.70
6/27/2015	1300	6/28/2015	no data	no data	no data	no data	no data	no data	no data
6/28/2015	no data	6/29/2015	1150	17.55	13.72	94	6.963	17.6	1.23
6/29/2015	1150	6/30/2015	1157	17.4	10.18	93	6.6	9.4	1.30
6/30/2015	1157	7/7/2015	1340	20.8	9.3	203	7.5	1.1	0.70
7/7/2015	1340	7/10/2015	1600	22.4	8.3	183	7.7	0.0	1.40
7/10/2015	1600	7/13/2015	1235	22.9	9.1	156	8	no data	0.70
7/13/2015	1235	7/15/2015	1607	24.5	12.5	200	7.8	0.3	1.30
7/15/2015	1607	7/20/2015	1315	22.9	9.5	156	7.6	0.4	1.30
7/20/2015	1315	7/27/2015	1345	22.1	130	9.2	7.7	0.1	no data
7/27/2015	1345	7/29/2015	1245	23.3	9.4	136	7.7	no data	no data

Table 5.3-3. Sea Lamprey nest cap monitoring, Partridge Brook (site 16-VT-018A and B).

Date Set	Time Set	Date Pull	Time Pull	Water Temp (°C)	DO (mg/l)	Cond. (µS/cm)	pH	Turbidity (NTU)	Velocity, Cap 1 (ft/s)	Velocity, Cap 2 (ft/s)
6/13/2015	1115	6/14/2015	0840	17.6	9.8	291	7.9	0.1	1.00	1.20
6/14/2015	0840	6/15/2015	no data	17.1	10.3	210	7.2	no data	0.60	0.60
6/15/2015	no data	6/16/2015	1110	15.6	10.4	271	7.7	3.5	1.00	1.00
6/16/2015	1110	6/17/2015	1540	20.7	9.6	274	7.7	0.2	1.10	2.40
6/17/2015	1540	6/18/2015	1755	19.6	9.5	288	7.6	0.0	1.10	2.00

Date Set	Time Set	Date Pull	Time Pull	Water Temp (°C)	DO (mg/l)	Cond. (µS/cm)	pH	Turbidity (NTU)	Velocity, Cap 1 (ft/s)	Velocity, Cap 2 (ft/s)
6/18/2015	1755	6/19/2015	1725	22.2	9.7	294	7.8	0.0	0.60	1.60
6/19/2015	1725	6/20/2015	1040	17	11.3	285	7.8	0.3	0.50	1.00
6/20/2015	1040	6/21/2015	0909	16.9	10.5	281	7.8	0.9	1.10	1.50
6/21/2015	0909	6/22/2015	1345	22.1	9.8	279	7.7	0.1	0.80	2.00
6/22/2015	1345	6/23/2015	1558	22.2	10.4	276	7.5	0.3	0.80	0.57
6/23/2015	1558	6/24/2015	1434	22.1	9.4	248	7.6	0.7	0.30	0.10
6/24/2015	1434	6/25/2015	1700	22.3	9.8	258	7.8	0.7	0.70	0.40
6/25/2015	1700	6/26/2015	1810	21.7	9.2	283	7.9	0.0	1.00	1.30
6/26/2015	1810	6/27/2015	1400	19.6	9.7	276	7.8	0.0	1.30	1.30
6/27/2015	1400	6/28/2015	1235	14.3	10.5	182	7.8	36.2	3.50	3.30
6/28/2015	1235	6/29/2015	1215	15.8	18	194	7.7	no data	1.00	1.00
6/29/2015	1215	6/30/2015	1236	18.2	10	183	6.8	no data	0.70	1.12
6/30/2015	1236	7/1/2015	1330	16.5	10.3	191	7.6	27.0	2.50	2.50
7/1/2015	1330	7/6/2015	1306	20.4	9.8	242	7.7	no data	1.30	2.00
7/6/2015	1306	7/13/2015	1307	22.8	9.5	228	8	no data	0.70	1.30
7/13/2015	1307	7/15/2015	1700	23.6	12.4	277	7.9	0.2	0.60	no data
7/15/2015	1700	7/20/2015	1345	25	9.5	229	7.7	no data	0.50	1.30
7/20/2015	1345	7/27/2015	1425	22.5	9.4	198	7.9	no data	0.90	1.70
7/27/2015	1425	7/29/2015	1141	23.2	10	229	8	no data	0.30	1.30

No ammocoetes were collected from any of the nest caps set during this study. Although spawning activity was observed, the actual deposition of eggs cannot be confirmed. As described for site 16-BT-018, the nest cap artificially facilitated the deposition of sand in the nest. However, whether that deposition may have been detrimental to hatching is unknown. In a laboratory study, Smith and Marsden (2009) found that Sea Lamprey eggs incubated in fine silt survived at a higher rate than exposed eggs, suggesting that suffocation may not be a major factor in egg survival. In all nest cap sets, mesh clogging by terrestrially derived detritus and algae was also noted. Clogging appeared to reduce velocities significantly inside the cap. Water quality was good at these sites throughout the study, so it is unlikely that the nest cap significantly altered critical variables, such as DO, but the effect of diminished velocity is unknown.

5.3.2 Evidence from Other Studies

Despite the lack of observation of emergent ammocoetes through nest cap collections, ammocoetes were collected in the course of simultaneous studies, demonstrating spawning success in the study areas.

Study 21 - American Shad Telemetry Study – Vernon

In the American Shad telemetry study, samples were collected from May 26 through July 2, 2015 to document American Shad spawning. Samples were collected in the Bellows Falls riverine reach, Vernon impoundment, and riverine reach at night using a 0.5-m (1.64 ft) diameter ichthyoplankton net (see Study 21 report [Normandeau, 2016e] for details). Overall, 120 tows were made and 37 Sea Lamprey ammocoetes were identified from six (5%) of those, ranging from 1 to 18 ammocoetes per sample (Table 5.3-4). Although lengths were not specified, taxonomists that identified the specimens indicated that they were approximately 30 mm total length. Since they were collected in the water column, it was likely that they were post-emergent young-of-year moving to preferred juvenile habitat. Ammocoetes were collected from June 3 through July 2.

Eighteen ammocoetes were collected from the Vernon riverine reach. Seventeen ammocoetes were collected in three tows on two separate dates from site 16-VL-001. Fourteen of those were collected from tows near the downstream end of the east side of the island – very close to where nests were identified. Three were collected from a single tow in the side channel on the west side of the island. A single ammocoete was collected from a tow in the mainstem river in the Vernon impoundment, approximately 1 mile downstream of the mouth of the West River (16-VT-040), an area characterized by fine sediments. Eighteen ammocoetes were collected from a single tow in the Bellows Falls riverine reach that extended more than a mile, but started and ended at lamprey spawning assessment sites (16-BL-002 and 16-BL-003).

Table 5.3-4. Ichthyoplankton samples from Study 21(Normandeau, 2016e) containing Sea Lamprey ammocoetes.

Date	Sample No	Reach	Latitude	Longitude	Count	Study 16 Site Association
6/3/2015	021-07-11-27	VL	42.7731	72.4993	1	downstream end of 16-VL-002
6/22/2015	021-06-11-83	VT	42.8526	72.5530	1	Vernon impoundment, 1 mile downstream of 16-VT-040
7/1/2015	021-07-11-115	VL	42.7656	72.5140	9	downstream end of 16-VL-001
7/1/2015	021-07-11-116	VL	42.7656	72.5140	5	downstream end of 16-VL-001
7/2/2015	021-05-11-119	BL	43.0791	72.4365	18	from 0.25 miles downstream of 16-BL-002 to channel adjacent to 16-BL-003
6/27/2015	021-07-11-103	VL	42.7669	72.5158	3	west channel adjacent to 16-VL-001

Reach: BL = Bellows Falls riverine, VT = Vernon impoundment, VL = Vernon riverine

Study 10 - Fish Assemblage Study

In Study 10 – Fish Assemblage Study (Normandeau, 2016b), an electrofishing survey (along with more size-selective fish collection methods), was conducted at sites throughout the three project areas in spring, summer, and fall, 2015. Overall, 62 juvenile Sea Lamprey were collected from sites in all reaches except the Wilder impoundment and the Bellows Falls bypassed reach (Table 5.3-5). Lamprey were collected from the Wilder riverine reach in all three seasons, the Bellows Falls impoundment in spring and fall, Bellows Falls riverine reach in spring, and both the Vernon impoundment and Vernon riverine reaches in spring and summer. In those reaches, lamprey were collected in samples from up to 46% of all sites by season with the greatest distributions in the Vernon impoundment in spring (6 of 3 sites, 46%, Figure 5.3-3).

No adult lamprey were collected in electrofishing samples, and based on length frequencies (Figure 5.3-4), it is likely that most were ammocoetes, though it is possible that some specimens were 'transformers' (metamorphosing from the larval ammocoete life phase to the parasitic juvenile phase). In the spring, lengths ranged from 71 – 180 mm (2.8-7.1 in.), in summer from 61 – 145 mm (2.4 – 5.7 in.), and in fall 99 to 140 mm (3.9 – 5.2 in.).

Anecdotal Record of Ammocoetes

Anecdotal reports of the presence of small eels in the Vernon and Bellows Falls fish ladders seasonal dewatering, often ~ 4 inches long, have been made by TransCanada staff. Additionally, TransCanada staff reported large numbers of small eels, ~ 4 inches long, in a silt-filled drum recovered from Herrick's Cove in the Bellows Falls impoundment. The vast majority of juvenile American Eels passed upstream at Holyoke dam, 56 river miles downstream of the Vernon project and 88 river miles downstream of the Bellows Falls project are longer than 4 inches (Normandeau, 2015B). In considering anecdotal reports of eels in the Connecticut River, it is important to note that the term 'eel' is often used colloquially to describe lamprey. Given the general size of eels that passed Holyoke, the distance between projects, and therefore potential for growth of Juvenile American Eels prior to reaching the Vernon Project, it is likely that fish described as eels approximately 4 inches long were Sea Lamprey ammocoetes.

On December 7, 2015, upon dewatering of the Vernon fish ladder, lamprey ammocoetes (approximately 5.7 inches long, total lengths were estimated using ImageJ software, Version 1.49, courtesy of National Institutes of Health [http://imagej.nih.gov/ij]) as well as American Eels (approximately 13.0 inches long, Figure 5.3-5) were observed emerging from a silt bed in a pool section of the ladder (Figure 5.3-6). This supports the anecdotal reports of ammocoetes in the fish ladders, and given the season and the presence of fine sediment deposits suggests that ammocoetes were residing there rather than actively migrating through.

Table 5.3-5. Electrofishing samples in Study 10 with juvenile Sea Lamprey collections (Normandeau, 2016b).

