Penacook Lower Falls Hydroelectric Project (FERC No. 3342)

Penacook Upper Falls Hydroelectric Project (FERC No. 6689)

Rolfe Canal Hydroelectric Project (FERC No. 3240)

Application for Subsequent License
Major Water Power 5 Megawatts or Less

EXHIBIT E – ENVIRONMENTAL REPORT

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List of Abbreviations

Category	Abbreviation	Meaning
Applicant/projects	Briar Hydro	Briar Hydro Associates / project owner / applicant
	PLF	Penacook Lower Falls
	PUF	Penacook Upper Falls
	RC or Rolfe	Rolfe Canal
	Projects or three projects	Penacook Lower Falls, Penacook Upper Falls, and Rolfe Canal collectively
Agencies	FERC	Federal Energy Regulatory Commission
	USFWS	United Stated Fish and Wildlife Service
	NMFS	National Marine Fisheries Service
	EPA	Environmental Protection Agency
	USGS	United States Geological Survey
	NH DES	New Hampshire Department of Environmental Services
	NHDHR	New Hampshire Department of Historical Resources
	NHFG	New Hampshire Fish and Game
	NH NHB	New Hampshire Natural Heritage Bureau
Units	cfs	cubic feet per second
	kW	killowatt
	kWh	Kilowatt hour
	ft	feet
	in.	inch
	mm	millimeter
	mi^2 or sq.mi.	square mile
	mg/L	milligram per liter
	µg/L	microgram per liter
	°C	degree celcius
	s.u.	standard unit
	MSL	Mean Sea Level
	NGVD	National Geodetic Vertical Datum
Policies and plans	CWA	Clean Water Act
	CZMA	Coastal Zone Management Act
	ESA	Endangered Species Act
	NHPA	National Historic Preservation Act
	SWQPA	Shoreland and water quality protection act
	SCORP	Statewide comprehensive outdoor recreation plan
	FPA	Federal Power Act

Relicensing process	PAD	Pre-Application Document
	PSP	Preliminary Study Plan
	RSP	Revised Study Plan
	SAP	Sampling and Analysis Plan
	IFS	Instream Flow Study
	WQC	Water Quality Certificate
	PM&E	Protection, mitigation, and enhancement
Fish	DPS	Distinct Population Segment
	EFH	Essential Fish Habitat
	HAPC	Habitat Area of Particular Concern
Miscellaneous	BMP	Best Management Practice
	TMDL	Total Maximum Daily Load
	IPaC	Information for Planning and Consultation

Exhibit E Environmental Report

2.1 Consultation and relicensing process timeline

Activity	Schedule	Comments
a) File NOIs, PAD and Request for TLP	November 30, 2019	Existing licenses expires on 11/30/2024
b) Publish notice of the filing of NOI, PAD and Request for TLP in a daily or weekly newspaper in each county	November 30, 2019	Solicit comments to be filed with the Commission within 30 days of the filing date of request
c) Deadline for Public Comment on Request to Use TLP	December 30, 2019	
d) FERC approve TLP	February 6, 2020	
First Stage Consultation (Pre-Application)		
e) Host public consultation meeting	June 18, 2020	online virtual meeting due to COVID19 pandemic
f) Host site visits	July 28, 2020	Delayed due to COVID19 pandemic
g) Study Scoping & Planning:	May-December 2020	
a. Deadline to Receive written agency comments & study requests	September 30, 2020	Received comments/requests from NH DES, NHFG, USFWS, NMFS
b. Proposed Study Plan distributed to stakeholders	December 15, 2020	
c. Deadline to receive comments on proposed Study Plan	February 11, 2021	
d. Stakeholder meeting to discuss study plan and comments	March 3, 2021	
e. File revised study plan	July 6, 2022	
Second Stage Consultation (Information Gathering and Studies)		
h) Conduct Studies	June 2021-October 2021 *(Spring & Summer Studies)*	
i) Distribute Study reports to stakeholders	March 29, 2022	

j)	Meeting to present and discuss study results with stakeholders	May 4, 2022	
k)	Deadline for comments on study reports and PM&E measures requests	June 26, 2022	Only response received was NH DES comments on the IFS
l)	Prepare draft license application	June/July 2022	Contains the results of studies requested by agencies and discussion of study results and proposed protection, mitigation, and enhancement measures
m)	Distribute and file Draft license Application with Written request for review/comment	July 15, 2022	
n)	Receive agency comments	October13 2022	Within 90 days of DLA release
o)	Multiple meetings with USFWS, NHDES, NHFG, and NMFS staff to discuss fish passage PM&E and fish passage feasibility study	October-November 2022	
Third Stage Consultation (License Application Filing)			
p)	File final license application with FERC	November 2022	**Must be filed no later than 24 months before the existing license expires (deadline 11/30/2022)**

2.1.1. Compliance with or Consultation under the Following Laws

A license issued for the Rolfe Canal, Penacook Upper Falls, and Penacook Lower Falls would be subject to several applicable statutes and requirements under the Federal Power Act. Relevant federal regulations are discussed below in detail.

2.1.1.2 Section 401 of the Clean Water Act

The three projects are subject to Water Quality Certification from the New Hampshire Department of Environmental Services and Section 401(a)(1) of the Federal Clean Water Act of 1977.

Briar Hydro will provide a copy of the request to the State of New Hampshire for a Section 401 Water Quality Certification within 60 days of the FERC notice of acceptance of the Final License Application (FLA).

2.1.1.3 Endangered Species Act (ESA)

State and Federal database (NH NHB and USFWS IPaC) were checked for known occurrences of rare, threatened, and endangered species in the vicinity of the projects.

Federal and state listed threatened or endangered species and proposed mitigation steps are discussed in Section 2.7.

2.1.1.4 Magnuson-Stevens Fishery Conservation and Management Act

Based on a review of the National Marine Fisheries Service online database, the Contoocook River is listed as an EFH for the federally listed Atlantic salmon. Atlantic salmon in the Central New England DPS are considered extirpated and therefore not protected under the ESA. With the discontinuation of propagation and stocking of salmon in the Merrimack River in 2013, only remnant or stray fish may return. No other designations such as habitat areas of particular concern (HAPC) or critical habitat as defined under the Magnuson-Stevens Fishery Conservation and Management Act have been identified in the Contoocook River.

2.1.1.5 Coastal Zone Management Act (CZMA)

Under section 307(c)(3)(A) of the Coastal Zone Management Act (CZMA), the Commission cannot issue a license for a project within or affecting a state's coastal zone unless the state CZMA agency concurs with the license applicant's certification of consistency with the state's CZMA program, or the agency's concurrence is conclusively presumed by its failure to act within 180 days of its receipt of the applicant's certification.

The projects are not located within the designated coastal zone of NH. We provide below, correspondence confirmation of this determination from NH DES coastal program coordinator.

From:	Williams, Chris <CHRISTIAN.P.WILLIAMS@des.nh.gov>
Sent:	Wednesday, October 19, 2022 2:12 PM
To:	Madeleine Mineau
Subject:	RE: CZMA determination requested

Hello Madeleine,

Thanks for your email. You are correct that the three hydroelectric facilities referenced in your email below (Penacook Lower Falls P-3342, Penacook Upper Falls P-6689, and Rolfe Canal P-3240) are located outside New Hampshire's coastal zone. As a result, the proposed relicensing of the three hydroelectric facilities is not subject to Coastal Zone Management Act federal consistency review by the New Hampshire Coastal Program.

Please feel free to contact me should you have any further questions.

Regards,

Christian Williams | Program Coordinator
Coastal Program
Watershed Management Bureau
Water Division, NH Department of Environmental Services
222 International Drive, Suite 175
Portsmouth, NH 03801
Phone: 603-559-0025
Christian.Williams@des.nh.gov

2.1.1.6 National Historic Preservation Act Section 106

Section 106 of the National Historic Preservation Act (NHPA) requires that every federal agency consider that an undertaking could affect historic properties and to consult with the Advisory Council on Historic Preservation (ACHP) regarding such undertakings. Historic properties are defined as districts, sites, buildings, structures, traditional cultural properties, and objects significant in American history, architecture, engineering, and culture that are eligible for inclusion in the National Register of Historic Places (National Register).

Pursuant to Section 106, Briar Hydro has consulted with the New Hampshire Historic Preservation Officer (od NH Department of Historic Resources NH DHR) and affected Indian tribes. Briar Hydro previously requested project review for each of the three projects, gave the NH DHR the opportunity to request studies, and consulted with NH DHR staff in a meeting on 06/29/2022. No studies related to historical or cultural resources were requested. The existing information available from previous project review and consultation is presented in section 2.10 of this Exhibit E. Briar has requested a written NH DHR concurrence on the Area of Potential Effect and will file the response when it is received.

2.1.1.7 Wild and Scenic Rivers Act

Section 7(a) of the Wild and Scenic Rivers Act requires federal agencies to make a determination as to whether the operation of a project would affect the scenic, recreational, and/or fish and wildlife values present in a designated or study river corridor. The Contoocook River is not a National Wild and Scenic Rivers System nor is it included as a study river or currently being considered for study.

2.2 General Description of the Watershed

The Contoocook River flows for 71 miles from Poole Pond in Rindge, NH north to the state capital of Concord, where it enters the Merrimack River. Encompassing a drainage basin of approximately 760 square miles, the Contoocook has a total drop of over 700 feet.

The North Branch River is a major tributary of the Contoocook and flows for 16 miles from its headwaters in Stoddard through Antrim and Hillsboro where it joins the main stem of the Contoocook River. The entire lengths of these two rivers were designated into the New Hampshire Rivers Management and Protection Program in June 1991.Other major tributaries of the Contoocook River include the Warner River and the Blackwater River.

The Contoocook River watershed includes significant flood control infrastructure built in the late 1950s and early 1960s. The Hopkinton-Everett Flood Risk Management program is operated by the U.S. Army Corp of Engineers. The flood storage area behind Hopkinton Lake totals 3,700 acres and extends about 8.5 miles upstream through Henniker to the Contoocook Valley Paper Company. This acreage includes areas that are normally empty and areas that have permanent bodies of water. Hopkinton Lake is connected to Everett Lake another flood control facility on the Piscataquog River. Most flooding on the Contoocook River is either minor or moderate and does not require the transfer of excessive floodwaters through the canals. Since the project's completion in December 1962, the diversion of Contoocook River floodwaters from behind the dam at Hopkinton Lake to the flood storage area behind the dam at Everett Lake has occurred only seven times, the last in April 1987 when the combined reservoir area of the two dams was filled to 95 percent of capacity, its highest level ever. The Hopkinton Dam is located at approximately River Mile 22.5.

The Penacook Lower Falls (P-3342), Penacook Upper Falls (P-6689), and Rolfe Canal (P-3240), all commonly owned by Briar Hydro Associates, are the first three dams on the Contoocook River closest to the confluence with the Merrimack River. They are located at river mile 0, 1, and 2.1, respectively. Upstream of the Briar Hydro projects, there are 7 additional hydropower projects and the Hopkinton flood control dam. Those dams are Hopkinton Hydro P-5735 owned by Contoocook Hydro LLC at river mile 17. Hoague-Sprague P-4337, Hopkinton flood control dam owned by the US Army Corp of Engineers, Hosiery Mill P-6116, Steeles Pond P-3265, Monadnock Paper Mills P-6597, Noone Mills dam P-4318, and Cheshire dam P-9509.

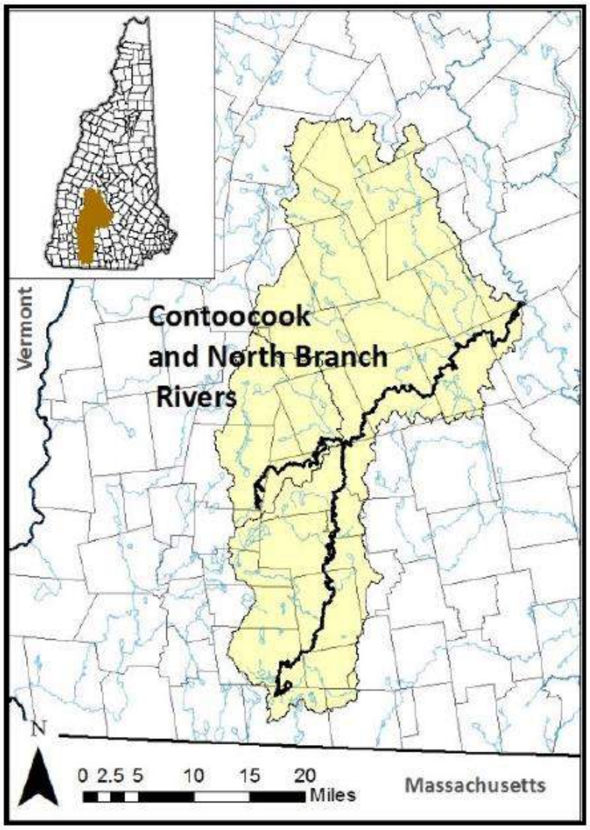


Figure E.1 Map of the Contoocook River Watershed.