Reach	Sites (N)	Sites with Lamprey (N)	Sites with lamprey (%)	Catch (N)
Spring				
Wilder Impoundment	16	0	0%	0
Wilder Riverine	14	1	7%	1
Bellows Falls Impoundment	13	5	38%	7
Bellows Falls Riverine	15	4	27%	13
Bellows Falls Bypassed Reach (not surveyed in spring)	n/a	n/a	n/a	n/a
Vernon Impoundment	13	6	46%	16
Vernon Riverine	5	1	20%	1
Total	**76**	**17**	**22%**	**38**
Summer				
Reach				
Wilder Impoundment	16	0	0%	0
Wilder Riverine	14	3	21%	6
Bellows Falls Impoundment	13	0	0%	0
Bellows Falls Riverine	14	0	0%	0
Bellows Falls Bypassed Reach	3	0	0%	0
Vernon Impoundment	15	4	27%	7
Vernon Riverine	4	1	25%	2
Total	**79**	**8**	**10%**	**15**
Fall				
Reach				
Wilder Impoundment	17	0	0%	0
Wilder Riverine	13	2	15%	8
Bellows Falls Impoundment	14	1	7%	1
Bellows Falls Riverine	13	0	0%	0
Bellows Falls Bypassed Reach	3	0	0%	0
Vernon Impoundment	14	0	0%	0
Vernon Riverine	4	0	0%	0
Total	**78**	**3**	**4%**	**9**

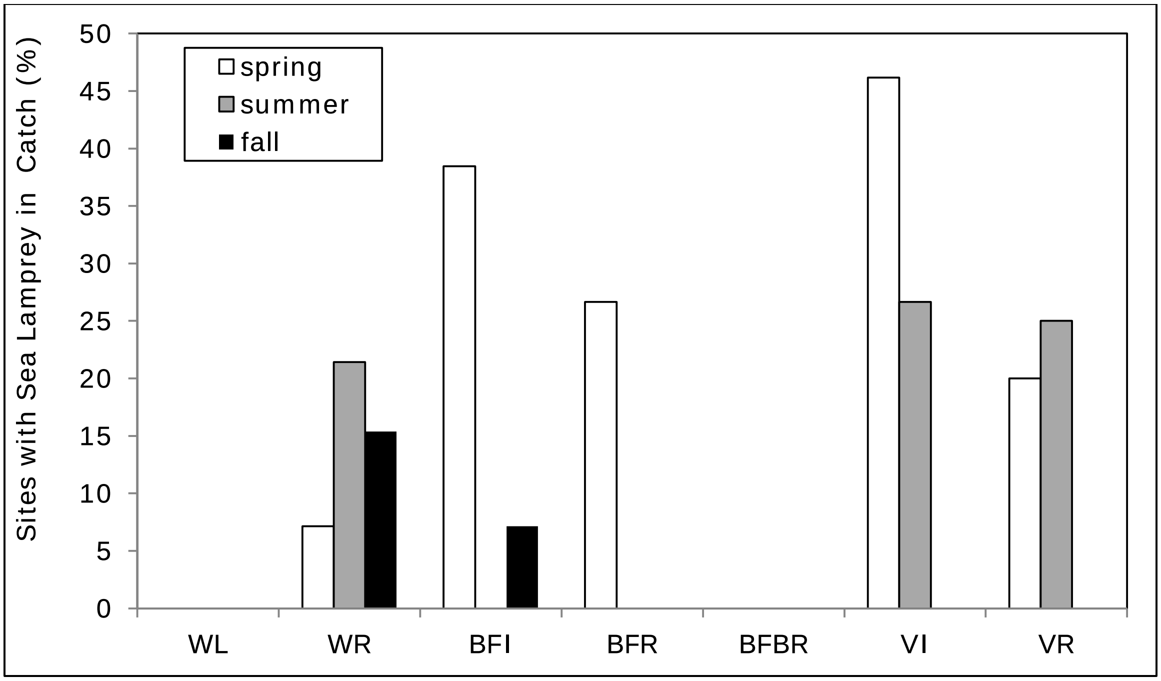

Figure 5.3-3. Percent of Study 10 electrofishing sites that included Sea Lamprey in the catch by reach and season (Normandeau, 2016b).

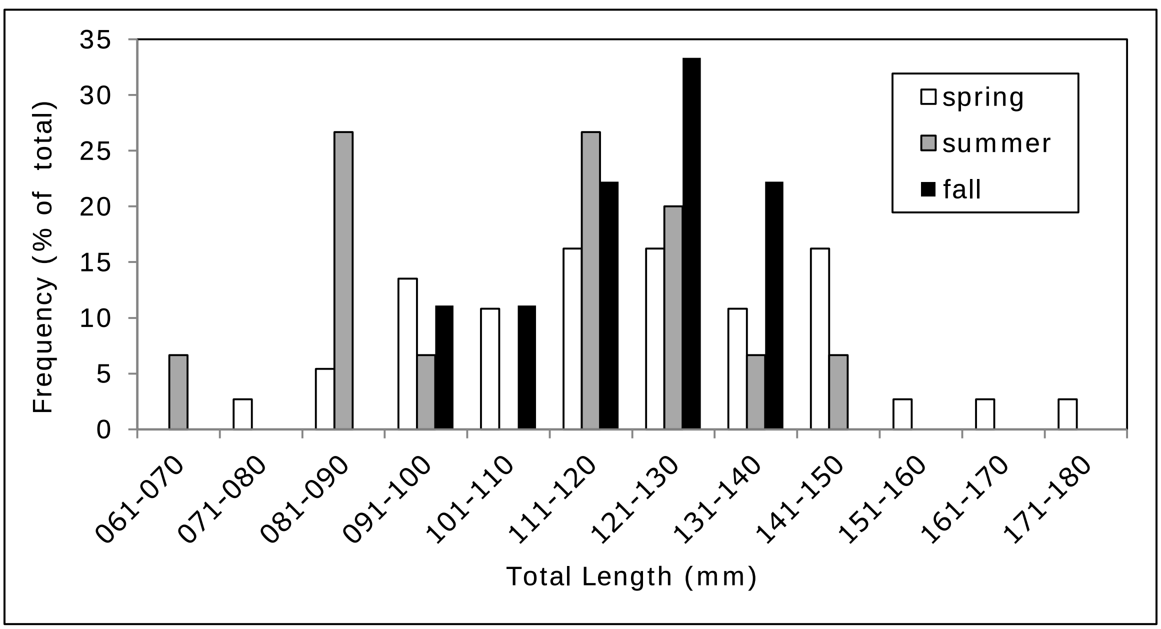

Figure 5.3-4. Length frequency distribution of Sea Lamprey collected in Study 10, by season (Normandeau, 2016b).

Photo credit: Jennifer Griffin, TransCanada.

Figure 5.3-5. Sea Lamprey ammocoetes and juvenile American Eels collected from the Vernon fish ladder, December 7, 2015.

Figure 5.3-6. Sea Lamprey ammocoete emerging from sand/silt deposit in the Vernon fish ladder, December 7, 2015.

6.0 ASSESSMENT OF PROJECT EFFECTS

Wilder, Bellows Falls, and Vernon project operations have the potential to affect Sea Lamprey spawning habitat through water level and flow fluctuations, water quality effects, and potential nest scour and flushing. Of primary importance is the impact of project-related water level fluctuations during the spawning season that have the potential to limit access to, and intermittently submerge and expose, spawning habitat. Sea Lamprey may be especially vulnerable due to their preference to spawn in shallow fast water in gravel and cobble substrates. Those habitats exist throughout areas of each riverine reach at gravel and cobble bars associated with the heads and margins of islands, tributary mouths, and within tributaries near the upstream extent of project-influenced reach where stream gradients begin to increase.

Water level fluctuations in the project-affected areas occur because of changes in natural flows, changes in flow and water levels due to upstream flow management at TransCanada projects, US Army Corps of Engineer Flood Control dams and other public and private dams, as well as by the operation of the Wilder, Bellows Falls and Vernon projects. This assessment of project effects relied upon associating observed and Operations Model (Study 5 [Hatch, 2016]) data on changes in water levels at the study sites with specific project operations that are not otherwise caused by the influences stated above.

6.1 Water Level Fluctuation and Nest Exposure

Project-related water level fluctuations were analyzed using operations data, water level logger observations, and Hydraulic and Operations Model data (Studies 4, 5). Each site was classified as an active spawning area, an area of non-suitable habitat and no nest identification, or an area containing suitable habitat, but with no nest identification (see Section 5.2).

For sites with nests identified, water level logger data (period of record for each logger) for the spawning season were analyzed to determine the frequency and duration of periods of observed exposure for each nest elevation, understanding that the closest level logger to some sites were at relatively long distances from the site and so the results could be biased. If level logger data indicated that all nests identified at a site were continuously submerged for the period of record, then preliminary assignation of ‘no project effects’ was made. If logger data indicated that any nest was exposed during the period of record, then a preliminary assignation of ‘moderate project effects’ was made.

Next, operations model output was similarly analyzed for the five modeled annual hydrologies. It is probable that the selection of a nest location by Sea Lamprey, is somewhat dependent on the particular water year since higher flows in one spawning season make more habitat at higher elevations available than would otherwise be available in a lower flow season. If all nest elevations recorded at a site were continuously submerged for the defined season in all modeled years, the determination of 'no project effects' was retained. If all nest elevations were continuously submerged for any one model year, but any nest was exposed in one or more model years or if any nest was continuously submerged for all model years, then an assignation of 'moderate project effects' was made. If all nests were exposed in all model years, then an assignation of 'project effects' was made.

Overall, 23 sites were assessed, 12 in riverine habitats and 11 in impoundment habitats. Four sites (17%) were classified as unsuitable spawning habitat. Three of those were in impoundment reaches and one was in a riverine reach. Of the remaining 19 sites, sixteen (84%) were classified as active spawning areas, and 3 (16%) sites were classified as having suitable habitat, but with no evidence of spawning. Of the 16 active spawning sites, 10 were in riverine reaches (83% of riverine sites) and six were in impoundment reaches (55% of impoundment sites) including two in tributaries.

Assumed nest exposure based on 2015 level logger (period of record) data indicated that 54 of 70 nests (77%) with recorded elevations were not exposed. A summary assessment of nest exposure is included in Table 6.1-1. For nest-specific exposure data, see Appendix E. Operations model predicted incidence of exposure for the worst-case scenario – the lowest water year modeled and the highest elevation nest recorded at each site - suggested that 23 of 56 nests (excluding nests in tributary sites with applicable no model data - 16-BT-018, 16-VT-018) analyzed (41%) were predicted not to be exposed. Nest elevations that did experience exposure ranged from relatively frequent occurrence, such as for site 16-WL-005 where one nest elevation was exposed from 49-74% of normal project operations periods, depending on water year; to infrequent, such as site 16-VL-002, where only the three highest nest elevations recorded experienced any exposure, from 0–5% of normal project operations periods. A summary of nest elevation exposures relative to Operations Model output is included in Appendix F.

In review of predicted nest exposure of the 16 sites with verified spawning activity, three sites (19%) had 'no project effects'. One of those was in riverine habitat, and two were in impoundment habitats, though they were both in tributaries. Nine sites (56%) were found to have 'moderate project effects', meaning that some nests were exposed (at any point in the analysis), but at least one nest elevation was continuously inundated. The remaining four sites (25%) experienced 'project effects', meaning all nests were exposed at some point (regardless of frequency or duration). Note that this assessment is based on the 'worst-case' scenario modeled.

Vulnerability of nests to dewatering exposure was greatest at sites in the Wilder riverine reach (WL-01, WL-02, WL-05), but relatively high vulnerability was also apparent in sites ranging from impoundment habitats (e.g., 16-BT-004, 16-VT-016), whereas nest elevations in some riverine experienced relatively little potential exposure (e.g., 16-BL-001, -002, -003, 16-VT-001, -002). The most vulnerable Wilder riverine sites were closest to project tailwaters or otherwise located where the magnitude of discharge variations on WSE was most dynamic. Generally, those effects attenuate where tailwaters are wide and with less steep banks, such as below Vernon dam, and into impoundment habitats where WSE variation was less than in riverine reaches.

Exposure of a nest is not necessarily related to mortality because the assignation of risk assumes that exposed nests were occupied during periods of normal project operations. Exposure of a nest that is occupied may result in a detrimental effect, such as prevention of access by adults during active nest construction and spawning, abandonment of nest construction or spawning, egg mortality due to desiccation or unsuitable water quality (such as when water in an exposed nest warms quickly), and mortality of ammocoetes. There are several potential mitigating factors to evaluating the risk of exposure. Note that these mitigating factors were not specifically evaluated in this study.

- The spawning season included periods when high river discharges exceeded project generating capacity, conditions that typically occur during the spring spawning season. Vulnerable nest elevations were therefore most accessible to spawning lamprey in flow periods beyond project operations. Spawning and gestation could occur entirely or mostly during extended periods of continuous submergence. An unoccupied nest that becomes exposed does not constitute a detrimental effect.
- It is not clear that spawning occurs in all nests. As noted in Section 5.1, radio telemetry tracking suggested the potential for serial spawning or, alternatively, exploratory nest construction. Nests that may be abandoned or unoccupied due to non-operational flows are inconsequential in terms of project affects. Again, an unoccupied nest that becomes exposed does not constitute a detrimental effect.
- Nests may not be the sole rearing habitat. Only a small portion of eggs are deposited in nests or remain there once deposited. This may reflect a bet-hedging spawning strategy that Sea Lamprey have evolved so that a small percentage are protected in the nest while the majority is essentially broadcast which could help ensure that some portion of the eggs are located in favorable habitat, such as interstitial spaces in the substrate (Smith and Marsden, 2009).
- Ammocoetes are adapted to survive some dewatering. In a laboratory study that evaluated the effects of dewatering on larval Pacific Lamprey movement and survival (Liedtke et al., 2015), about one-half of ammocoetes emerged from the sand following exposure to dewatering conditions and about one-half stayed burrowed. Those that emerged tended to do so only after substrate exposure, increasing the potential for stranding, and those that remained burrowed were more than four times more likely to survive. Mortality was less than 7 percent for exposure periods of less than 24 hours. For nests in this study that experienced exposure, the average period of exposure at each site was no more than 11 hours based on 2015 level logger data and, except for one specific nest elevation at Site 16-BT-003, less than 24 hours for all model years (Table 5.2-3).

- At all sites except one (16-BT-004) where identified nests were exposed in low or minimum flow periods, there were other nests identified that were always submerged in 2015 level logger data. Additionally, suitable habitat was often available in channel areas adjacent to island / bar assessment sites. It is possible that spawning occurred in those deeper habitats as well. Radio telemetry tracking indicated that adult lamprey were frequently located in areas of suitable substrate, but that were more than 10 feet deep. Those areas were generally out of the scope of this study because they were not vulnerable to normal fluctuations in WSE (Revised SSR). There is substantial evidence that suitable habitat that has little to no risk of exposure exists. At most sites where spawning activity was identified, those habitats were used. Although the proportion of the spawning population using continuously inundated habitats is unknown, it is erroneous to assume that all spawning occurs in shallow water.

- Analysis of a two-month period was highly conservative. The period during which spawning lamprey construct a nest and spawn appears to be relatively short and the gestation period is approximately two weeks. Since specific spawning dates could rarely be assigned, the full range of the spawning season was incorporated in this analysis although any specific nest was likely to have been occupied for only about a quarter of that time.

Table 6.1-1. Analysis summary of project operations effects on Sea Lamprey nest exposure.

Site ID	Habitat Assessment				
	Site Classification	Nests (N)	Elevation (range) NAVD88	Vertical Distribution (ft.)	Conclusion
16-WL-001	active spawning area	3	324.7-329.1	4.4	moderate project effect
16-WL-002	active spawning area	5	324.4-327.7	3.3	moderate project effect
16-WL-003	non-suitable spawning habitat / [limited habitat, but no observed spawning]	0	.	.	Insufficient habitat
16-WL-004	suitable spawning habitat but no observed spawning	0	.	.	No spawning evident in 2015
16-WL-005	active spawning area	3	300.3-302.7	2.4	Project Effect
16-WL-006	active spawning area	3	293.1-293.8	0.7	Moderate Effect
16-WL-007	active spawning area	4	291.4-293.7	2.3	Moderate Effect
16-BT-004	active spawning area	1	291.1	.	Project Effect
16-BT-003	active spawning area	1	290.1	.	Project Effect
16-BT-006	suitable spawning habitat but no observed spawning	0	.	.	No spawning evident in 2015
16-BT-013	active spawning area	2	287.8-290.0	1.2	Moderate Effect
16-BT-018	active spawning area with larval sampling	10	289.0-290.5	0.5	No Effect

Site ID	Habitat Assessment				
	Site Classification	Nests (N)	Elevation (range) NAVD88	Vertical Distribution (ft.)	Conclusion
16-BT-031	non-suitable spawning habitat / [limited habitat, but no observed spawning]	0	.	.	Insufficient habitat
16-BL-001	active spawning area	6	218.1-220.8	2.7	Moderate Effect
16-BL-002	active spawning area	3	219.1-219.2	0.1	Project Effect
16-BL-003	active spawning area	4	215.7-217.0	1.3	No Effect
16-VT-014	suitable spawning habitat, but no observed spawning	0	.	.	No spawning evident in 2015
16-VT-016	active spawning area with larval sampling	4	218.2-219.3	1.1	Moderate Effect
16-VT-018	active spawning area with larval sampling	4	220.3-220.8	0.5	No Effect
16-VT-040	non-suitable spawning habitat	0	.	.	Insufficient habitat
16-VT-046	non-suitable spawning habitat	0	.	.	Insufficient habitat
16-VL-001	active spawning area	13[a]	177.7-182.7	5.0	Moderate Effect
16-VL-002	active spawning area	28[b]	179.5-181.1	1.6	Moderate Effect

a. Overall, 13 nests / nest clusters were identified. Water surface elevations were recorded for 6 that represented the range of elevations observed.

b. Overall, 28 nests / nest clusters were identified. Water surface elevations were recorded for 11 that represented the range of elevations observed.

6.2 Water Quality Effects

Instantaneous water quality measurements taken at the spawning habitat assessment sites (see Sections 5.2.2 and 5.3):

- DO: all met Vermont's instantaneous minimum standard DO for Class A waters of 6.0 mg/l (and New Hampshire's lower standard of 5.0 mg/l).
- pH: most met Vermont's instantaneous standard for Class B waters of 6.5 – 8.5 su. One site had a pH record lower than 6.5 (16-BT-018) and that same site had records above New Hampshire's 8.0 su standard. That site was within a tributary at the upstream extent of the project–influenced reach.
- Turbidity: Instances of elevated turbidity (>10 NTU) occurred at several sites (16-BT-006, 12 NTU; 16-BT-018, 27.3 NTU; 16-VT-014, 23.7 NTU; 16-VT-018, 36.2 NTU) during high flow events. Most were in tributaries and were likely influenced by non-point sources and considered naturally occurring. Instances of elevated conductivity are also considered naturally occurring, due primarily to tributary inflows during rain events.
- Variations in temperature were considered naturally occurring.

6.3 Scour and Flushing

Nest structure condition was evaluated by comparing nest characterization criteria for those nests that had repeated visits (Table 6.3-1). Limited data were available because many specific sites could not be located during high flow (including high operational discharge into riverine reaches), were located only once, or were not located until after the spawning season. The most frequently revisited nests were those that were capped, however it was determined that the nest caps protected nest structures from the forces of water velocity, and altered deposition of fine substrates in the nest so those sites were disregarded in this evaluation. Nest condition was classified in terms of overall structure. An increased condition classification value was interpreted as nest structure degradation. Substrate embeddedness inside the nest and the amount that course substrates (gravel – boulder) were embedded in fine substrates (mud – sand) was classified, and a decreased embeddedness classification value was interpreted as scour while an increased value was interpreted as deposition.

Of 13 nests evaluated, structure degradation was noted for eight (62%), five of those were attributed to tributary effects; nest scour was noted for five of 13 nests (38%), four of those were attributed to tributary-effects; and sediment deposition was noted in seven of 13 nests (54%) four of those were attributed to tributary-effects.

Observed changes in nest structure and embeddedness were subject to the number and timing of visits, site location, and nest meso-habitat. For example, site visits that occurred before a rain event that resulted in high river discharges would potentially yield different observations than immediately after such an event. Site location was important because sites located above tributary mouths were subject to changes in nest condition as a result of the effects of tributary flows such as increased WSE, velocity, and suspended sediments. Spawning habitat in those sites tended to occur toward the upper extent of the project-influenced reaches where stream gradient began to increase and project impoundment effects were negligible. Meso-habitat changes were important because evident nest degradation, scour, and sediment deposition could vary within a site.

There are several potential mitigating factors to project effects based on degradation, scour, and deposition. Note that those mitigating factors were not specifically evaluated in this study.

- Nest structure degradation naturally occurs over time with bed-load movement, and presumably would have little effect on survival of eggs or ammocoetes. It is not clear what, if any, effect scour and deposition have on ammocoete survival.
- Scour is related to high flows and may result in egg loss from the nest (Smith and Marsden, 2009). However, to interpret scour as a project effect assumes that eggs were present during the conditions that resulted in scour and that eggs were in fact lost from a nest that experienced scour.
- Ammocoetes are expected to emerge from the nest and are therefore adapted to displacement downstream to pool habitats characterized by fine sediments. Incidental collections of ammocoetes in ichthyoplankton samples as evidence of the emergence and downstream transport support this (see Section 5.3.2).

Deposition of sediments including sand, to the moderate degree observed is likely not detrimental, and may be protective. Smith and Marsden (2009) found that Sea Lamprey eggs incubated in fine silt survived at a higher rate than those incubated without substrate. They concluded that suffocation by silt may not be a major factor influencing mortality of lamprey eggs.

Table 6.3-1. Observations of Sea Lamprey nest condition and substrate embeddedness.

Site ID[a]	Nest No.	Dates	Nest Condition[b]	Nest Substrate Embeddedness[c]	Interpretation
16-BT-013	1	6/17, 6/19	1, 1	1, 1	no change
16-BT-018	2	6/17, 6/25	1,1	1,0	scour: tributary effect
16-BT-018	3	6/17, 6/20, 6/25, 7/15	2,1,2,2	1,0,3,0	scour and deposition: tributary effect
16-BT-018	4	6/18, 6/25, 7/15	1, 2, 3	0. 2, -	degradation and deposition: tributary effect
16-BT-018	5	6/19, 6/25	1,2	0,2	degradation and deposition: tributary effect
16-BT-018	6	6/19, 6/25, 7/15	., 2, 3	5, 0, -	degradation and scour: tributary effect
16-BT-018	7	6/20, 6/25, 7/15	., 2, 3	1, 3, -	degradation and deposition: tributary effect
16-BT-018	9	6/25, 7/15	2, 2	3, 1	scour: tributary effect
16-VT-016	3	6/19, 7/7, 7/15	1, 2, 2	2, 1, 1	degradation and scour: project / non-project effect
16-VT-016	4	6/17, 6/19, 7/7, 7/15	1, 2, 2	0, 2, 2	degradation and deposition: project / non-project effect
16-VT-018	3	6/12, 6/18	1, 2	1, -	degradation: tributary effect
16-VL-001	1	6/19, 7/6	1, 1	0, 1	deposition: project / non-project effect
16-VL-001	2	6/19, 7/7	1, 2	0, 1	degradation and deposition: project / non-project effect

a. Observations for nests with repeated visits, disregarding those for capped nests.

b. Nest Condition- 1: good condition, 2: moderate degradation – gravel/cobble mobilized into nest, 3: severe degradation - progressively collapsed - significant gravel/cobble mobilized into nest.

c. Embeddedness (in silt – sand) - 0: negligible- <5%, 1: low - 5-25%, 2: moderate, 25-50%, 3: high, 50-75%, 4: very high, >75%.