2.2.1 Climate

The project is within a climate region typical of north-central New England and inland New Hampshire, as it is characterized by moderately warm summers, cold winters, and adequate precipitation. Shown in Figure E.2 is the average monthly precipitation (in.) and average high and low monthly temperatures. The average annual precipitation is 40.61 inches, while the coldest and warmest months of the year are January and July, respectively.

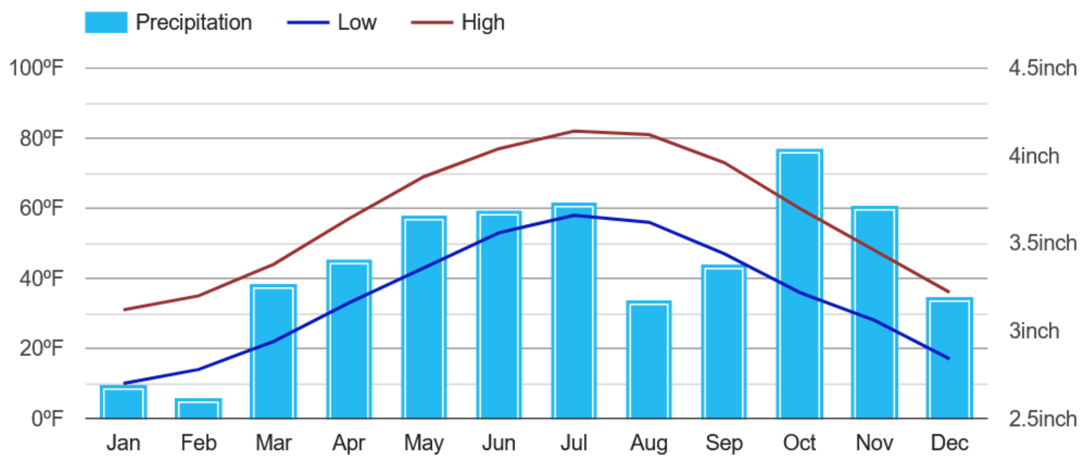


Figure E.2. Graph showing average monthly high (red line) and low (blue line) temperatures as well as average monthly total precipitation (blue bars) for Concord NH.

2.2.2 Topography

The projects are located in the Merrimack River valley which is relatively flat with some hilly terrain. Slopes of the river banks in the area are mostly shallow. The only notable high point in the area is Dagody Hill which rises from a base elevation of approximately 400 feet to an elevation of 625ft. A topographic map of the area with 40ft elevation contours is shown below in figure E.3.

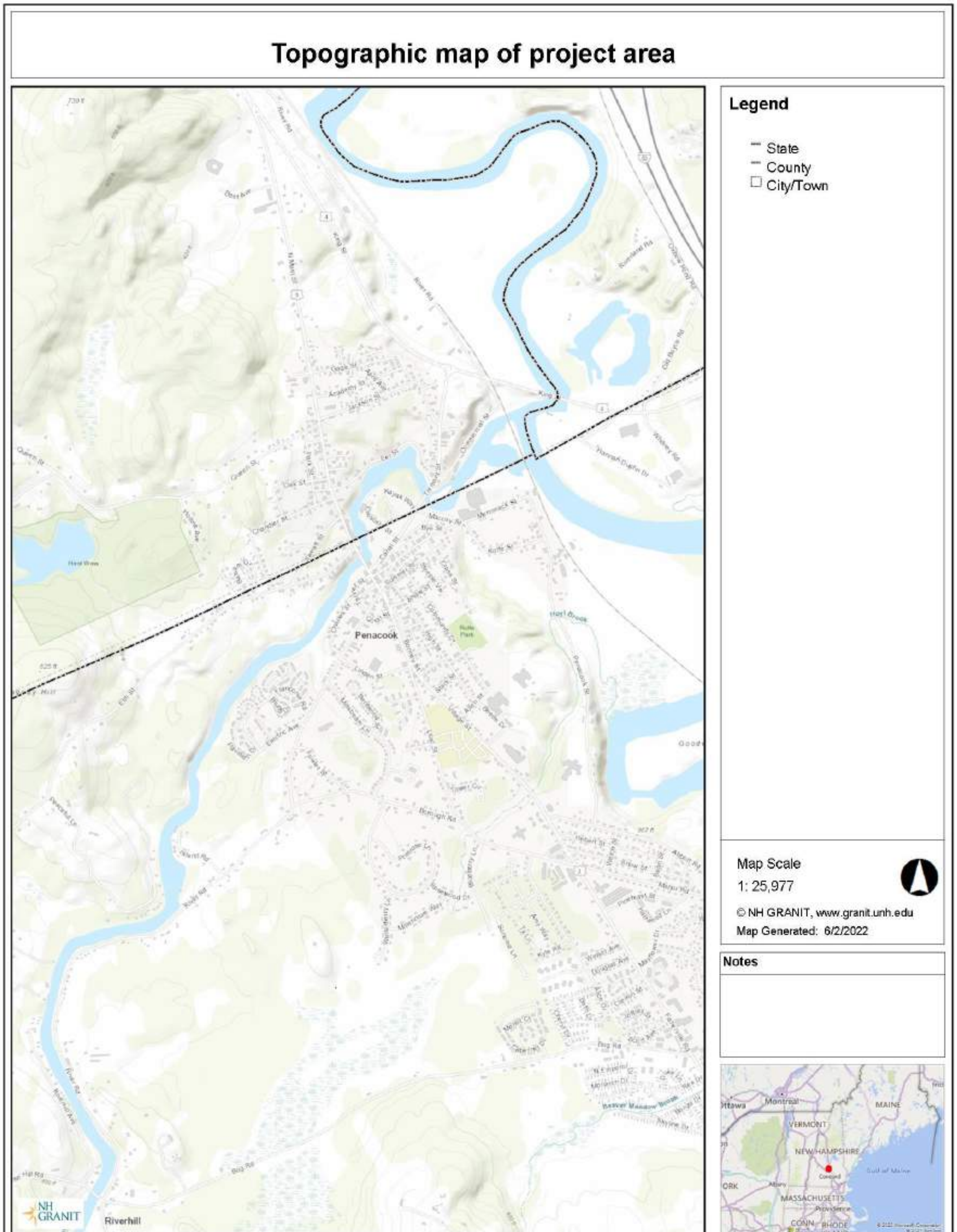


Figure E.3 Topographic map of the vicinity of the three project areas.

2.3 Geology and Soils

2.3.1 Affected environment

2.3.1.1 Bedrock Geology

The bedrock geology underlying the project area is the Rangeley formation and the unit description is gray, thinly laminated (5-25 mm) metapelite containing local lentils of turbidites and thin quartz conglomerates in western New Hampshire. Sparse calc-silicate pods and coticule. Probably equivalent to member B of Rangeley Formation of Maine. Other formations nearby include Concord Granite, the Upper part of Rangeley Formation, and Kinsman Granodiorite. A map of bedrock geology in the vicinity of the project area is shown in figure E.4 below.

2.3.1.2 Surficial Geology

The surficial geology in the project area is composed primarily of alluvium, stream terrace deposits, Penacook delta, till, and localized areas of bedrock exposure. These layers are made up mostly of sand or sand and gravel. The alluvium can be as much as 25feet deep, while the stream terrace deposits can be up to 10 feet deep (Pendleton,1995 surficial geology map of the Penacook Quadrangle).

There are no known or documented mineral resources located within the project area.

2.3.1.3 Soils

The soils in the project area are made up of Millsite-Woodstock-Henniker Complex, Boscawen fine sandy loam, and Champlain-Urban land complex

Millsite-Woodstock-Henniker Complex (480 C and 480B): This map unit consists of Millsite, Woodstock, and Henniker soils that are so intermingled that it was not practical to map them separately. They formed in glacial till on hills, ridges, and mountains. Millsite soils are well drained and have bedrock at a depth of 20 to 40 inches. Woodstock soils are somewhat excessively drained and have bedrock at a depth of 10 to 20 inches. Henniker soils are well drained and have a depth to bedrock of more than five feet. This map unit is about 35 percent Millsite, 20 percent Woodstock, 20 percent Henniker, and 25 percent other soils. Stones cover 0.01 to 3 percent of the surface.

Boscawen fine sandy loam (220B): This excessively drained soil is on glacial outwash plains and terraces. Permeability is rapid to very rapid. Available water capacity is very low. Depth to bedrock is more than 5 feet. Seasonal high water table is at depths greater than 6 feet. Frost action potential is low.

Champlain-Urban land complex (789B): This map unit consists of Champlain soils and Urban land that are so intermingled that it was not practical to map them separately. These areas are on glacial outwash plains and terraces that have been partially covered by streets, parking lots, and buildings. They are rectangular or irregular in shape and range from 6 to 250 acres in size. This map unit is about 45 percent Champlain soils, 40 percent Urban land, and 15 percent other soils.

A soils map of the general vicinity of the project area is shown in figure E.5 below.

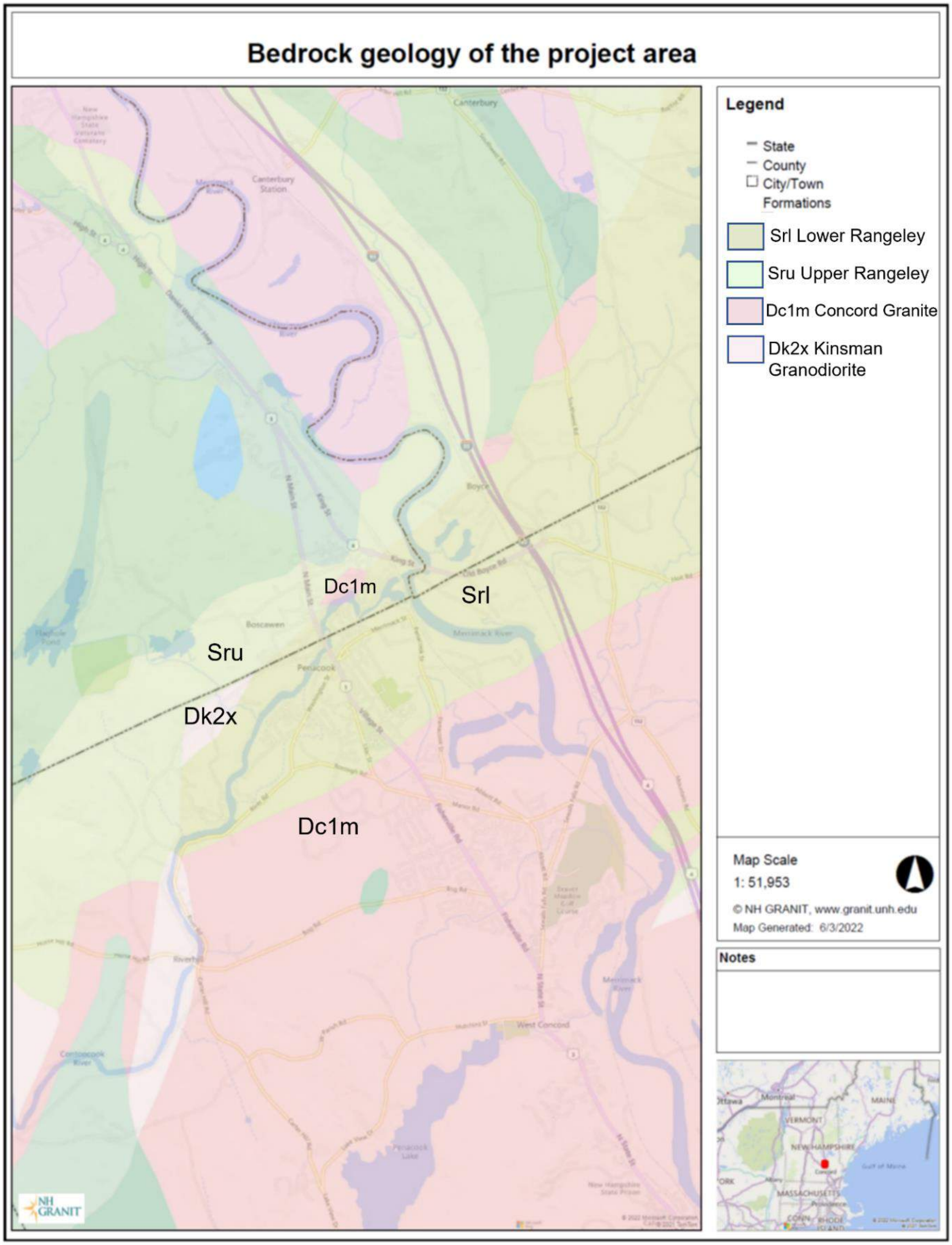


Figure E.4 Bedrock geology in the vicinity of the project area.

Figure E.5. Soils in the vicinity or the project area showing areas of Millsite-Woodstock-Henniker Complex (480 B and 480 C), Boscawen Fine Sandy Loam (220B), and Champlain Uraban Land Complex (789B).

2.3.1.4 Reservoir Shoreline

The shoreline of the project impoundments is a mix of natural and man-made surfaces including some tree cover, landscaped areas such as lawns, and some retaining walls, buildings, or bridge abutments that abut the river directly.

2.3.1.5 Aquifer

Stratified-drift aquifers discontinuously underlie 121 mi^2 (square miles) of the Contoocook River Basin, which has a total drainage area of 760 mi^2 (Harte and Johnson, 1995). The distribution of stratified-drift aquifers is largely controlled by the Pleistocene glaciation process and the formation of multiple glacial lakes along the main stem of the Contoocook River (Harte and Johnson, 1995). Locally, saturated thickness of stratified drift within these aquifers are as great as 200 feet (Harte and Johnson, 1995).

2.3.1.6 Wells

Residences and businesses in the vicinity of the project area are supplied with water by the Penacook Boscawen Water precinct. The Penacook-Boscawen water system draws from three gravel packed wells located on land near the Merrimack County Complex which is located approximately 7 miles north-north-west of the projects. We are not aware of any wells that would be affected by the project.

2.3.2 Project Impact of Geology and Soils

The shoreline within the Project boundary is either vegetated or adjacent to developed lands, and sometimes armored, which limits erosion potential. Additionally, soils within the Project area are unlikely to have high erosive characteristics. The Project will continue to operate in a run of river mode, which minimizes large fluctuations of flow in downstream reaches and maintains stable flows, which reduces the potential for erosion within the Project boundary. Any water level fluctuations will only be attributable to natural flow conditions. As such, it is not expected that Project operations will adversely affect shoreline erosion, or impacts relating to geology and soils.

2.3.3 Protection, Mitigation, and Enhancement Measures (PM&E)

2.3.3.1 Agency Recommended mitigation

Briar Hydro is not aware of any agency proposed PM&E measures related to geology and soils resources.

2.3.3.2 Applicant Proposed Mitigation

Briar Hydro is not proposing any PM&E measures related to geology and soils.

2.4 WATER RESOURCES

2.4.1 Affected environment

The project is located on the Contoocook River near the confluence with the Merrimack River. A description of the Contoocook River watershed is included in section 2.2 of this report.

2.4.1.1Water Quantity

A US Geological Survey (USGS) gage (01088000), located one-half mile upstream from the mouth of the Contoocook River, was maintained on the river from 1928 to 1977. The average flow over the 49 years of record was 1,255 cubic feet per second (cfs). The maximum discharge of record, 46,800 cfs, occurred on March 20, 1936; the minimum, 38-cfs, occurred August 17, 1965. The 7Q10 for this period is 94 cfs. Daily minimum flows of 57 cfs were recorded on October 12, 1964 and August 16, 1965. The highest mean monthly discharge occurs in April at 3,890 cfs and the lowest monthly mean discharge occurs in August at 331 cfs.

Monthly minimum, mean and maximum recorded flows for the recorded period 1928-1977 at stream gauge USGS 01088000 are shown below.

YEAR	Monthly mean in ft3/s (Calculation Period: 1928-12-01 -> 1977-08-31)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	1,050	1,060	2,170	3,890	1,920	982	475	334	465	501	1,000	1,200
Maximum	2,388	3,206	9,197	7,305	4,075	2,297	1,972	993	5,117	2,088	2,964	3,292
Minimum	284	280	361	1,501	692	206	115	87	101	119	177	318

The nearest currently functioning USGS stream data gage is located below the Hopkinton Dam (01085500). This gage is located at a watershed area of 427 square miles and does not include discharge from the Warner River or the Blackwater River. To scale discharge at this station to the whole watershed we multiplied discharge by 1.77 (427 sq mi x 1.77 = 760 sq.mi.) to generate the extrapolated below monthly average discharge values for the most recent 10 years (2011-2021, note there are months omitted in 2013 and 2014 due to incomplete data).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean (cfs)	1,894	1,528	1,894	2,620	1,519	885	889	786	609	1,301	1,823	2,283

Briar Hydro is not aware of any current or proposed water withdrawal from the project impoundment.

Impoundments

The Penacook Lower Falls reservoir has a normal maximum water surface area of 8.4 acres at 278.6 feet NGVD29. The gross storage capacity is 54 acre-feet. The mean depth is approximately 12 feet and the shoreline length is approximately 1.8 miles.

The Penacook Upper Falls reservoir has a surface area of 11.4 acres and the normal water surface elevation is 306 feet MSL. The dam has a negligible storage capacity.

The Rolfe Canal reservoir created by the York Dam has negligible storage and a surface area of 50-acres, and normal water surface elevation of 342.46 feet NGVD29. A reservoir created by the dam at the end of the power canal has a surface area of 3-acres with negligible storage and a normal water surface elevation of 342.5 feet NGVD29.

2.4.1.2 Water Quality

The New Hampshire Department of Environmental Services (NHDES) is the agency responsible for establishing and administering surface water quality standards for New Hampshire and is the agency responsible for issuing 401 WQC. The Project will be required to obtain a 401 WQC as a condition of the FERC license and will therefore need to demonstrate that Project operations will comply with state water quality standards. State water quality standards are described in the NHDES "Consolidated Assessment and Listing Methodology" (NHDES 2020a) and summarized in NHDES (2019a). The following description of New Hampshire water quality standards most relevant to hydropower projects is an excerpt from Section 2 of NHDES (2019a): New Hampshire surface water quality standards are included in statute (RSA 485-A:8) and regulation (Env-Wq 1700) [see Section 5, reference (ref) 4]. Surface water quality standards include designated uses, criteria to protect the designated uses and antidegradation provisions to protect and maintain existing uses and to minimize degradation of high quality surface waters. Designated uses include recreation (i.e., swimming and other recreation in and on the water), fish consumption, shellfish consumption (tidal waters only), aquatic life integrity, wildlife and potential drinking water supply (Env-Wq 1702.17). The majority of the criteria are included in Env-Wq 1700. In cases where the standards include narrative criteria but no numeric criteria, the New Hampshire Consolidated Assessment and Listing Methodology (CALM) often includes numeric thresholds which are used as translators of the narrative criteria in the standards. Criteria or thresholds are often dependent on the waterbody classification. In New Hampshire, there are two classes, A and B with most surface waters classified as B.

Table 1 shows the surface water quality criteria or thresholds for the parameters addressed in this guidance for class A and B waters as well as the primary designated uses the criteria and thresholds are designed to protect. As shown below the designated uses for the criteria listed are for protection of aquatic life and recreation. With regards to aquatic life protection, these criteria and thresholds help to maintain Biological and Community Integrity which is addressed in the following regulations:

Table 1 Surface Water Quality Criteria and Thresholds for Class A and B waters

Parameter (designated use)	Surface water quality criteria or threshold
Dissolved Oxygen *(for protection of aquatic life)*	*Env-Wq 1703.07 Dissolved Oxygen.* *(a) Class A waters shall have a dissolved oxygen content of at least 75% saturation1, based on a daily average, and an instantaneous minimum of at least 6 mg/l at any place or time except as naturally occurs.* *(b) Except as naturally occurs and subject to (c) and (e), below,* *class B waters shall have a dissolved oxygen content of: (1) At least 75% of saturation1, as specified in RSA 485-A:8, II, based on a daily average; and (2) An instantaneous minimum dissolved oxygen concentration of at least 5 mg/l.* *(c) In areas identified by the New Hampshire Fish and Game Department (NHF&G) as cold water fish spawning areas of species whose early life stages are buried in the gravel on the bed of the surface water, the 7 day mean dissolved oxygen concentration shall be at least 9.5 mg/l and the instantaneous minimum dissolved oxygen concentration shall be at least 8 mg/l for the period from October 1 of one year to May 14 of the next year, provided that the time period shall be extended to June 30 for a specific discharge to a specific waterbody if modeling done in consultation with the NHF&G determines the extended period is necessary to protect spring spawners or late hatches of fall spawners, or both.* *(d) Unless naturally occurring or subject to (a), above, surface waters within the top 25 percent of depth of thermally unstratified lakes, ponds, impoundments, and reservoirs or within the epilimnion of stratified waterbodies shall contain a dissolved oxygen content of at least 75 percent saturation1, based on a daily average and an instantaneous minimum dissolved oxygen content of at least 5 mg/l. Unless naturally occurring, the dissolved oxygen content below those depths shall be consistent with that necessary to maintain and protect existing and designated uses.*
Temperature *(for protection of aquatic life)*	*Env-Wq 1703.13 Temperature.* *(a) There shall be no change in temperature in class A waters, unless naturally occurring.* *(b) Temperature in class B waters shall be as specified in RSA 485-A:8, II and VIII. RSA 485-A:8, II (regarding Class B waters): "Any stream temperature increase associated with the discharge of treated sewage, waste or cooling water, water diversions, or releases shall not be such as to appreciably interfere with the uses assigned to this class." RSA 485-A:8, VIII: "In prescribing minimum treatment provisions for* *thermal wastes discharged to interstate waters, the department shall adhere to the water quality*

	requirements and recommendations of the New Hampshire fish and game department, the New England Interstate Water Pollution Control Commission, or the United States Environmental Protection Agency, whichever requirements and recommendations provide the most effective level of thermal pollution control."
pH *(for protection of aquatic life)*	*Env-Wq 1703.18 pH.* *(a) The pH of Class A waters shall be as naturally occurs.* *(b) As specified in RSA 485-A:8, II, the pH of class B waters shall be 6.5 to 8.0 unless due to natural causes.* *(c) As specified in RSA 485-A:8, III, the pH of waters temporary partial use areas shall be 6.0 to 9.0 unless due to natural causes.*
Nutrients – Total Phosphorus and Nitrogen *(for protection of aquatic life and recreation)*	*Env-Wq 1703.14 Nutrients.* *(a) Class A waters shall contain no phosphorus or nitrogen unless naturally occurring.* *(b) Class B waters shall contain no phosphorus or nitrogen in such concentrations that would impair any existing or designated uses, unless naturally occurring.* *(c) Existing discharges containing phosphorus or nitrogen, or both, which encourage cultural eutrophication shall be treated to remove the nutrient(s) to ensure attainment and maintenance of water quality standards.* *(d) There shall be no new or increased discharge of phosphorus into lakes or ponds.* *(e) There shall be no new or increased discharge containing phosphorus or nitrogen to tributaries of lakes or ponds that would contribute to cultural eutrophication or growth of weeds or algae in such lakes and ponds. Numeric thresholds for Total Phosphorus (TP) in lakes, ponds, reservoirs and impoundments are dependent on trophic classification and are provided in the CALM (Indicator 7b) for the protection of aquatic life as follows:* *Best Historical Trophic Category TP (ug/L)* *Oligotrophic < 8.0* *Mesotrophic ≤ 12.0* *Eutrophic ≤ 28* *where TP represents the median of at least 5 (and preferably more) samples collected between May 24 and September 15 in the upper layer (e.g., epilimnion if stratified).*
Chlorophyll a *(for protection of aquatic life and recreation)*	*Env-Wq 1703.14 (see above) which references "cultural eutrophication" which is defined as follows: Numeric thresholds for chlorophyll a for the protection of recreational uses (Indicator 3) and aquatic life in lakes, ponds, reservoirs and impoundments) (Indicator 7a) are provided in the CALM as follows:* *For protection of recreational uses (i.e., primary contact recreation):* *Chlorophyll a (μg/L)*

	Freshwaters: ≤ 15 *Tidal Waters: ≤ 20* *For protection of aquatic life in lakes, ponds, reservoirs and impoundments (which behave more like lakes than riverine segments):* *Best Historical Trophic Category Chlorophyll a (μg/L)* *Oligotrophic < 3.0* *Mesotrophic ≤ 5.0* *Eutrophic ≤ 11* *where Chlorophyll a represents the median of at least 5 (and preferably more) samples collected between May 24 and September 15 in the upper layer (e.g., epilimnion if stratified).*
Secchi Disk *(for protection of aquatic life and recreation)*	*There are no numeric criteria in regulation or a numeric threshold in the CALM. This data helps to determine the depth and extent of the littoral zone and to corroborate chlorophyll data.*

NHDES Water Quality Assessment and Total Maximum Daily Loads (TMDLs)
Sections 303(d) and 305(b) of the Clean Water Act (CWA) require each state to submit two reports (CWA 303(d) report and CWA 305(b) report) to the U.S. Environmental Protection Agency (EPA) every 2 years, documenting the water quality status of surface waters within the state. New Hampshire's "305(b) Report" describes the quality of New Hampshire's surface waters and analyzes the extent to which all such waters provide for the protection and propagation of a balanced population of shellfish, fish, and wildlife and allow recreational activities in and on the water.