6.4 Study Conclusions

Sea Lamprey were distributed among all study reaches, and evidence of spawning activity was recorded in all study reaches. The results reported here supported the finding of Kart et al. (2005) that Sea Lamprey spawn in the Connecticut River as far upstream as Wilder dam and in tributaries such as the West, Williams, Black, and White rivers (Kart et al., 2005).

Large areas of suitable habitat were associated with the riverine reaches, and the Vernon riverine reach hosted the highest density of identified spawning activity. Since lamprey tend not to arrive within the Vernon riverine reach until water temperatures are generally at or above 15°C, the physiological trigger to spawn may occur for many fish before they have an opportunity to pass Vernon dam. Additionally, there is a large area of excellent habitat in the 1.5 mile long Vernon riverine reach. Laboratory studies have suggested that pheromone signals originating from ammocoetes may attract migrating adults to suitable spawning habitat, and mature adults release pheromones, which attract the opposite sex (Teeter 1980). Therefore, the most successful spawning habitat theoretically attracts more spawners. Generally, adult Sea Lamprey demonstrated an ability to rapidly distribute upstream. Nonetheless, the overall abundance of adults available to spawn in Vernon impoundment and Bellows Falls riverine reach was 2.6 times the number available to spawn in the Bellows Falls impoundment and Wilder riverine reach. Therefore, it is plausible that the lack of evidence of spawning at certain sites in those reaches that were characterized as suitable habitat (e.g. 16-WL-04, 16-BT-06) was simply a function of lower spawner density.

Geographic use of the impoundment reaches for spawning varied particularly in the lower Vernon impoundment. Tributaries in the middle and upper impoundment reaches typically had gravel/cobble deposits at the mouth, though spawning was not evident at all tributary mouth bars surveyed. For example, in the Vernon impoundment, spawning was not evident at the mouth of Aldrick Brook (16-VT-14), but was evident at the mouth of Mill Brook (16-VT-16). Further downstream in the impoundment, the mouth of Partridge Brook represented unsuitable lentic habitat, but good habitat with identified spawning occurred near the upstream extent of the project-influenced tributary reach, and, based on visual observation of post-spawned moribund adults drifting from upstream, spawning occurred in that area as well. In the lower Vernon impoundment, the West River (16-VT-40) had unsuitable lentic habitat throughout the project-influenced reach, but based on telemetry tracking and observation of post-spawned moribund adults drifting from upstream, spawning occurred above that area. In the downstream most tributary surveyed, Broad Brood (16-VT-46), not only was the lower tributary lentic, but it transitioned to a high gradient stream just above the project–influenced extent and no evidence of spawning was identified. Similarly, in the upper Bellows Falls impoundment, tributary mouth bars supported spawning (16-BT-03, 16-BT04, 16-BT-13), and lower impoundment tributaries supported spawning near the upstream extent of the project–influenced reaches (16-BT-18, 16-BT-31), but the tributary mouths were unsuitable lentic habitat.

The preferred water temperature range for Sea Lamprey spawning has been reported as between 10° and 18.5°C, with temperatures above those levels thought to reduce migration and spawning intensity (Beamish, 1980). Direct observations in this study of adults engaged in spawning activity, such as nest building / tending occurred with water temperatures ranging from 16.9 – 20.3°C, and most observations occurred with water temperatures >18.5°C. Therefore, the upper extent of the thermal window for spawning is, at least in the Connecticut River, higher than previously reported.

Attempts to document spawning success using nest caps in this study failed. There are several potential explanations for that, including failed spawning, inadvertent capping of unused nests, improper timing of capping, and/or escapement. However, it was also noted that the nest caps themselves may have altered nest meso-habitat conditions. On the other hand, overall spawning success was evident through observations made in the course of concurrent studies (10 and 21).

Results of this study indicated verified spawning activity on at least 16 of 23 (70%) sites surveyed, with spawning potentially associated with tributary reaches outside of the project-influenced reach for two additional sites, and potential spawning in deeper habitats associated with at least two more sites (overall 87% of study sites had potential spawning). Of the 16 sites with identified nests, 13 (81%) were shown to potentially be exposed to nest dewatering under normal project operations during the spawning season. Of all nest elevations recorded, 20 of 70 (29%) had potential exposure based on 2015 level logger data, and 25 of 56 (45%) had potential exposure based on Operations Model data.

Overall, three of 16 (19%) sites evaluated based on nest elevations were found to experience no project effects, 9 (56%) were found to potentially experience moderate project effects in terms of periodic dewatering of some, but not all identified nests during normal operations periods. Four sites (25%) potentially experience project effects in terms of periodic dewatering of all identified nests during normal project operations. However, several potential mitigating factors (see Section 6.1) may alleviate some of those effects.

It is important to note that this study relied on a selected subset of habitat–based sites and was limited to 23 total sites throughout the over 77-mile study reach. The study was also inherently biased toward relatively higher elevation habitat in shallower water (usually < 3 ft.) because the study was intended to ignore deeper depths that are not vulnerable to dewatering and because observation of lamprey spawning activity at deeper depths is exceptionally difficult. As a result only the most vulnerable habitats were surveyed, but it is likely that Sea Lamprey also spawned in relatively deep water, despite literature suggesting that spawning occurs at shallow depths. This was evidenced by radio telemetry locations of fish in water more than 8 feet deep during the spawning season, which, when surveyed during low water periods was approximately 2 feet deep or less when nests were identified.

In addition, observational depths were limited in the spring due to high flow events during June, the approximate midpoint of the expected May 15 – July 15 spawning season. Actual spawning and gestation typically occurs over a much shorter period (e.g., 2 weeks). Therefore, it is reasonable to assume that this relatively short spawning window is highly responsive to the flow and WSE conditions at the time of spawning. The model analysis does not reflect the specific conditions observed in 2015, but rather depicts more typical WSE's for the same period (e.g., June) which are generally lower than earlier in the spring. Thus, using the model and hydrologies that do not reflect the actual hydrology experienced in 2015 is very problematic in terms of assessing actual project effects.

Study 9 – Instream Flow Study (Normandeau, 2016a), when analysis is complete, may provide additional information on project effects on habitat availability for Sea Lamprey in the riverine reaches.

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APPENDICES A – F are being filed separately in a single zipfile as follows:

Appendices A, B, C and D are in a single Excel file.

Appendix A: Spawning Habitat Characteristics for Sea Lamprey

Appendix B: Radio Telemetry Manual Tracking Location Results

Appendix C: Spawning Site Assessment: Water Surface Elevation Plots

Appendix D: Water Quality Data

Appendices E and F are in separate Excel files

Appendix E: Summary Analyses of 2015 Water Surface Elevations and Nest Exposure

Appendix F: Summary Analyses of Water Surface Elevations and Nest Exposure for Operations Model Output

Appendix G is included herein:

Appendix G: Maps of Sea Lamprey Spawning Habitat Assessment Sites with Meso-Habitat (Riverine Habitats) or Substrate Type (Impoundment Habitats)

Appendix H: Supporting Geodata is being filed separately in kmz and Arc (zipfile) format.

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APPENDIX G

Maps of Sea Lamprey Spawning Habitat Assessment Sites with Meso-Habitat (Riverine Habitats) or Substrate Type (Impoundment Habitats)

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Data Provided By:
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0 200 400 800 Feet

Spawning Locations

Nest Location

Study 16 Site

Meso-Habitat

Glide

Pool

Rapid

Riffle

Run

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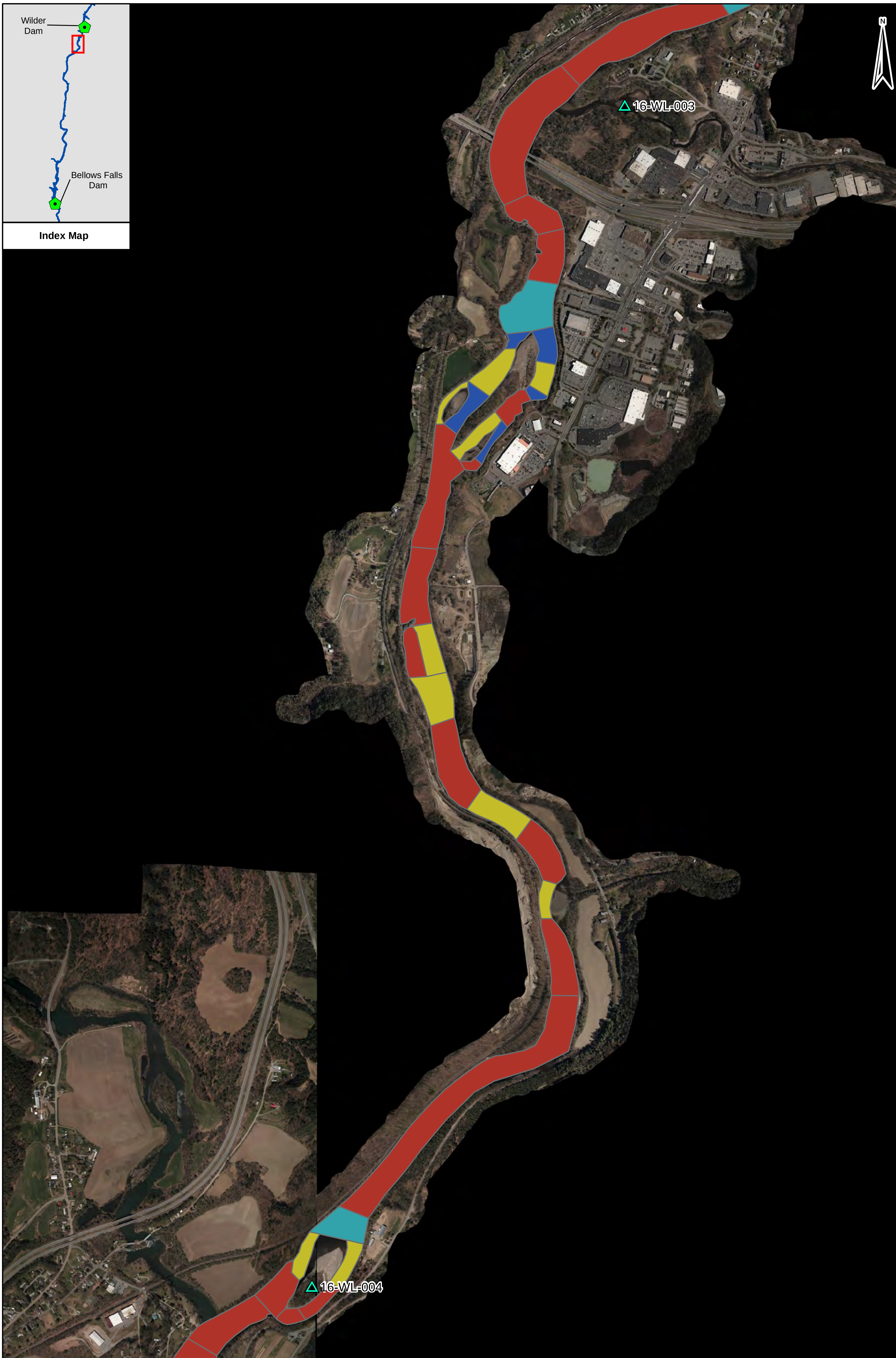

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Data Provided By:
U.S. Imaging

0 400 800 1,600 Feet

Spawning Locations

Nest Location

Study 16 Site

Meso-Habitat

Glide

Pool

Rapid

Riffle

Run

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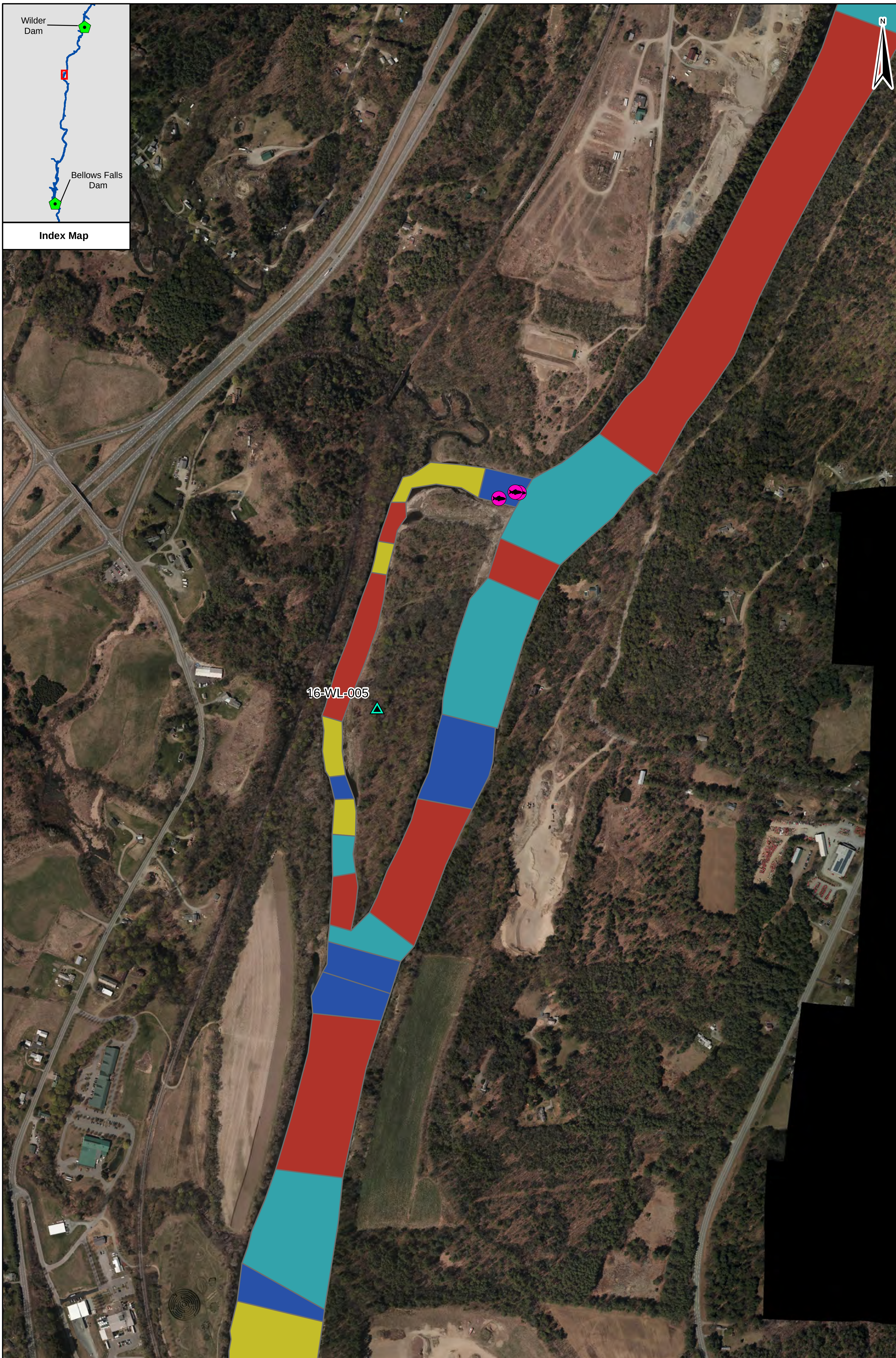

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Data Provided By: U.S. Imaging

0 200 400 800 Feet

Spawning Locations

- Nest Location
- Study 16 Site

Meso-Habitat

- Glide
- Pool
- Rapid
- Riffle
- Run

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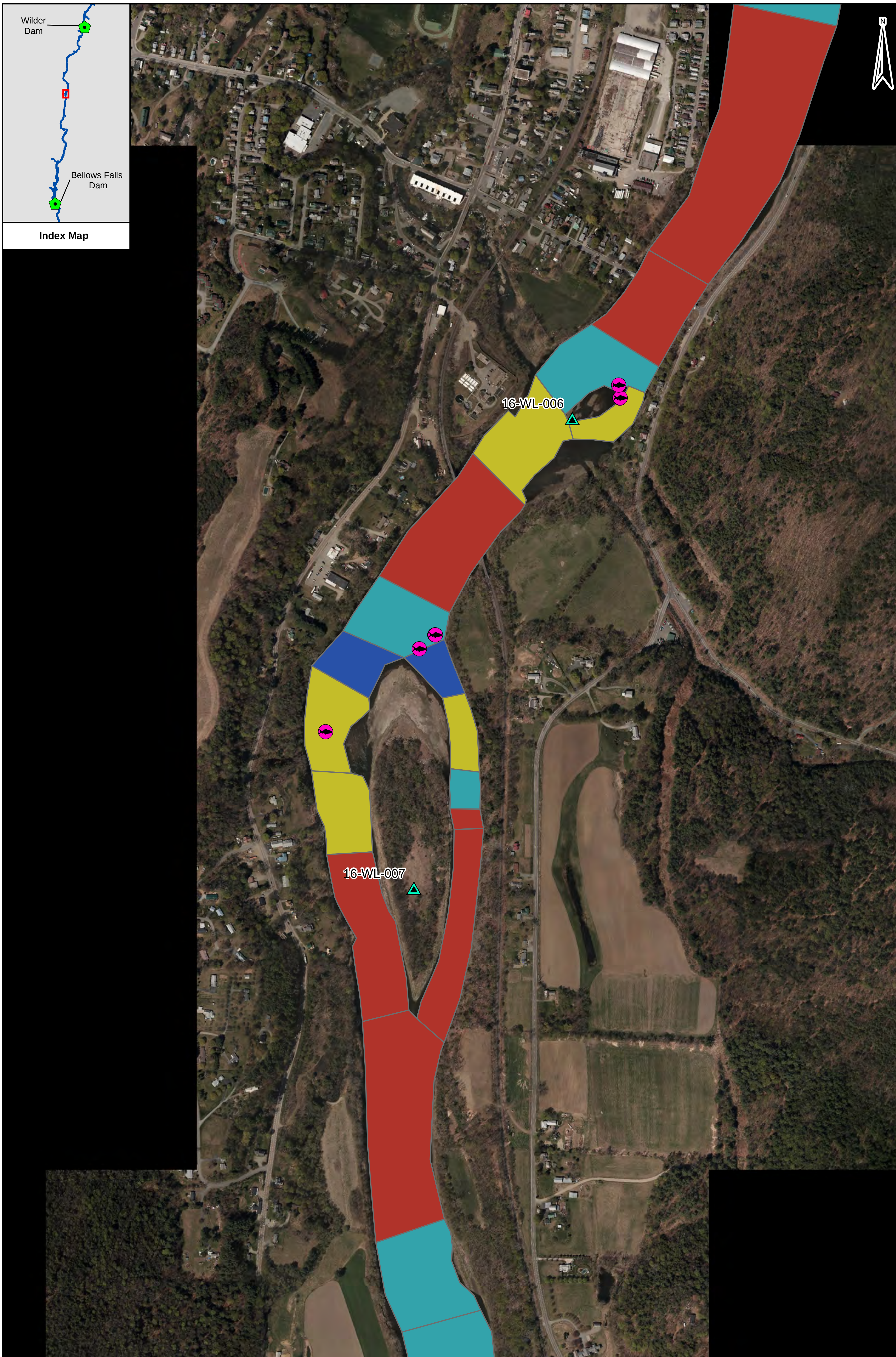

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Data Provided By:
U.S. Imaging

0 200 400 800 Feet

Spawning Locations

Nest Location

Study 16 Site

Meso-Habitat

Glide

Riffle

Pool

Run

Rapid

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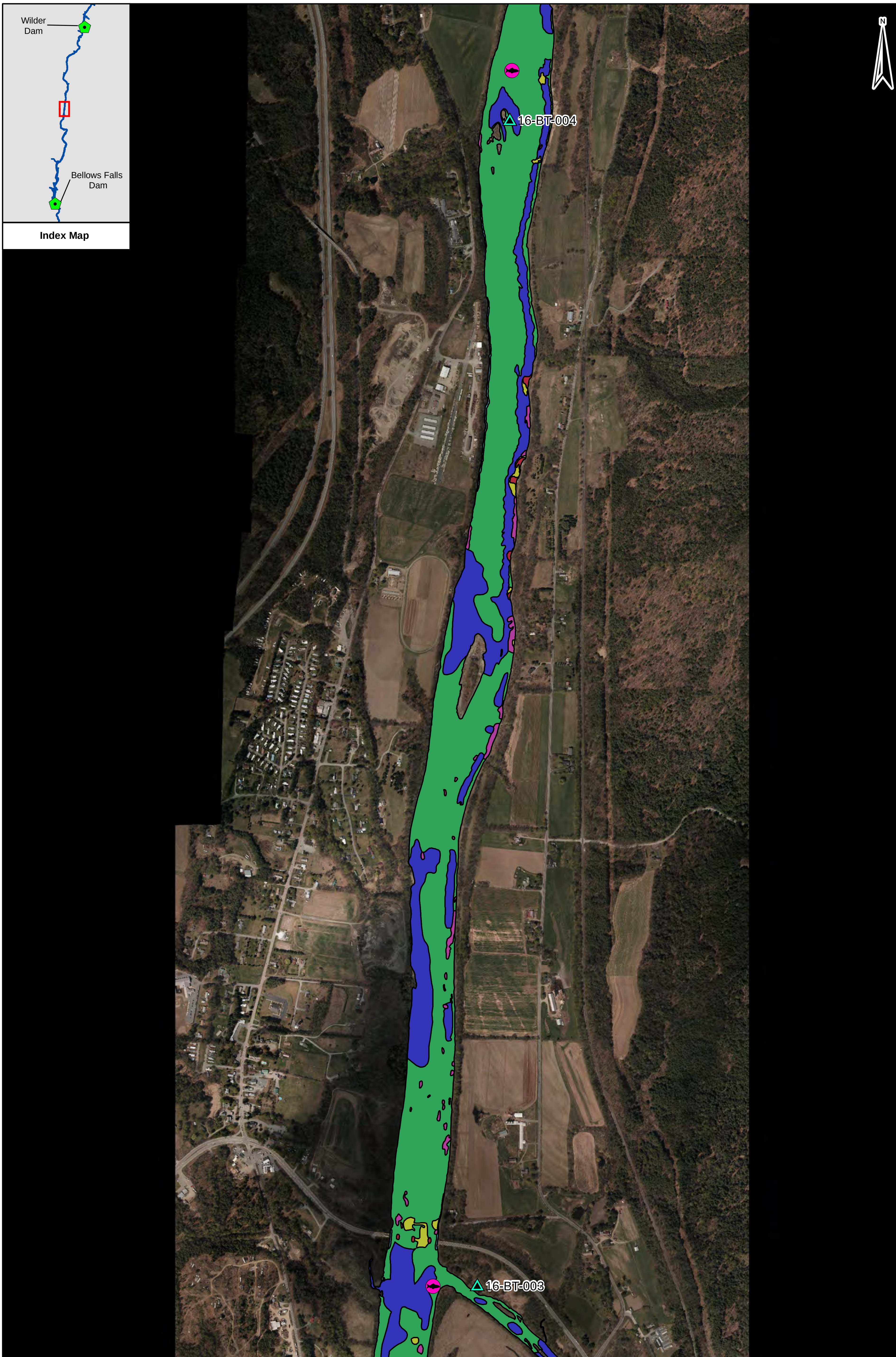