The second report, required by Section 303(d) of the CWA, requires submittal of a list of waters that are: impaired or threatened by a pollutant or pollutant(s); not expected to meet water quality standards within a reasonable time even after application of best available technology standards for point sources or best management practices (BMPs) for nonpoint sources; and require development and implementation of a comprehensive water quality study (i.e., a TMDL study) designed to meet water quality standards. New Hampshire's process for assessing surface water quality is detailed in the "CALM" that interprets New Hampshire's Surface Water Quality Regulations (Env-Wq 1700). Waterbodies designated in New Hampshire as AU Category 5 (updated every 2 years in the NHDES 303(d) list) are impaired or threatened waters for one or more designated uses by a pollutant or pollutants and require development of a TMDL for the pollutant(s) causing the threat(s) or impairment(s). The TMDL establishes the maximum amount of a pollutant that can be allowed in a waterbody to achieve water quality standards for all designated uses.

The impoundment of the Penacook Lower Falls project (Assessment Unit NHIMP700030507-07) and the impoundment of the Penacook Upper Falls Project (Assessment Unit NHIMP700030507-06) are listed in the NHDES list of priority waterways pursuant to section 303(b) of the Clean Water Act. This assessment unit represents 8.5 acres of the Contoocook River for Penacook Lower Falls and 11 acres for Penacook Upper Falls. The impoundments are listed under threatened or impaired waterways that require a Total Maximum Daily Load study ("TMDL") and are listed as category 5 impairment for pH. The source of the pH impairment is unknown; however, this type of impairment is not attributable to operation of the dam and is likely caused by environmental pollutants outside of the control of Briar Hydro, such as acid rain.

Relicensing Study: Water Quality

The relicensing studies for these project were done together with the Briar Hydro Associates owned project on the Contoocook River therefore the results of this and other studies include Rolfe Canal (FERC No. 3240), Penacook Upper Falls (PUF; FERC No. 6689), and Penacook Lower Falls (PLF; FERC No. 3342) Hydroelectric Projects. The Projects are located on the Contoocook River in Boscawen and Concord, New Hampshire. PLF sits at river mile 0 of the Contoocook River, above the confluence with the Merrimack River. The Upper Penacook and Rolfe Canal Projects are located upstream at river miles 1.0 and 2.1, respectively.

A summary of the water quality study is presented here and the full study report is included at the end of this report in section 2.13.

In response to requests provided by the resource agencies as part of the relicensing process, Briar Hydro prepared a Preliminary Study Plan (PSP). The intent of the PSP was that the goals, methodology, scope, and schedule would be refined in consultation with interested stakeholders, as necessary. Briar Hydro distributed a copy of the PSP to representatives from the representatives from the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFGD) and the New Hampshire Department of Environmental Services (NHDES) on December 14, 2020. Following receipt and consultation related to comments on the PSP, Briar Hydro prepared a Revised Study Plan (RSP) which was finalized in March 2021 and filed with FERC on July 6, 2021.

NHDES is the agency responsible for establishing and administering surface water quality standards for New Hampshire and is the agency responsible for issuing 401 Water Quality Certification (WQC). The Projects will be required to obtain a 401 WQC as a condition of the FERC license and will therefore need to demonstrate that Project operations will comply with state water quality standards. A Sampling and Analysis Plan (SAP) was developed in response to the NHDES PAD and PSP comments and study requests and was developed consistent with the Revised Study Plan (RSP) dated March 23, 2021. The SAP was developed in coordination was NHDES and was determined acceptable by NHDES as communicated in an email dated July 16, 2021. The water quality study was completed in accordance with the SAP to the extent practicable.

The water quality study consisted of continuous monitoring of temperature, dissolved oxygen, and pH using deployed water quality data loggers at fourteen locations in the Project area, including an upstream reach, Project impoundments, bypass reaches, tailrace areas, and in the Rolfe Canal and historic Rolfe Canal Channel. Continuous data was supplemented with recurring water quality profiles and Secchi Disk depth measurements in the deep spot of each impoundment and at the Rolfe Canal Project intake to determine changes in water quality with depth and assist with trophic state determination. In addition, water quality samples were collected for laboratory analysis of nutrients and chlorophyll-a in each of the Project impoundments and the Rolfe Canal Project intake.

The field study was completed between July 28, 2021 and September 23, 2021, a period of nine weeks, and included periods of high water temperature and low river flows, as well as during flows supportive of a range of generating conditions including high flows with spill conditions. Water surface elevations in the impoundments are monitored as part of Project operations and inflows to the Projects were estimated using the nearest available USGS gage data. Inflow was determined by scaling the available USGS gage data using watershed areas and outflows were determined from the inflow and generation data.

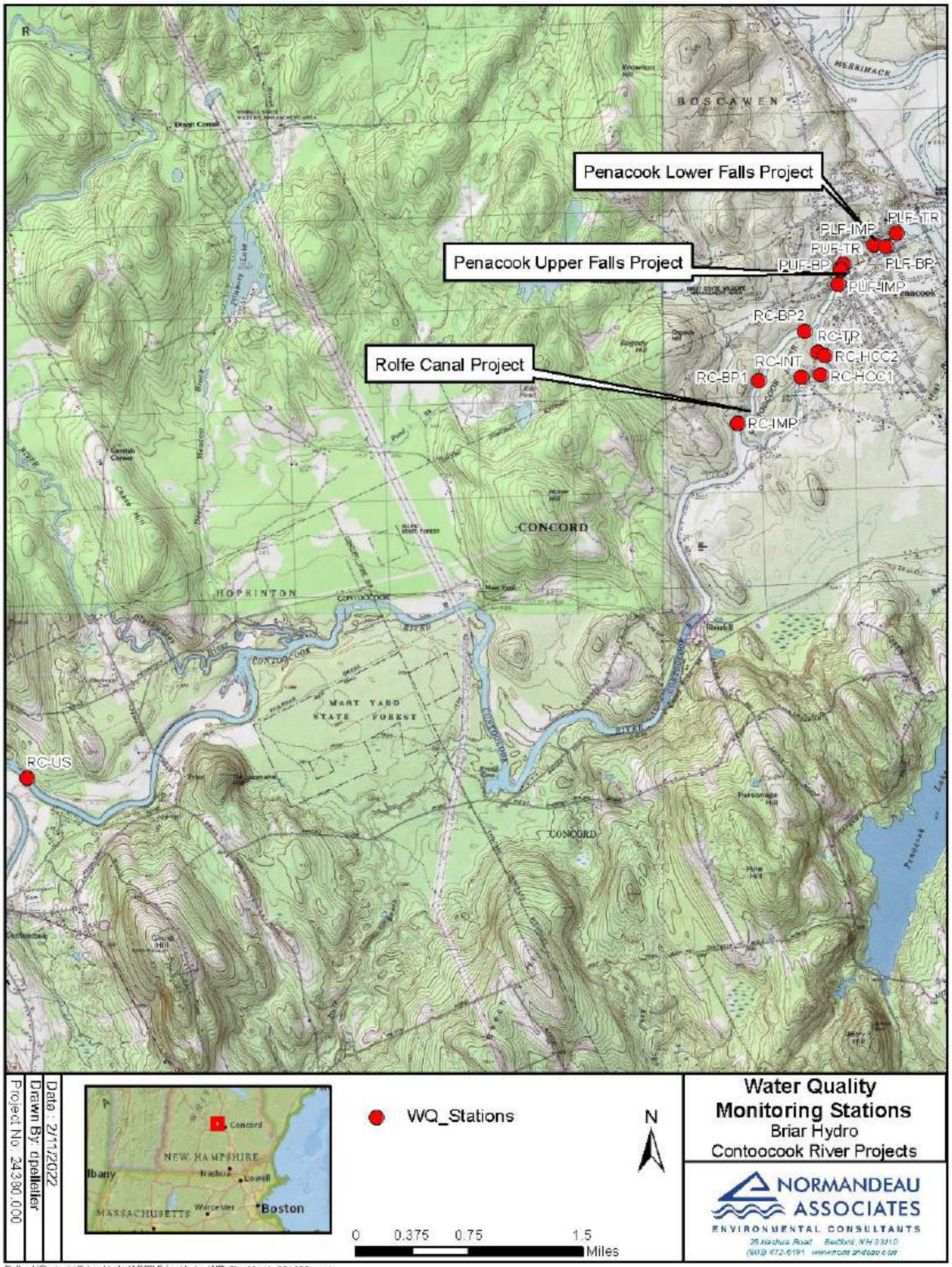


Figure E.6 Map of water quality study monitoring locations.

Dissolved oxygen

Penacook Lower Falls and Penacook Upper Falls continuous monitoring locations met or exceeded water quality standards for dissolved oxygen throughout the study period. At Rolfe Canal there was one incidence where the recorded dissolved oxygen at the intake was below the threshold of 5 mg/L on 7/30/21 when dissolved oxygen was 4.81 mg/L. In addition, the dissolved oxygen saturation at the same location was below 75% on 7/28 and 7/29 (74% and 70.5%). These lower dissolved oxygen levels at the Rolfe Canal intake occurred during a period of time when this hydropower project was not operating due to necessary maintenance. As a result, the flow of the river was entirely directed to the York bypass other than the historic channel minimum flow of 5cfs.

Two dissolved oxygen profiles in the Rolfe impoundment also showed stratification and low dissolved oxygen in bottom waters on 8/12 and 8/17. All profiles in the Penacook Upper Falls and Penacook Lower Falls impoundments did not show stratification and all dissolved oxygen levels were above the 5mg/L threshold.

pH

Continuous pH was recorded at 13 of the 14 monitoring locations for the 8-week study period. PH varied from 6.2 – 7.7 s.u. across all continuous monitoring stations during the study with median values ranging from 6.5 at multiple stations to 6.9 at PLF-BP. Acidic river waters are common in this area and due primarily to atmospheric deposition and acidic precipitation and cannot be attributed to hydroelectric operations.

Nutrients, Chloropyll *a* and Secchi depth

Water samples were collected once or twice per week in August and September 2021 from the three impoundment stations (RC-IMP, PUF-IMP, PLF-IMP) and the Rolfe Canal Project Intake (RC-INT) and submitted for laboratory analysis. Secchi depth was measured concurrent with collection of laboratory samples. The results of that sampling and measurements are shown below.