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Data Provided By:
U.S. Imaging

0 400 800 1,600 Feet

Spawning Locations
- Nest Location
- Study 16 Site

Substrate Type
- Boulder
- Gravel, Cobble
- Ledge
- Rip Rap
- Sand, Silt, Clay
- Woody Debris

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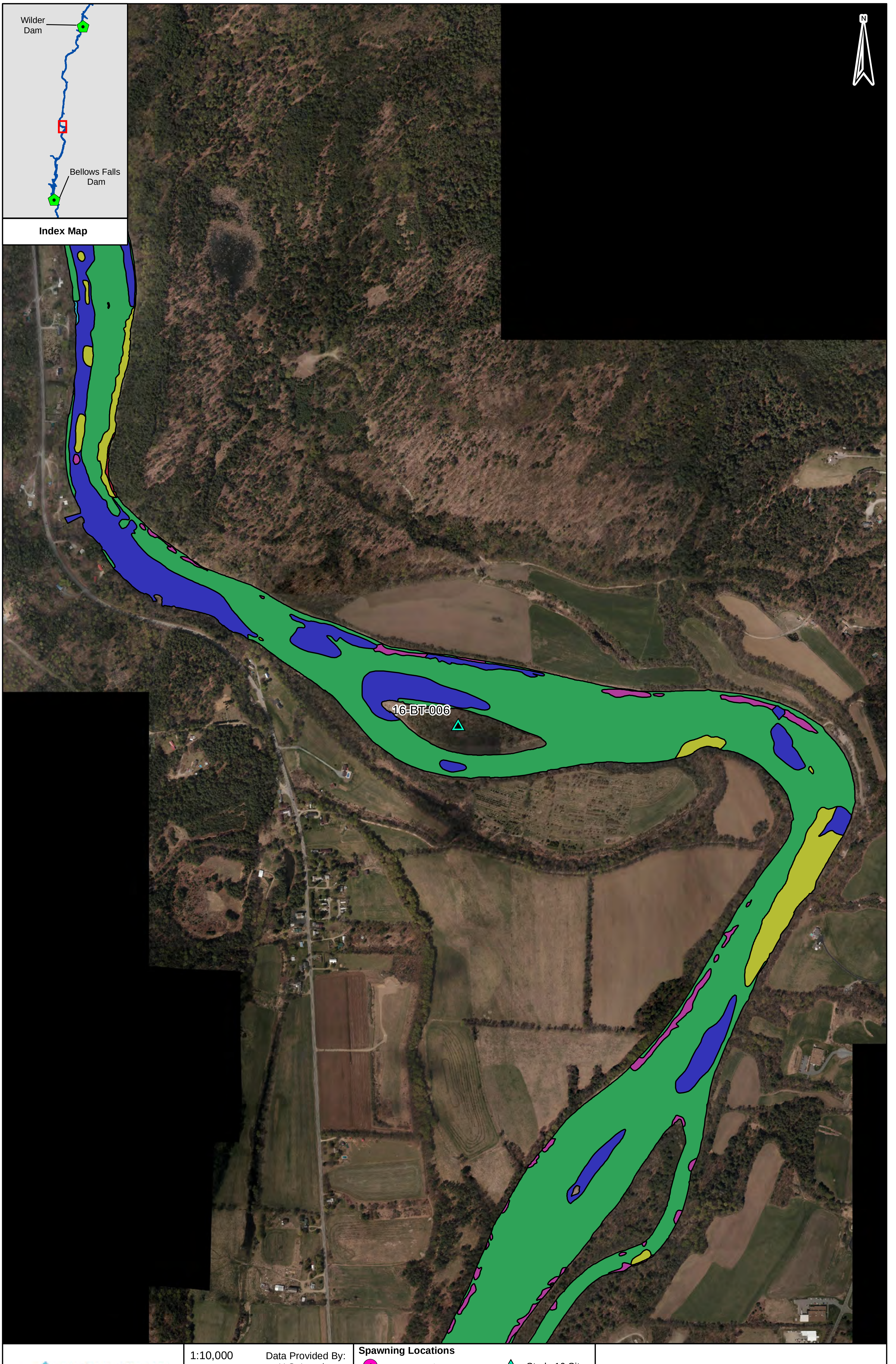

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Data Provided By: U.S. Imaging

0 300 600 1,200 Feet

Spawning Locations

- Nest Location
- Study 16 Site

Substrate Type

- Boulder
- Gravel, Cobble
- Ledge
- Rip Rap
- Sand, Silt, Clay
- Woody Debris

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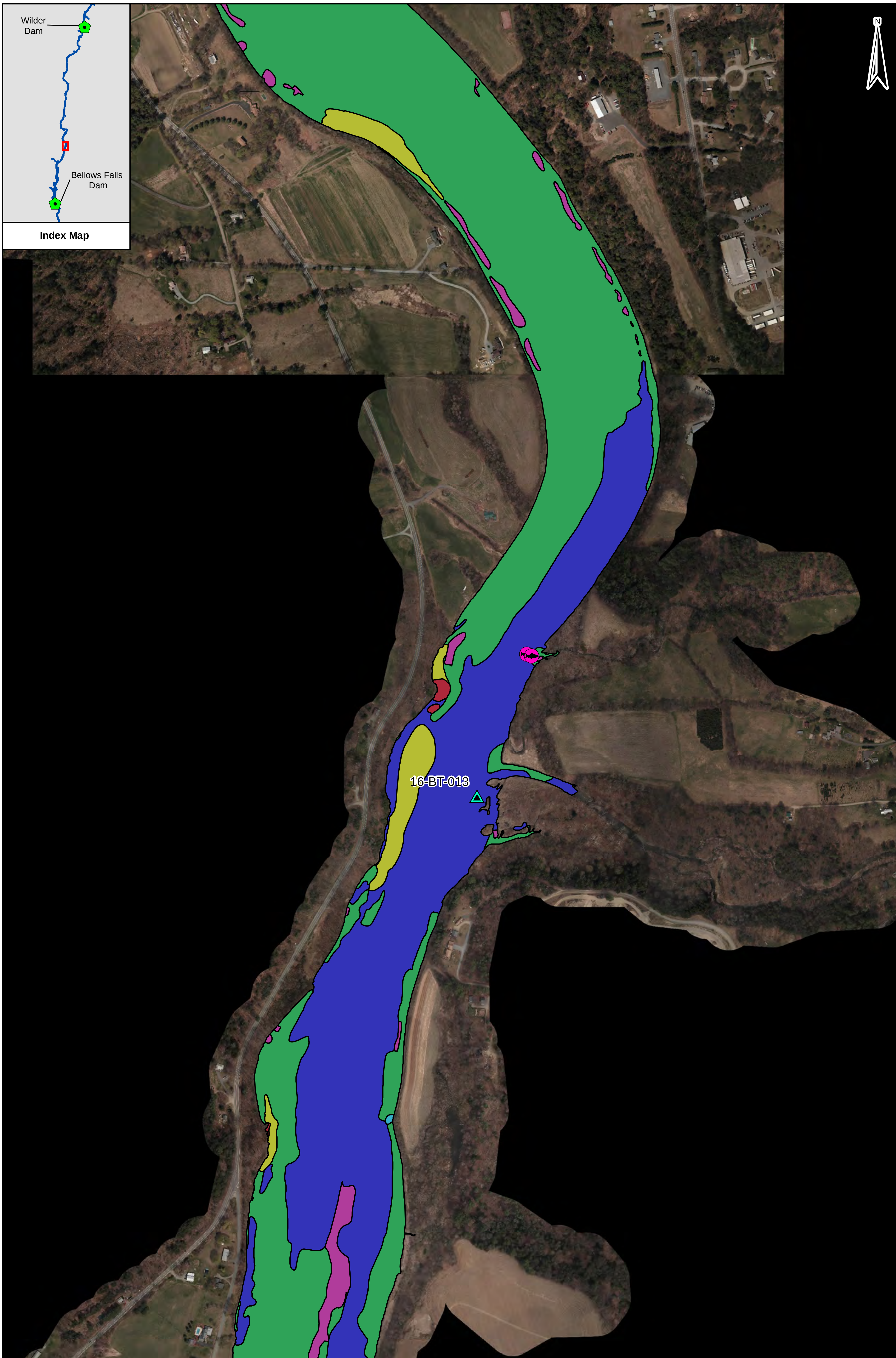
Study Site Locations & Nests



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Data Provided By:
U.S. Imaging

0 200 400 800 Feet

Spawning Locations

Nest Location

Study 16 Site

Substrate Type

Boulder

Rip Rap

Gravel, Cobble

Sand, Silt, Clay

Ledge

Woody Debris

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Data Provided By:
U.S. Imaging

0 200 400 800 Feet

Spawning Locations
Nest Location
Study 16 Site

Substrate Type
Boulder
Gravel, Cobble
Ledge
Rip Rap
Sand, Silt, Clay
Woody Debris

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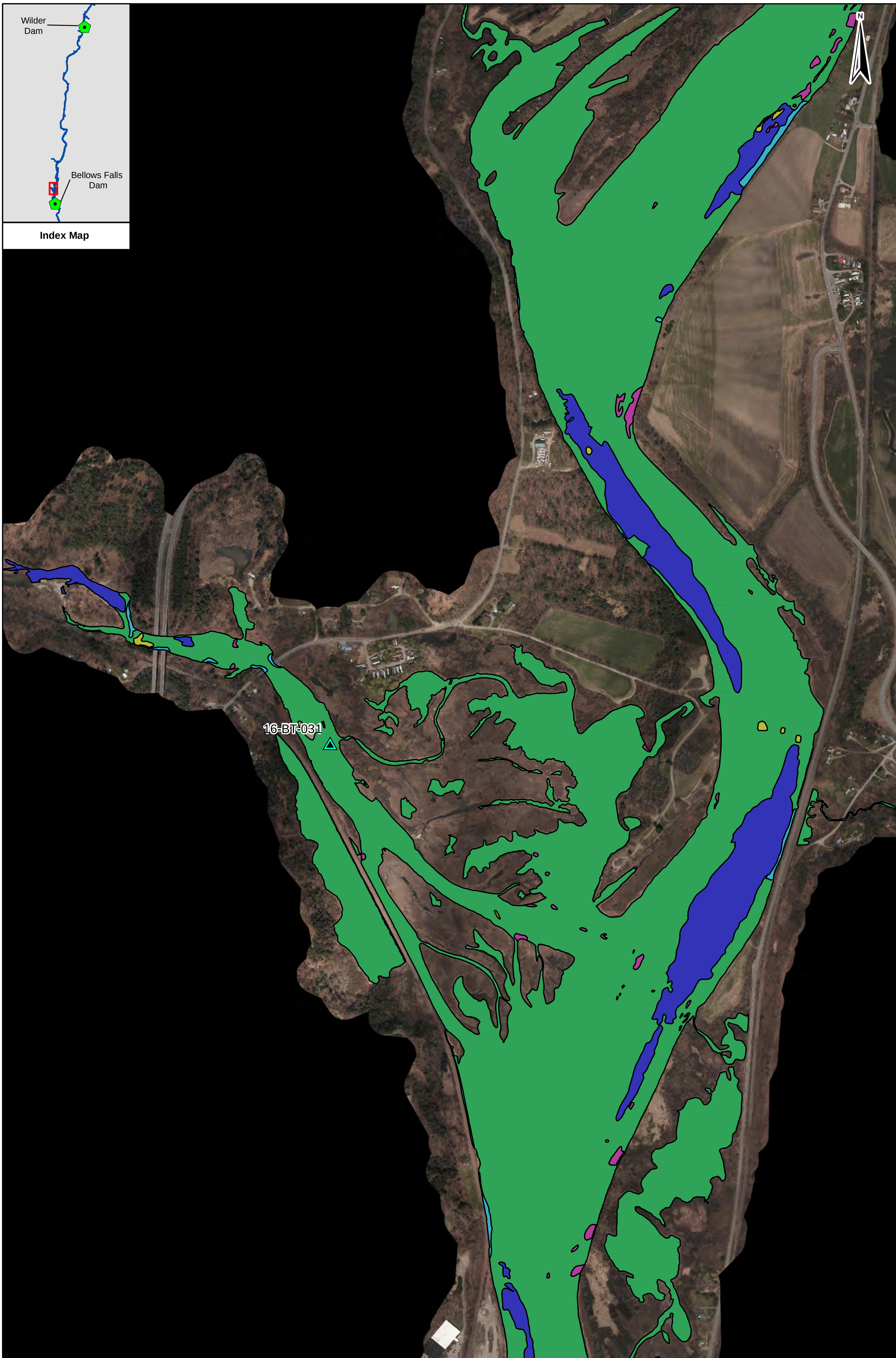