Table 2. Summary of laboratory results at RC-IMP

Date	NO3-N	NO2-N	TKN	TP	TKN	TP	Chlorophyll a	Notes
			Epilimnion		Hypolimnion			
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	
8/5/2021 9:30	0.067	<0.05	0.48	0.023	-	-	1.6	Secchi depth 8 ft
8/10/2021 11:20	0.11	<0.05	0.46	0.026	-	-	1.7	Secchi depth 10 ft
8/12/2021 13:15	0.093	<0.05	0.39	0.062	-	0.066	1.6	Secchi depth 11 ft
8/17/2021 9:35	0.11	<0.05	0.94	0.098	-	0.099	2.1	Secchi depth 11 ft
8/23/2021 9:05	0.12	<0.05	0.37	0.1	-	-	0.8	Secchi depth 10.5 ft
8/30/2021 10:05	0.099	<0.05	0.49	0.083	-	-	1.3	Secchi depth 8 ft
8/30/2021 10:05	0.077	<0.05	0.58	0.017	-	-	1.6	Field replicate
9/1/2021 10:39	0.1	<0.05	0.33	0.094	-	-	1.7	Secchi depth 9 ft
9/6/2021 14:30	0.06	<0.05	0.36	0.02	-	-	1.2	Secchi depth 9.5 ft
9/8/2021 14:59	0.085	<0.05	0.31	0.011	-	-	1.1	Secchi depth 11 ft
9/14/2021 11:00	0.14	<0.05	0.73	0.02	-	-	1.7	Secchi depth 9.5 ft
10 sample median	0.0965	<0.05	0.425	0.038	-	0.0825	1.6	

Table 3. Summary of laboratory results at RC-INT

Date	NO3-N (mg/L)	NO2-N (mg/L)	TKN (mg/L)	TP (mg/L)	Chlorophyll a (µg/L)	Notes
8/5/2021 10:30	0.056	<0.05	0.46	0.023	1.6	Secchi depth 8 ft
8/10/2021 10:00	-	-	-	-	-	Secchi depth 10 ft
8/12/2021 8:40	0.1	<0.05	0.51	0.021	1.2	Secchi depth 11 ft
8/17/2021 9:30	-	-	-	-	-	Secchi depth 11 ft
8/23/2021 10:12	0.12	<0.05	0.45	0.031	1.1	Secchi depth 10.5 ft
8/30/2021 11:38	0.088	<0.05	0.54	0.024	1.3	Secchi depth 8 ft
8/30/2021 11:38	0.08	<0.05	0.53	0.093	1.8	Field replicate
9/1/2021 10:39	-	-	-	-	-	Secchi depth 9 ft
9/6/2021 15:35	0.052	<0.05	0.35	0.019	1.6	Secchi depth 9.5 ft
9/8/2021 14:59	-	-	-	-	-	Secchi depth 11 ft
9/14/2021 13:05	0.093	<0.05	0.35	0.019	1.4	Secchi depth 9.5 ft
10 sample median	0.0885	<0.05	0.455	0.022	1.475	

Table 4. Summary of laboratory results at PUF-IMP

Date	NO3-N (mg/L)	NO2-N (mg/L)	TKN (mg/L)	TP (mg/L)	Chlorophyll a (µg/L)	Notes
8/5/2021 9:30	-	-	-	-	-	Secchi depth 8 ft
8/10/2021 11:20	-	-	-	-	-	Secchi depth 10 ft
8/12/2021 10:35	0.091	<0.05	0.41	0.077	1.3	Secchi depth 11 ft
8/17/2021 10:40	0.11	<0.05	0.58	0.077	1.8	Secchi depth 11 ft
8/23/2021 11:15	0.12	<0.05	0.33	0.094	1.3	Secchi depth 10.5 ft
8/30/2021 12:45	0.082	<0.05	0.56	0.075	1.5	Secchi depth 8 ft
8/30/2021 12:45	0.087	<0.05	0.5	0.09	1.6	Field replicate
9/1/2021 12:47	0.11	<0.05	0.33	0.079	1.5	Secchi depth 9 ft
9/6/2021 12:05	0.066	<0.05	0.4	0.018	1.6	Secchi depth 9.5 ft
9/8/2021 12:10	0.1	<0.05	0.23	0.022	1.4	Secchi depth 11 ft
9/14/2021 12:00	0.089	<0.05	0.97	0.021	2	Secchi depth 9.5 ft
10 sample median	0.0955	<0.05	0.405	0.077	1.525	

Table 0. Summary of laboratory results at PLF-IMP

Date	NO3-N	NO2-N	TKN	TP	Chlorophyll a	Notes
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	
8/5/2021 11:40	0.057	<0.05	0.45	0.022	1.8	Secchi depth 8 ft
8/10/2021 12:55	0.11	<0.05	0.44	0.097	1.6	Secchi depth 10 ft
8/12/2021 14:00	0.099	<0.05	0.37	0.062	1.6	Secchi depth 11 ft
8/17/2021 11:35	0.11	<0.05	0.61	0.076	1.4	Secchi depth 11 ft
8/23/2021 12:05	0.13	<0.05	0.47	0.085	1.2	Secchi depth 10.5 ft
8/30/2021 14:15	0.086	<0.05	0.53	0.094	1.6	Secchi depth 8 ft
8/30/2021 14:15	0.086	<0.05	0.47	0.069	1.3	Field replicate
9/1/2021 14:16	0.11	<0.05	0.35	0.028	2	Secchi depth 9 ft
9/6/2021 13:35	0.062	<0.05	0.34	0.017	1.1	Secchi depth 9.5 ft
9/8/2021 13:38	<0.050	<0.05	0.24	0.014	1.6	Secchi depth 11 ft
9/14/2021 14:36	0.091	<0.05	0.52	0.019	1.6	Secchi depth 9.5 ft
10 sample median	0.099	<0.05	0.445	0.045	1.6	

Total Kjeldahl nitrogen (TKN) was detected in all samples collected at concentrations ranging from 0.23 to 0.97 mg/L, both measured at Station PUF-IMP, with median values by station ranging from 0.405 mg/L at PUF-IMP to 0.455 at RC-INT. There are no numerical standards for nitrogen in freshwater surface waters in NH; however, EPA guidance for the region lists a reference condition of 0.71 mg/L for total nitrogen which can be used for evaluation of water quality. During this study total nitrogen (estimated as nitrate + TKN) ranged from <0.29 – 1.06 mg/L with median station values ranging from 0.48 mg/L at PUF-IMP to 0.54 mg/L at RC-INT which were below the EPA reference condition of 0.71 mg/L. Total phosphorus was measured in both the epilimnion and hypolimnion samples as in the SAP and varied from 0.011 – 0.100 mg/L (Station RC-IMP) with median station values ranging from 0.022 mg/L at RC-INT to 0.077 at PUF-IMP. The detected phosphorus concentrations were generally within or in excess of the CALM (indicator 7b) category for Eutrophic waters of 0.012-0.028 mg/L. Chlorophyll *a* was measured at levels ranging from 0.8 – 2.1 ug/L, with median station values ranging from 1.475 ug/L at RC-INT to 1.60 ug/L at RC-IMP and PLF-IMP, all below the NH numeric threshold (CALM indicator 7b) for an oligotrophic lake of <3.3 ug/L.

There are six municipal wastewater treatment facilities upstream of the projects that discharge effluent into the Contoocook and Warner River. These are located in Henniker, Hillsboro, Warner, Antrim, Jaffrey, and Peterborough, NH. These facilities along with stormwater runoff associated with nonpoint source pollution such as fertilizer used in farming, golf courses, or residential lawns are the likely sources of nutrient levels observed in the Contoocook River at the hydropower projects during the water quality study.

The Contoocook River corridor management plan (2011) list stormwater runoff and septic systems as primary concerns related to water quality. The plan also notes that water quality has improved likely due to improvements made in wastewater treatment plants. The plan also does not mention dams or hydropower operations as a concern.

Water temperature
Temperature conditions in the Project study area were variable during the study period, and exhibited a seasonal pattern with a general warming trend early in the study followed by a general cooling trend after a mid-August peak with water temperatures in excess of 25 °C. Temperatures in the upstream reach, outside the direct hydraulic influence of the Project, were comparable to the other stations in the study area and all station temperatures were within ~3 °C or less of each other throughout the study. The temperature data collected in this study indicate that water temperatures in areas affected by the Project generally follow a natural temperature regime that is comparable to areas outside the Project influence.

2.4.2 Project Impact on Water Resources
The project is operated in run of river mode which minimizes impoundment fluctuations and any modifications of natural hydrologic regime.

Observed and previously known pH and nutrient impairments in the Contoocook River are likely due to upstream and atmospheric pollution and unrelated to the hydroelectric projects.

Overall, dissolved oxygen levels were good in all tailraces and did not decrease with project startup or operation. Dissolved oxygen levels were also compliant with water quality standards in the Penacook Lower Falls and Penacook Upper Falls impoundment throughout the study period. The only dissolved oxygen level slightly below the concentration and percent saturation thresholds occurred at the Rolfe Canal intake while the project was not operating. The Rolfe Canal impoundment also was thermally stratified on two dates and had low bottom dissolved oxygen levels.

2.4.3 Protection, Mitigation, and Enhancement Measures

2.4.3.1 Agency Recommended Mitigation
Briar Hydro is not aware of any agency proposed PM&E measures to protect water resources at this time.

2.4.3.2 Applicant Proposed Mitigation
The applicant is proposing the following PM&E measures to protect water resources.

- Continue to operate the project in run-of-river where inflow to the impoundment approximately matches outflow with the exception of approved maintenance or operating emergencies.
- Continue current bypass flows at Rolfe Canal which are 5 cfs in the historic channel that bypasses the penstock and 100 cfs in the York bypass at York dam. Though the Rolfe Canal license requires 50 cfs flow in the York bypass, Briar has voluntarily increased the bypass flow to 100 cfs for Low Impact Hydro Institute certification and is now proposing

to maintain the 100 cfs bypass flow under a new license. There are no required bypass flows at Penacook Upper Falls or Penacook Lower Falls and there is no evidence that a bypass flow in those locations is necessary to protect water resources. Bypass flows will be addressed in more detail in the next section 2.5 Fish and aquatic resources.

2.5 Fish and Aquatic Resources

2.5.1 Affected Environment

2.5.1.1 Fish Community

The Contoocook River watershed hosts both cold and warmwater fish species typical of river and stream habitats in New Hampshire. The upper reaches of the Contoocook River reportedly provide some of the best trout fishing in southern New Hampshire. Brown trout successfully breed in many tributaries, and brook trout are regularly stocked. The main stem, however, and the Merrimack River north of Concord are inhabited primarily by warm water species. The Merrimack River historically has supported runs of Atlantic Salmon, River Herring, Shad, American eels, and Sea Lamprey.

From the original license application, the single most common species near the project site was yellow perch. The lower Contoocook also supports a good bass fishery. An intensive State of New Hampshire fishery survey of the lower Contoocook in 1972 yielded 17% yellow perch with pumpkinseed and white sucker close behind in total abundance. Nearly 12% of the fish recovered were smallmouth bass, a locally sought-after game species. Other species present included chain pickerel, brown bullhead, and white perch. Further upstream, white sucker becomes the most numerous main stem fish species (Wightman 1973). Available fisheries data suggest that the fishery below the project is essentially similar but that white perch are relatively more abundant in the Merrimack then in the Contoocook.

Finfish Species Found in or Near Three Project Sites[1]

Scientific Name	Common Name
Anguilla rostrata	American eel
Esox niger	Chain pickerel
Notemingonus crysoleucas	Golden Shiner
Semotilus atromaculatus	Creek chub
Semotilus corporalis	Fallfish

[1] Source: Penacook Lower Falls Original License Application; Bailey 1938, NHFG, Stolte, Wightman 1972

Catostomus commersoni	White sucker
Ictalurus natalis	Yellow Bullhead
Ictalurus nebulosus	Brown Bullhead
Morone americana	White Perch
Lepomis auritus	Redbreast Sunfish
Lepoomis gibbosus	Pumpkinseed
Micropterus dolomieui	Smallmouth bass
Perca flavescens	Yellow Perch
Stizostedium vitreum vitreum	Walleye

Resident Fish Species

The existing fish community and available aquatic habitat in the Project impoundment and tailwaters are representative of that of a mid-size, warmwater tributary of the Merrimack River. NH Fish and Game regularly conduct presence-absence surveys on the Contoocook river in the vicinity of the projects using electrofishing. The results of these surveys are published on the statewide fish survey map: https://nhfg.maps.arcgis.com/apps/MapJournal/index.html?appid=d6549e90155b441fa0e29bdc44eebc2b

The most recent surveys near each project and the fish species present are listed in the table below.

Year	Location	Fish species present
2021	Downstream of Penacook Lower Falls	Brown trout (hatchery origin) Margined madtom Redbreasted sunfish Spottail shiner
2019	Between Penacook Lower Falls and Penacook Upper Falls	American eel Fallfish Margined madtom Redbreasted sunfish Smallmouth bass
2021	Immediately upstream of Penacook Upper Falls	American eel Rock bass Redbreasted sunfish Smallmouth bass

2020	Near York dam	American eel Bluegill Common sunfish Common White sucker Fallfish Longnose dace Margined madtom Rock bass Redbreasted sunfish Smallmouth bass

Migratory Fish Species
As noted in the table above American eel a catadromous fish is present in the Contoocook river near the projects. Penacook Upper Falls also has an eel lift facility that passed 873 juvenile American eels in 2021 and 259 in 2022 (see figure E.7 below for 2021 data).