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Data Provided By:
U.S. Imaging

0 250 500 1,000 Feet

Spawning Locations
- Nest Location
- Study 16 Site

Substrate Type
- Boulder
- Gravel, Cobble
- Ledge
- Rip Rap
- Sand, Silt, Clay
- Woody Debris

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Study Site Locations & Nests

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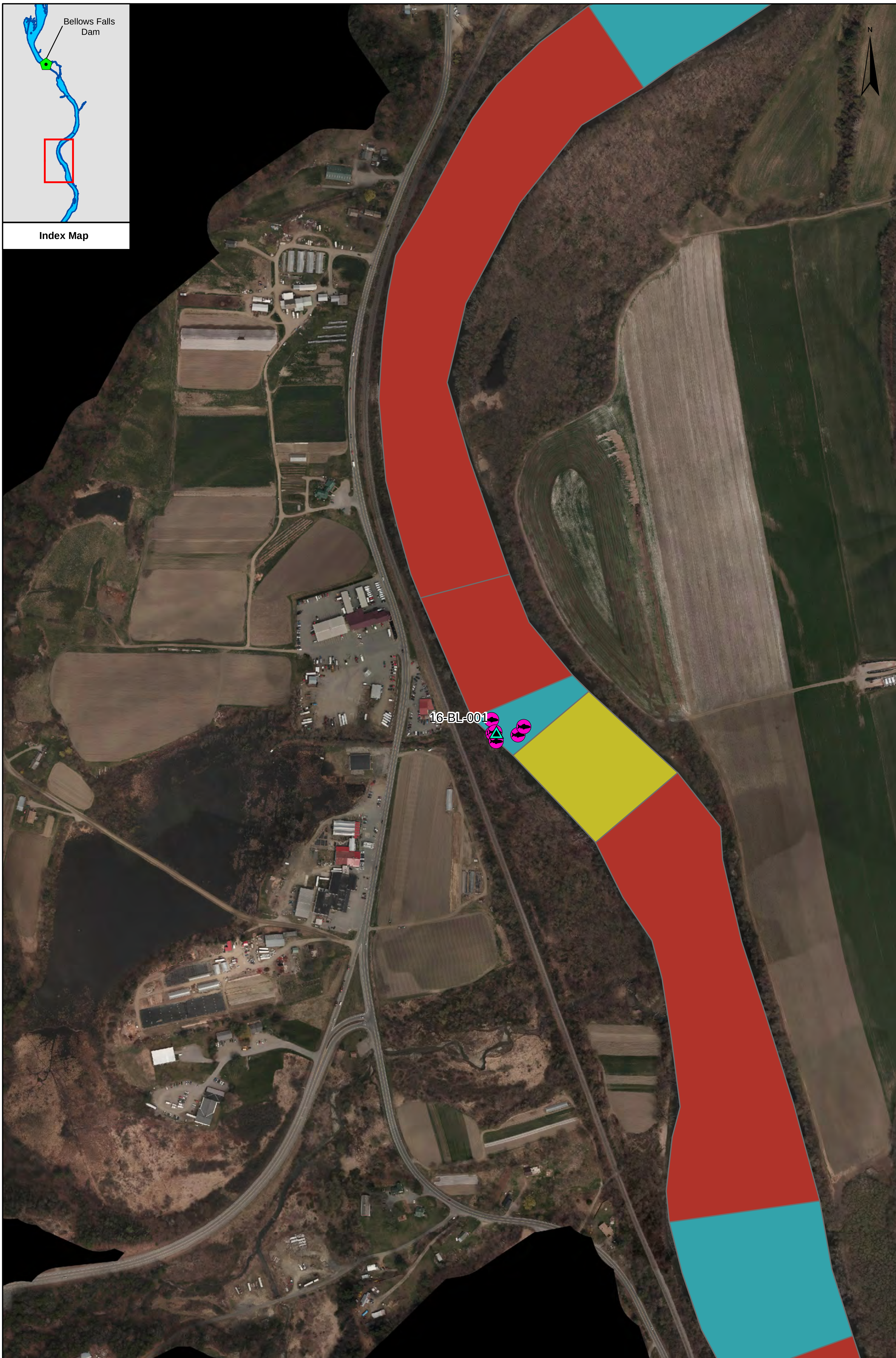

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Data Provided By:
U.S. Imaging

0 150 300 600 Feet

Spawning Locations

Nest Location

Study 16 Site

Meso-Habitat

Glide

Riffle

Pool

Run

Rapid

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Study Site Locations & Nests

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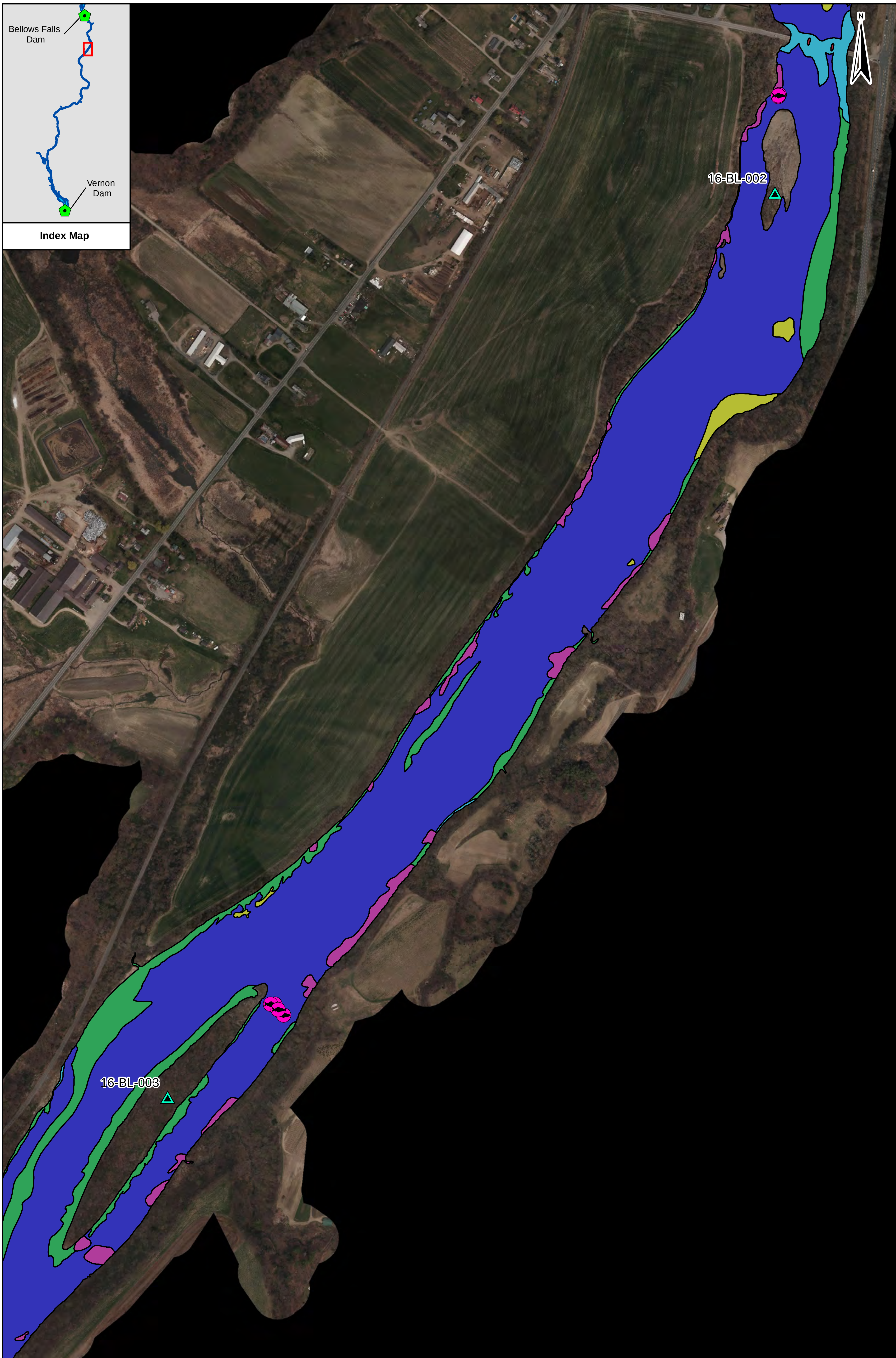

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Data Provided By:
U.S. Imaging

0 200 400 800 Feet

Spawning Locations

Nest Location

Study 16 Site

Substrate Type

Boulder

Gravel, Cobble

Ledge

Rip Rap

Sand, Silt, Clay

Woody Debris

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Study Site Locations & Nests