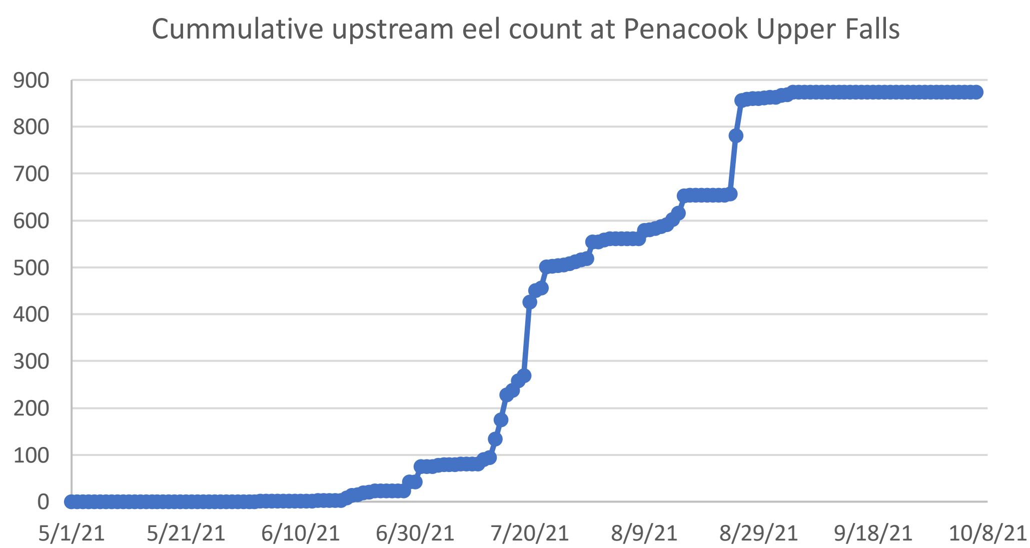


Figure E.7 Cumulative upstream eel count at Penacook Upper Falls eel lift in 2021

There are two dams, Hooksett and Garvins Falls, downstream of Penacook Lower Falls on the Merrimack River that do not currently have upstream fish passage. Therefore, diadromous fish that require upstream passage facilities such as alosines (river herring and shad) are not currently able to reach the Contoocook River. River herring are sometimes stocked in the Contoocook River upstream of the Rolfe Canal by NH Fish and Game however this has not occurred in recent years.

The Central New England Distinct Population Segment (DPS) of Atlantic salmon, in which the Merrimack River would exist, is considered extirpated. The USFWS ended its participation in the Merrimack River Salmon Restoration Program in 2013 although small numbers of returns continue through individual state-supported efforts. Stocking of Atlantic salmon life stages in New Hampshire ceased following the 2013 discontinuation of federal propagation efforts. While remnant or stray fish returning to the Merrimack River are not specifically protected under the Endangered Species Act (ESA), regional watersheds, including the Contoocook River watershed, are designated as essential fish habitat (EFH) for the Atlantic salmon. There currently are no stocking or plans to restore Atlantic salmon to the Contoocook River watershed.

Recreational Fishing

The Contoocook and North Branch Rivers provide both cold and warm water habitats for several species of recreational and sport fish. The most significant, high quality habitat cold water fish is the section of rapids in the Hillsboro-West Henniker area. Some sections of the Contoocook River are also stocked with trout and open to trout fishing year-round. The slower moving sections of the river and impounded areas provide warm water fish habitat. Fishing is popular above Peterborough along Route 202 and in most of the impounded areas and flat water stretches of the river.

Aquatic Habitat

Based on a review of the National Marine Fisheries Service online database, the Contoocook River is listed as an EFH for the federally listed Atlantic salmon. Atlantic salmon in the Central New England DPS are considered extirpated and therefore not protected under the ESA. With the discontinuation of propagation and stocking of salmon in the Merrimack River in 2013, only remnant or stray fish continue to return. No other designations such as habitat areas of particular concern (HAPC) or critical habitat as defined under the Magnuson-Stevens Fishery Conservation and Management Act have been identified in the Contoocook River.

Impoundment Habitat

The Penacook Lower Falls reservoir has a normal maximum water surface area of 8.4 acres at 278.6 NGVD29 feet MSL. The gross storage capacity is 54 acre-feet. The mean depth is approximately 12 feet and the shoreline length is approximately 1.8 miles.

The Penacook Upper Falls reservoir has a surface area of 11.4 acres and the normal water surface elevation is 306 feet MSL. The dam has a negligible storage capacity.

The Rolfe Canal reservoir created by the York Dam has negligible storage and a surface area of 50-acres, and normal water surface elevation of 342.46 feet NGVD29. A reservoir created by the dam at the end of the power canal has a surface area of 3-acres with negligible storage and a normal water surface elevation of 342.5 feet NGVD29.

Project bypass habitat

The PLF Bypass is a steep (3%-4%), bedrock-dominated reach approximately 680 ft in length bordered by a forested bank on the east and the spillway on the west bank.

Figure E.8 Photo of the Penacook Lower Falls bypass reach.

The PUF Bypass is a steep (3%-4%), bedrock-dominated reach 250 ft in length bordered by the powerhouse on the east bank and a warehouse building on the west bank.

Figure E.9 Photo of the Penacook Upper Falls bypass.

The Rolfe Canal bypasses a short, narrow Historic Channel approximately 1,800 ft in length (Figure E.10). The upper one-third of this Historic Channel is a deep, backwater pool habitat; the lower two-thirds is a narrow (~20 ft wide) low gradient channel bordered by dense riparian vegetation (Figure E.10).

Figure E.10 Photo of the Rolfe Canal Penstock Bypass reach or Historic Channel bypass.

The Rolfe Canal project also includes the York Dam bypass which was the primary study area for this instream flow study (IFS) from York Dam downstream approximately 4,000 feet to its confluence with the PUF headpond. This reach drops approximately 28 feet for an average gradient of 0.7%. The upper half of the Rolfe Bypass is composed of alternating short sections of bedrock ledge and rapids habitat and deeper pool/run habitat (Figure E.11). The lower half of the bypass is predominantly composed of shallow, cobble/boulder-dominated riffle and run habitat. Channel widths range from 50 feet to over 150 feet. Both banks are lined with mature deciduous and coniferous riparian trees, with limited shrub vegetation on exposed bedrock ledges.

Figure E.11 view of the York Dam bypass channel downstream of the dam

Current bypass reach flows

The current licenses do not require minimum bypass flows at Penacook Lower Falls or Penacook Upper Falls. At Rolfe Canal, there is a minimum bypass flow of 5cfs for the reach bypassed by the penstock and powerhouse and 50 cfs for the York bypass. However, in order to obtain Low Impact Hydropower Institute (LIHI) certification for this facility Briar Hydro agreed to increase the York bypass flow to 100cfs in 2012. In 2017, following field visit agency staff from USFWS and NH DES agreed that bypass flows of 5cfs in the canal bypass and 100 cfs in the York dam bypass were acceptable for LIHI certification.

Relicensing study: Instream Flow and Habitat Assessment Study

The complete instream flow study report is provided in section 2.13 at the end of this Exhibit.

The 4,000 ft York dam bypass was mapped into 16 habitat units (31% pool, 50% run, and 20% riffle (excluding terminal cascade). The lower 1,900 ft was dominated by cobble-boulder substrate, the upper 1,900 ft was bedrock dominated. Nine transects were placed in approximate proportion to habitat availability (3 pools, 4 runs, 2 riffles). Habitat was modeled for bypass flows ranging from 25 cfs to 500 cfs, based on 3 calibration flows (60 cfs, 109 cfs, and 172 cfs). Habitat was modeled for 14 species and life-stages

The magnitude of suitable habitat was minimal for spawning life-stages due to the abundance of bedrock substrate. Fry showed maximum habitat at lower flows than juvenile and adult life-stages. Combined across all species and life-stages, 70%, 80%, and 90% of maximum suitable habitat occurred at flows of 98 cfs, 150 cfs, and 275 cfs , respectively

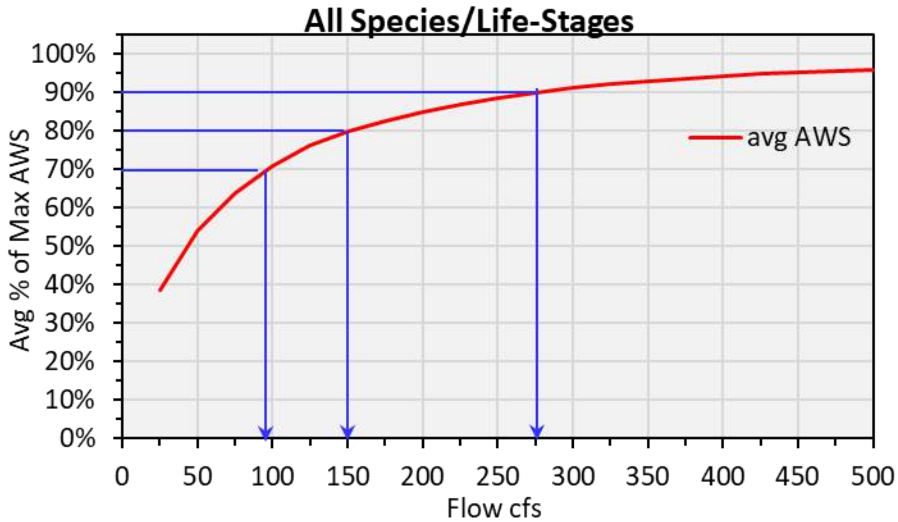


Figure E.12 Average percent maximum area weighted suitability across all species and life stages considered at a range of discharge in the York Dam bypass reach.

Qualitative habitat assessments were conducted in the Rolfe Canal bypass, the PUF bypass, and the PLF bypass. Spot measurements of depths and velocities suggested alosine passage to the face of the dams in the PUF but not in the PLF bypass.

Fish Passage
Several studies were requested and conducted to assess current upstream and downstream passage effectiveness and survival for alosines and American eel.

The studies included:

- Adult alosine downstream passage
- American eel downstream passage
- American eel upstream passage
- Downstream fish passage survival
- Fish passage study feasibility assessment

Complete study reports for these studies are included in section 2.13 of this exhibit except for the fish passage feasibility study which is anticipated to be completed by mid-March 2023 and will be provided to the Commission and other consulting agencies once it is completed.

<u>Adult alosine downstream passage</u>
The study consisted of tracking 100 individual tagged adult river herring to evaluate their residence time, passage location, and survival as they migrated downstream from above Rolfe Canal, through the three projects and to the Merrimack River. The median residence time upstream of each project was 22.3 hours for Rolfe Canal, 31.9 hours for PUF, and 39.6 hours for

PLF. At Rolfe Canal, 14% of individuals went through the turbine and 86% went through spill at York dam, at PUF 23% went through the turbine, 17% used spill, and 60% used the downstream passage, and at PLF 52% went through the turbine and 44% used the downstream passage. The downstream passage success was 91.4%, 91.8%, and 95% for Rolfe, PUF, and PLF, respectively.

American eel downstream passage

As a result of LIHI certification, Briar Hydro has implemented mitigation and protection for downstream migrating eels by shutting down operations from sunset to sunrise for three consecutive nights any time there is a precipitation event of at least 0.25 inches within 24 hours from August 15th to November 1st or when river water temperature reach 10 degrees C. These shutdowns were being done during the downstream eel passage study which occurred from mid-October to early November and there were 11 nighttime shutdowns during the study. Adult American eels were radio tagged (105 total) and released upstream of Rolfe (63), upstream of PUF (21), and upstream of PLF (21) on three separate release dates. The median residence time upstream of each project was 0.3 hours at Rolfe, 0.2 hours at PUF, and 1.2 hours at PLF. The overall downstream passage success for adult eels at each project was 92.1% at Rolfe, 84.8% at PUF, and 90.9% at PLF. However, as would be expected passage survival was much higher when the project shut down (100%, 96%, and 98%) than operating (78%, 57%, and 77%, respectively at Rolfe, PUF, and PLF).

American eel upstream passage

The study of juvenile American eel upstream passage had three components, nighttime surveys, backpack electrofishing surveys, and a mark-recapture study at the PUF eel lift. During four nighttime surveys only a total five juvenile eels were observed. Three were found in the York dam bypass reach and two were found at PLF near the auxiliary spillway while no eels were observed during any of the surveys at the Rolfe canal intake, Rolfe tailrace, or Rolfe penstock bypass. Two backpack electrofishing surveys conducted at three locations found no eels. Findings suggest low overall abundance of juvenile eels downstream of Rolfe Canal and PLF. There was also no discernible pattern based on these limited observation that would inform the placement of upstream eel passage at either project. The mark-recapture study marked two batches of approximately 100 individuals each that were collected after passing the PUF eel lift and released back downstream of the lift. Only 2% of marked eels from the first batch were recaptured and none from the second batch. This study was inconclusive as it is impossible to determine the fate of the marked eels that were not recaptured.

Desktop downstream migrating fish survival analysis

A desktop modeling analysis of downstream passage survival was conducted for Shad, adult and juvenile alosines for all three projects. For adult alosines, this analysis produced similar results than the empirical study for PUF and PLF but predicted lower survival at Rolfe (56 – 59%). Adult shad had lower estimated survival than alosines, likely due to larger body size (24-30% at Rolfe, 55-61% at PUF, and 72-75% at PLF). While juvenile alosines had high survival estimates at all three projects (97-99% at Rolfe, 96-98% at PUF, and 96-97% at PLF). Based on robust passage estimates obtained for out migrating American eel at the three projects during the fall 2021 empirical study, no desktop evaluation was conducted for that species.