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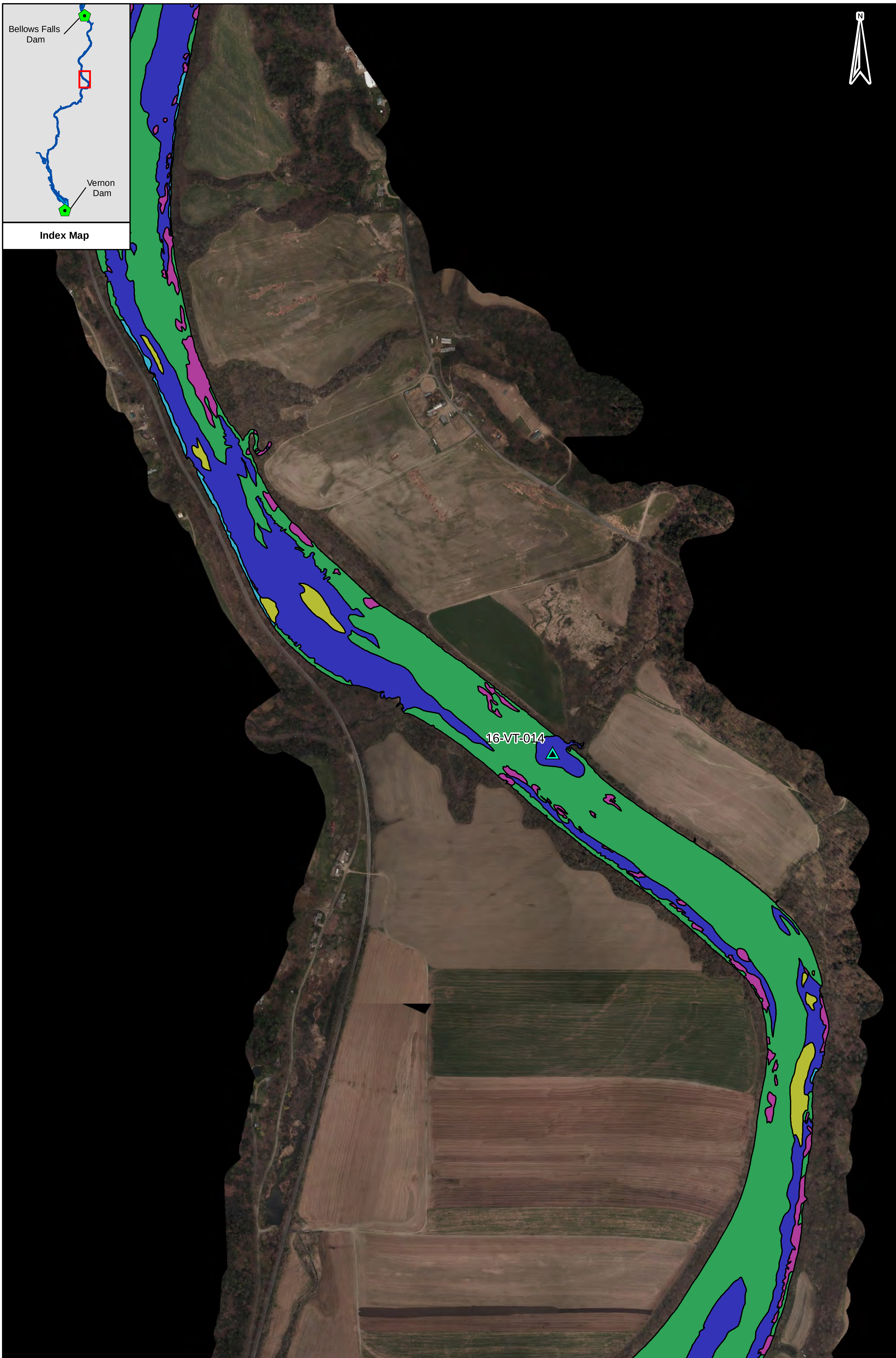

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Data Provided By:
U.S. Imaging

0 250 500 1,000 Feet

Spawning Locations
- Nest Location
- Study 16 Site

Substrate Type
- Boulder
- Gravel, Cobble
- Ledge
- Rip Rap
- Sand, Silt, Clay
- Woody Debris

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Study Site Locations & Nests

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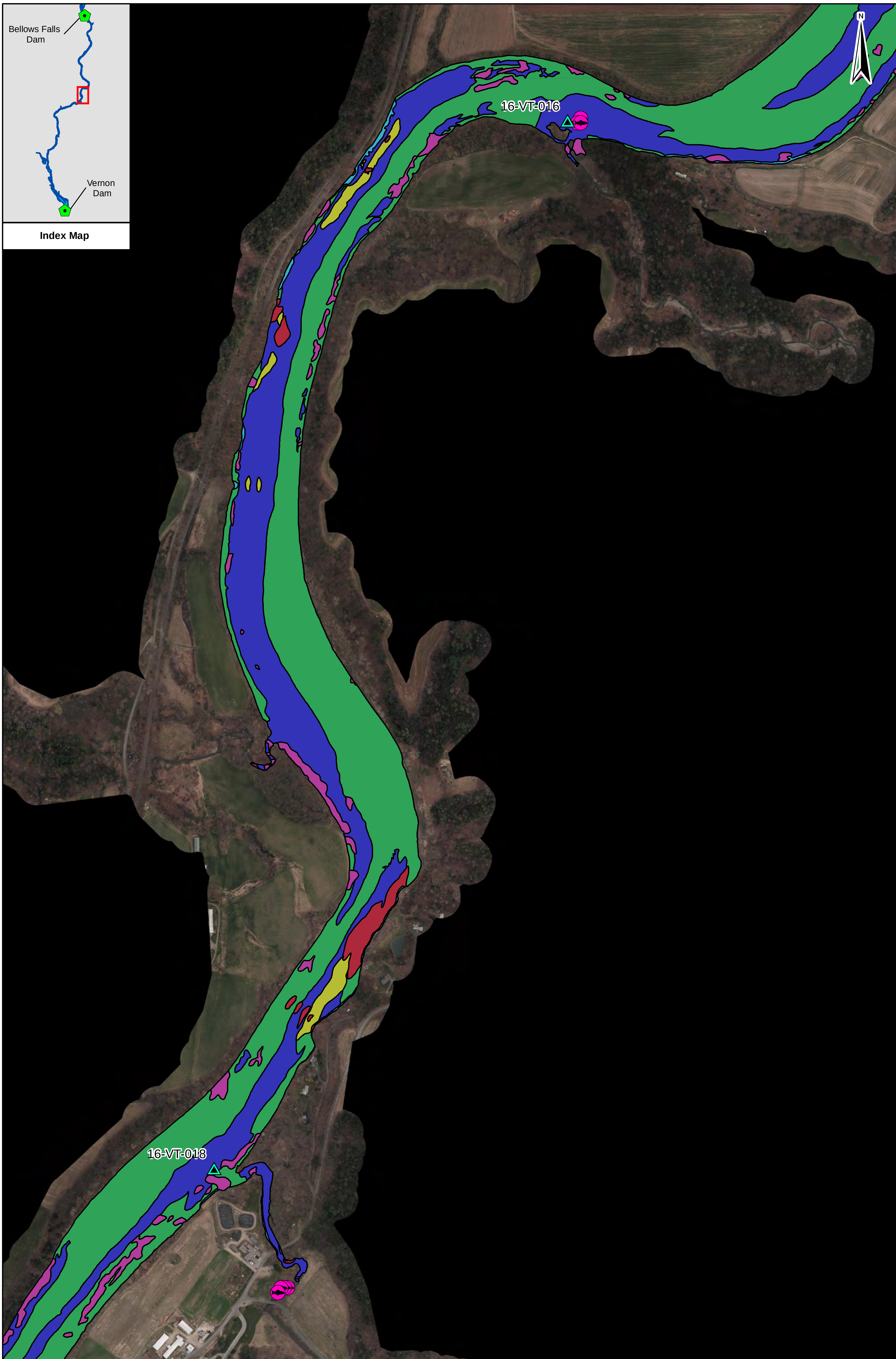

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Data Provided By:
U.S. Imaging

0 250 500 1,000 Feet

Spawning Locations
- Nest Location
- Study 16 Site

Substrate Type
- Boulder
- Gravel, Cobble
- Ledge
- Rip Rap
- Sand, Silt, Clay
- Woody Debris

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Study Site Locations & Nests

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Data Provided By:
U.S. Imaging

0 125 250 500 Feet

Spawning Locations
Nest Location
Study 16 Site

Substrate Type
Boulder
Gravel, Cobble
Ledge
Rip Rap
Sand, Silt, Clay
Woody Debris

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ILP Study 16
Study Site Locations & Nests

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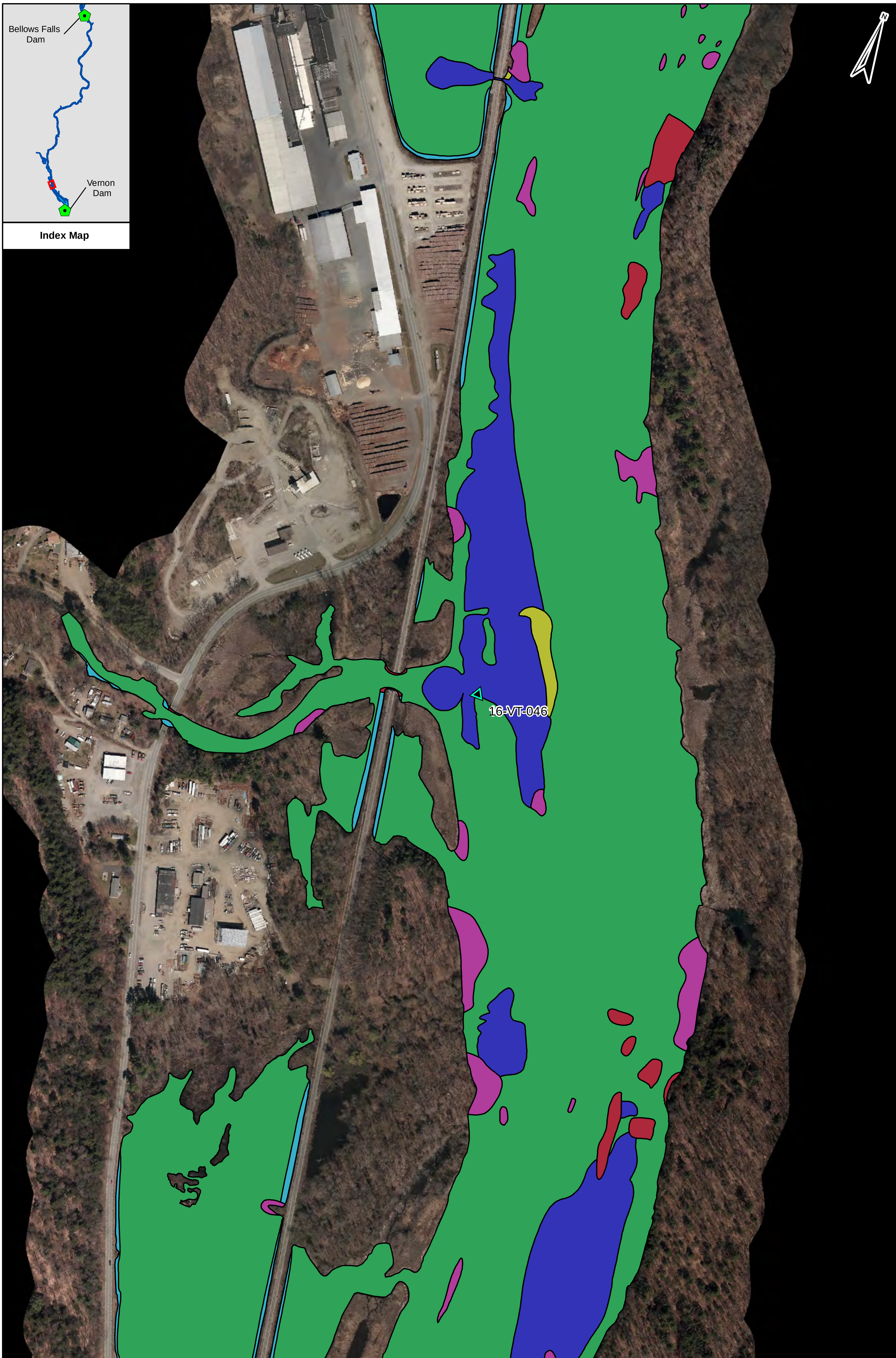

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Data Provided By:
U.S. Imaging

0 125 250 500 Feet

Spawning Locations

Nest Location

Study 16 Site

Substrate Type

Boulder

Gravel, Cobble

Ledge

Rip Rap

Sand, Silt, Clay

Woody Debris

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Study Site Locations & Nests

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1:7,000

Data Provided By:
U.S. Imaging

0 200 400 800 Feet

Site Features
Nest Location
Study 16 Site

Meso-Habitat
Glide
Pool
Rapid
Riffle
Run

TransCanada Hydro Northeast Inc.
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Study Site Locations & Nests

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