2.5.1.2 Mussel Community

<u>Freshwater Mussel Survey</u>

Mussel surveys were conducted in September 2021 at five locations including the impoundment for each of the three projects, the York dam bypass and downstream of PLF. A total of 2,700 individuals were collected and identified. The mussel species identified included Eastern elliptio, brook floater, triangle floater, eastern floater, eastern lampmussel. Mussel community was vastly dominated by Eastern elliptio representing 98% of all identified individuals. Of note was the 53 brook floater mussels found which were almost all located in the York dam bypass. Brook floaters are a state endangered species in NH and the population found in the York bypass is robust and healthy with several age classes identified. Based on these findings the population of brook floaters in the York bypass have established in a suitable habitat and any proposed deviations from proposed operations should consider potential impact on these mussels.

2.5.3 Protection, Mitigation, and Enhancement Measures

2.5.3.1 Agency Recommended Mitigation

NMFS submitted comments on the Draft License Application which included requested PM&E related to fish passage. Their comments are copied below:

Measure #1 - Project operations; remove the word "approximately".

Measure #2 - Minimum flows; the necessary flows may change depending on what is determined to be required for safe, timely, and effective downstream passage at Rolfe Canal and the penstock bypass. In particular, at the penstock/powerhouse intake, there will likely be a need to install a route of egress through the historic canal that currently takes 5 cfs. If this is done, the minimum flow will need to be increased to 25 or 30 cfs with the installation of an entrance that meets contemporary fish passage standards for alosines (USFWS 2019).

Measure #3 - Proposed measures related to American eel:

- One-inch clear spacing is not protective of adult American eel. We cite the recent study by Amaral et al. (2021) as evidence to support this position.
- Similarly, the proposed temporary overlay deployment period is not protective of adult alosines, which actually had lower survival in some instances than eels through the turbines. If overlays are the preferred alternative, then the clear spacing should be reduced to¾" and the deployment period should be increased to cover from May 15 to November30 (or 10°C) at Rolfe and PUF Projects.
- Further, if Briar prefers to have overlays and throttle down the units to meet approach velocity requirements, then this should be done nightly throughout the downstream passage season without any triggering rain event.
    - If the overlay approach is selected, we are agreeable to the proposed implementation in the second year after license issuance, provided that Briar maintains their current nighttime shutdown protocols.

  - For PLF, we agree generally with the proposed approach, noting that no specifics are yet detailed. However, the seven-year implementation schedule is longer than necessary. We contend that five years (2-3 years for design, a year for permitting, and a year for construction) is a more appropriate timeline to implement the proposed measures. As there is no current protection measures in place other than an ineffective bypass at PLF, additional delays in implementation are unacceptable.

Measure #4-Upstream alosine passage:

- We do not agree with the proposed trigger numbers, and will not support their inclusion in the new license. One passage alternative that is not discussed in the DLA but may be viable, is a single trap structure at PLF that would allow fish to be collected and trucked to the York impoundment, bypassing the other two projects entirely. Such a configuration would make trigger numbers at PUF and Rolfe Projects irrelevant. One of the purposes of the Passage Feasibility Study (which has not been completed to date) mentioned in our cover letter was to provide data necessary to evaluate the viability of building a single trap and truck(T&T) facility at PLF in lieu of individual fishways at each Project.

- If the T&T alternative is selected, we recommend Briar construct and begin operation of the facility within two years of implementation of upstream passage the Garvin's Falls Project. Agencies plan to stock fish upstream of the Contoocook projects in the interim and we anticipate plenty of fish will reach the Contoocook Projects once Garvin's Falls fishway begins operation to justify commencing the T&T operations.

- Upstream anadromous facilities at PUF and Rolfe Projects are likely not necessary with a well-maintained and operated T&T facility at PLF Project. Further, we estimate that even with optimistic passage efficiencies, three separate volitional passage facilities would not be able to match the efficiency gained from a single well-functioning T&T facility. The absence of meaningful amounts of diadromous fish habitat in the reaches between these Projects further supports this approach.

Measure #5 - Downstream fishways; some improvements/enhancements of the existing downstream fish passage measures will likely be needed. The entrance efficiency was not sufficient in the alosine study, though passage survival looked acceptable for fish routed through the existing bypasses. Briar should also consider the route of egress for eels, as it is important for them to move through the project boundaries quickly and safely, particularly once they are excluded from the turbines.

Measure #6 - Upstream eelway(s); permanent eelways (likely multiple) at Rolfe and PLF Projects are needed; we defer to NHFG and USFWS for specifics on the siting and design of these facilities.

Measure #7 - Necessary drawdowns; we recommend Briar consider including language mirroring FERC's standard language related to drawdowns/deviations to more clearly outline agencies involved and what these events entail, for example:

- “The licensee may deviate from the INSERT OPERATIONAL MEASURE HERE for short periods of time, of up to three weeks, after concurrence from LIST AGENCIES. The licensee must file a report with the Secretary of the Commission as soon as possible, but no later than 14 calendar days after the onset of the deviation. Each report must include: (1) the reasons for the deviation and whether operations were modified, (2) the duration and magnitude of the deviation, (3) any environmental effects, and (4) documentation of approval from the conditioning agencies. For deviations from the mandatory conditions exceeding three weeks, the licensee must file an application and receive Commission approval prior to implementation.”

- And for refill: “To protect aquatic resources of the INSERT NAME River downstream of the Project(s), the Licensee should implement a reservoir refill protocol whereby, following a reservoir drawdown, whether in support of power generation, planned or unplanned maintenance activities, or in response to conditions beyond the Licensee’s control, 90 percent of inflow is passed downstream of the Project’s tailrace and the reservoir is refilled on the remaining 10 percent of inflow. This refill protocol may be modified on a case-by-case basis with the prior approval of the Service, the New Hampshire Fish and Game Department, and the New Hampshire Department of Environmental Services.”

2.5.3.2 Applicant proposed Mitigation

As mentioned in the cover letter accompanying this application, the fish passage feasibility study is delayed and is now expected to be completed by mid-March 2023. This study will evaluate alternative approaches to upstream and downstream fish passage, recommend a preferred approach, and estimate the capital, operation, and maintenance cost as well as the effect on generation of proposed fish passage PM&E. The results of this study are necessary to inform applicant proposed fish passage PM&E measures, therefore we will submit updated applicant proposed fish passage PM&E after the feasibility study is completed.

A trap and truck approach to upstream fish passage that would capture fish at the Penacook Lower Falls project, transport, and release them upstream of York dam is being considered in the fish passage feasibility study and is likely to be the applicant’s preferred approach to upstream passage, pending the results of the feasibility study.

We propose the following PM&E measures for fish and aquatic resources, excluding fish passage.

- Continue to operate all three projects in run of river mode where inflow approximately equals outflow.
    - We continue to describe run-of-river operations as inflow approximately equaling outflow despite NMFS request that we delete “approximately”. Realistic expectations must recognize that even the best efforts to operate in true

instantaneous run of river mode will not result in absolute parity in instantaneous inflow and outflow at all times.

- Continue to maintain the existing minimum flow requirements at Rolfe Canal of 5 cfs in the canal/penstock bypass and 100 cfs in the York dam bypass.
    - We note, following discussions with state and federal resource agencies, that this proposed bypass flow PM&E may be updated pending the results of the fish passage feasibility study.
- If a drawdown of the York bypass is necessary for maintenance work at York dam or Penacook Upper Falls, Briar Hydro will consult with agencies to develop a plan to protect the identified population of brook floater mussels during any drawdowns.
- If a planned drawdown is necessary to perform maintenance on dam or project structures or equipment, we will notify NH DES, NH Fish & Game, USFWS, and NMFS staff at least 30 days in advance. We will also follow public notice requirements under NH RSA 482:13, if applicable. After a drawdown the impoundment will be refilled by passing 90% of inflow downstream and using 10% of the inflow to refill the impoundment until the normal pond level elevation is reached. This refill method will be used unless a different method has been proposed and approved by the agency staff listed above.

Cost of applicant proposed PM&E

The effect on lost generation and lost revenue of increasing the York bypass flow from 50 cfs to 100 cfs is estimated to be 889,987 kWh per year. Assuming a power price of $0.10/kWh that represents $88,998.70 in lost revenue per year. There is no capital cost associated with this change in operation.

The capital cost of constructing the upstream eel lift passage was $32,360. The estimated annual operation and maintenance cost associated with continued operation of the upstream eel lift passage is $5,520 and $1,000, respectively.

2.6 Terrestrial Resources

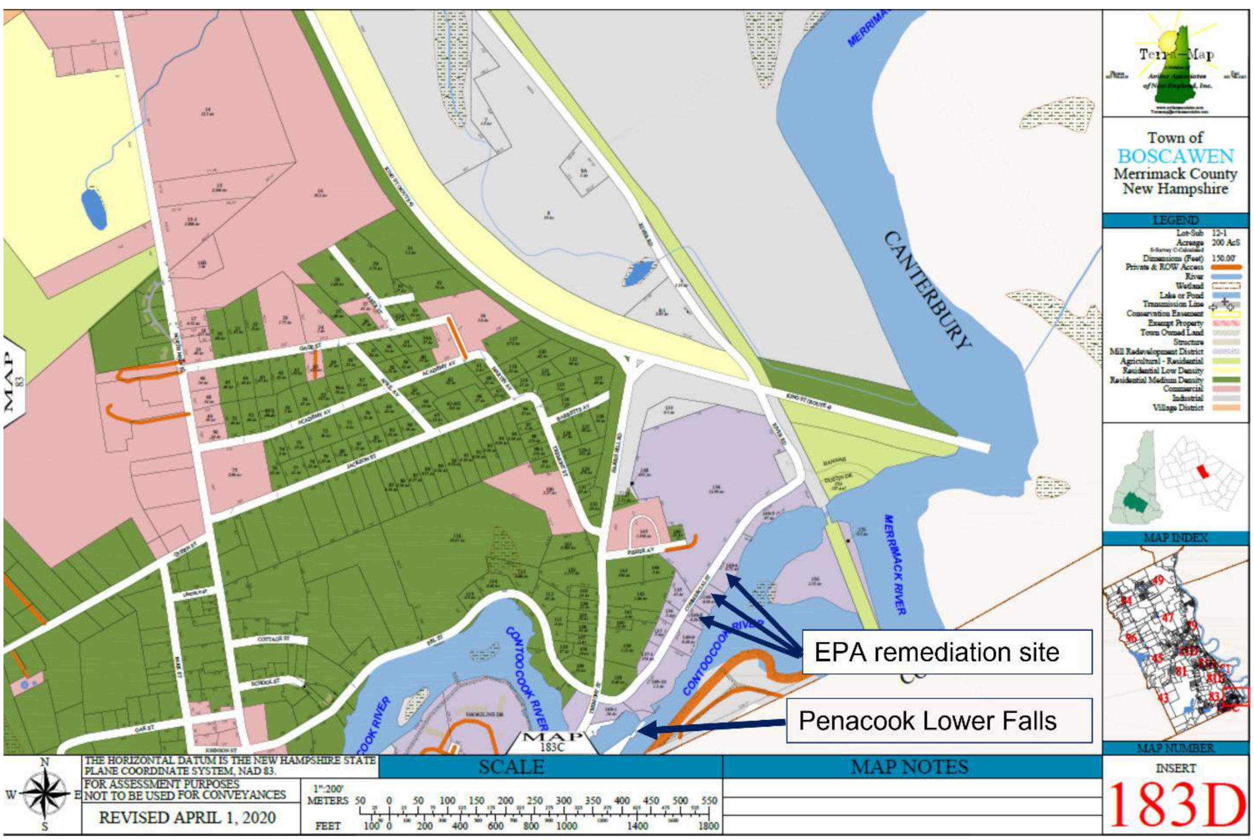
2.6.1 Affected environment

All three of the projects operate in run of river mode with minimal impoundment water level fluctuations therefore minimizing effects on terrestrial environment. There is also little land area included inside the project boundaries for each project.

2.6.1.1 Land Use

All three projects are located in developed areas and the land use in the project boundaries is predominantly a mix of residential and commercial. At Penacook Lower Falls a printing facility and warehouse borders the project as well as a former industrial site currently undergoing environmental remediation. The PLF impoundment is primarily bordered by residential properties with lawns and a narrow border of trees along the riparian habitat. Penacook Upper Falls is the most urban of the three projects located in the village of Penacook. The project boundary is bordered primarily by commercial properties with some buildings abutting the river directly. There are some multi-family residential units also nearby and the City of Concord is planning to redevelop a former industrial site into a small public park near the project. The Rofle Canal project boundary surrounds an island that is half developed into a residential area and half undeveloped and forested. The predominant land use surrounding the Rolfe Canal project area is residential including both single family and multi-family developments.

The environmental remediation site located near Penacook Lower Falls is now owned by the Town of Boscawen and due to its industrial history is contaminated with asbestos containing materials (ACM), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and other heavy metals in the soil and building materials. The site is 1.38 acres and is located on parcels 149-6, 149-7, and 149-8 shown on the map below. Lot numbers are also shown on the project boundary map in Exhibit G.



2.6.1.2 Plant community

The NH Wildlife Action Plan includes maps of habitat and forest type. Many areas around the projects are identified as developed and impervious. The limited forested patches near PLF and PUF are Hemlock-Hardwood-Pine while the forested areas near Rolfe Canal are Appalchian Oak Pine habitats.

Appalachian Oak and Pine forest is characterized by the presence of white oak (*Quercus alba*), black oak (*Quercus velutina*), scarlet oak (*Quercus coccinea*), chestnut oak (*Quercus montana*), and white pine (*Pinus strobus*). In addition, hickories (*Carya* spp.), sassafras (*Sassafras albidum*), pitch pine (*Pinus rigida*), and mountain laurel (*Kalmia latifolia*) are common. Understory plants may include blueberry (*Vaccinium* sp.), black huckleberry (*Gaylussacia baccata*), and may be dominated by mountain laurel shrubs (*Kalmia latifolia*). The habitat is found mostly below 900 ft elevation in nutrient poor, dry, sandplain or shallow bedrock (NHFG 2015).

Hemlock-Hardwood-Pine forest is a transitional forest containing a variable matrix of species. It can typically be characterized by white pine, and eastern hemlock (*Tsuga canadensis*). Depending on the substrate American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), and red oak (*Quercus rubra*) are common. The understory can include witch hazel (*Hamamelis virginiana*), maple-leaved viburnum (*Viburnum acerifolium*), black birch (*Betula lenta*), black cherry (*Prunus serotina*), and ironwood (*Olneya tesota*) (NHFG 2015).

Wetland habitat

The National Wetland Inventory (US FWS) shows that the Contoocook river is classified as riverine habitat except the area between PUF and PLF which is considered freshwater pond. There are isolated patches of forested/shrub wetland near the Rolfe Canal penstock and powerhouse and at the downstream end of the York bypass. There are also areas classified as freshwater emergent wetland and forested/shrub wetland downstream of PLF.

A map of wetland habitat in the vicinity of each project area is shown below in figure E-13.

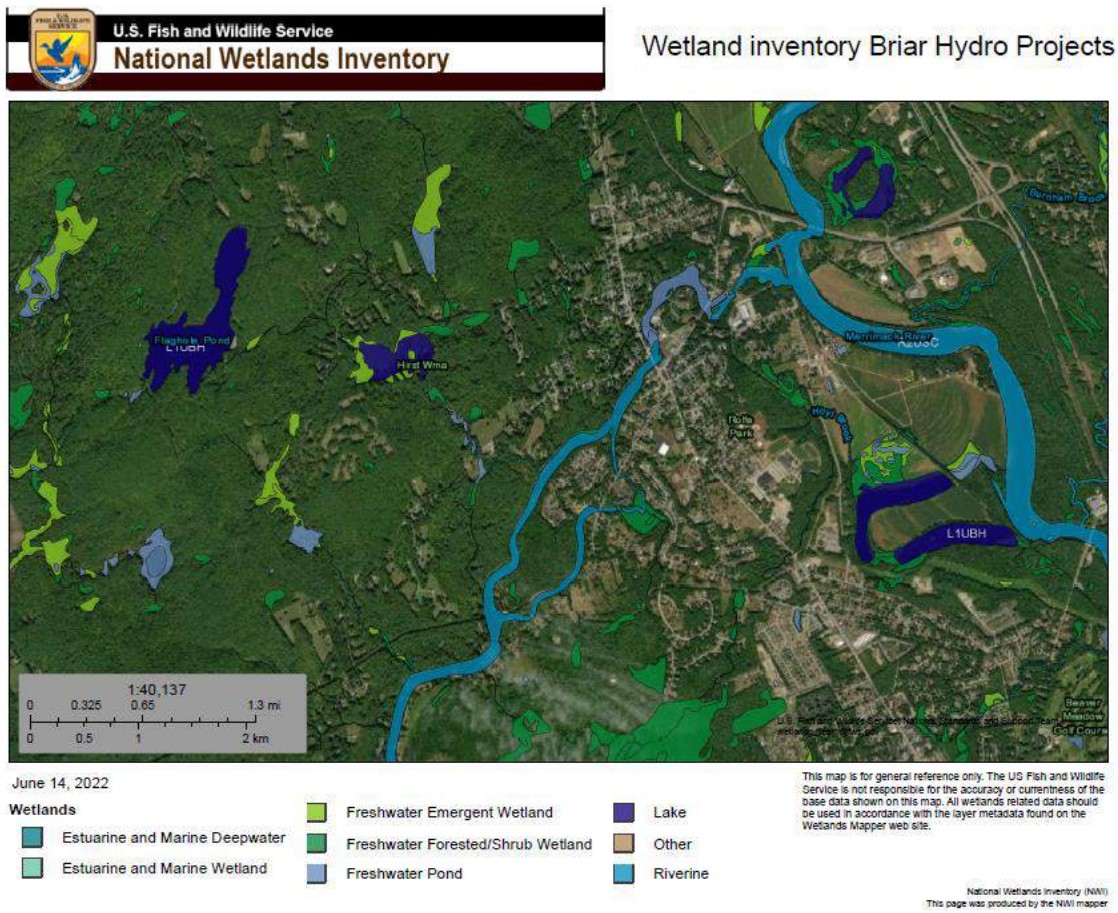


Figure E.13 Map of wetland habitat in the vicinity of the three project areas.

2.6.1.3 Wildlife

The projects are located in primarily developed area with mixed residential and commercial land use therefore much of the area is fragmented by roads and development, which restrict wildlife movement and limit the Project area's use to those species that can tolerate or thrive in proximity to humans. Examples of common mammals that may occur in the suburban and pockets of natural habitats in and bordering the project areas include small rodents (e.g., white-footed mouse [*Peromyscus leucopus*] and redbacked vole [*Myodes rutilus*]), shrews (e.g., short-tailed shrew [*Blarina brevicauda*], eastern chipmunk [*Tamias striatus*], gray squirrel [*Sciurus carolinensis*], red squirrel [*Tamiascuirus hudsonicus*], eastern cottontail rabbit [*Sylvilagus floridanus*], muskrat [*Ondatra zebithicus*], beaver [*Castor canadensis*], porcupine [*Erethizon dorsatum*], Virginia opossum [*Didelphus virginiana*], raccoon [*Procyon lotor*], striped skunk [*Mephitis mephitis*], short-tailed and longtailed weasels [*Mustela ermine* and *M. frenata*], mink [*Neovison vison*], otter [*Lutra canadensis*], red fox [*Vulpes vulpes*], gray fox [*Urocyon cinereoargenteus*], coyote [*Canis latrans*], bobcat [*Lynx rufus*], and white-tailed deer [*Odocoileus virginianus*]). All eight bat species may use the Project area either as summer residents or migrants: big brown bat (*Eptesicus fuscus),* little brown bat *(Myotis lucifugus),* eastern red bat *(Lasiurus borealis),* hoary bat *(Lasiurus cinereus),* silver-haired bat *(Lasionycteris noctivagans),* tricolored bat *(Perimyotis subflavus),* northern long-eared bat *(Myotis septentrionalis*), and eastern small-footed bat *(Myotis leibii).*

Reptiles and amphibians that are likely to occur the Project area include garter snake (*Thamnophis sirtalis*), milk snake (*Lampropeltis t. triangulum*), northern water snake (*Nerodia s. sipedon*), ring-necked snake (*Diadophis punctatus*), painted turtle (*Chrysemys picta*), snapping turtle (*Chelydra serpentine*), red-backed salamander (*Plethodon cinerus*), spotted salamander (*Ambystoma maculata*), blue-spotted/Jefferson salamander complex (*Ambystoma* spp), eastern newt (*Notophthalmus viridescens*), American toad (*Anaxyrus americana*), wood frog (*Lithobates sylvatica*), spring peeper (*Pseudoacris cristata*), bullfrog (*Lithobates catesbiana*), green frog (*Lithobates clamitans*) and pickerel frog (*Lithobates palustris*).

Many bird species may use the Project area during the breeding season, during migration and in the winter. The following list includes water-dependent birds known to or likely to occur in this region of New Hampshire : Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), American black duck (*Anas rubripes*), wood duck (*Aix sponsa*), hooded merganser (*Lophodytes cucullatus*), common merganser (*Mergus merganser*), common goldeneye (*Bucephela clangula*), bufflehead (*Bucephela albeola*), pied-billed grebe (*Podilymbus podiceps*), ring-billed gull (*Larus delawarensis*), double-crested cormorant (*Phalacrocorax auritus*), bald eagle (*Haliaeetus leucocephalus*), great blue heron (*Ardea herodias*), green heron (*Butorides virescens*), spotted sandpiper (*Actitis macularis*), belted kingfisher (*Megaceryle alcyon*), tree swallow (*Tachycineta bicolor*), common grackle (*Quiscalus quiscula*), and red-winged blackbird (*Agelaius phoeniceus*).

2.6.1.3.1 Avian interactions

The projects' transmission line poles and other equipment currently installed that are owned and maintained by the projects have not been evaluated to determine if they are consistent with the Avian Power Line Interaction Committee and USFWS guidelines to minimize adverse avian interactions. Electrical equipment associated with the projects is described, including photos, in Exhibit A of each project license application. There have been no requests by agencies consulted to implement any avian protection measures and we are not, at this time, proposing any avian protection measures nor do we have an avian protection plan. We also have no data regarding observed or documented avian interactions with project power lines. Anecdotally, we have not observed negative avian interactions at the projects.

2.6.1.4 Invasive Plant Species

Variable milfoil has been reported in the project area. No management is being done at this time, due to extensive upstream infestations that are currently under management. The exact location or extent of variable milfoil in the project areas is unknown. Variable milfoil was first documented in Contoocook lake in Rindge NH in 1989, Cheshire Pond in Jaffrey in 1994, Hopkinton Lake/Dam in 2000, and in "various locations" in the Contoocook Rive in 2001, and in 2004 in the Merrimack River at the confluence with the Contoocook River according to the NH DES Exotic aquatic species report issued in 2017. Treatments to control the variable milfoil have been made in Contoocook Lake by the local Lake Association in partnership with NH DES including herbicide application and benthic barriers. In Cheshire Pond a winter drawdown was done to attempt to freeze the milfoil. In Hopkinton dam reservoir the USACE have used both benthic barriers and herbicide treatments to attempt to control the variable milfoil infestation.

Invasive terrestrial plants have not been documented in the project areas. Some common terrestrial invasive plants in the region, including purple loosestrife and Japanese knotweed may be present but have not been explicitly identified. If present, invasive terrestrial plants would be managed according to the vegetation management plan described in section 2.6.1.5 below.

2.6.1.5 Vegetation Management

Vegetation management at the projects is done to maintain safety and necessary access to project features. Dam safety requires that vegetation be cleared or mowed regularly to avoid root damage to dam and other water retaining structures and to allow for visual inspection of these structures. Vegetation must also be kept clear from overhead power lines and other electrical equipment. We also must maintain vegetation to allow for access to necessary project areas for regular monitoring of project condition, maintenance, and recreation. Some vegetation such as poison ivy can create an unsafe work environment for our staff and must be removed to prevent work injuries.

Penacook Lower Falls: Within the project boundary, during the summer mowing and/or weed whacking is done near the access to the diversion structure and in the area immediately surrounding the substation on the south east shore of the river. This allows access to the substation and meter as well as prevents trees from growing under the overhead powerlines. A contractor is also hired to annually apply herbicide on the perimeter of the substation. The contractor is responsible for obtaining permits and following all applicable laws and rules regarding the application of herbicides. The access road and parking area at the boat ramp are maintained to allows access which may involve weed whacking during the summer and infrequently trimming branches.

Penacook Upper Falls: Mowing and/or weed whacking is done along the wingwall on the eastern shore of the river and around the transformer pad. A contractor is also hired to annually apply herbicide on the perimeter of the substation. The contractor is responsible for obtaining permits and following all applicable laws and rules regarding the application of herbicides.

Rolfe Canal: A landscaping contractor mows the lawn area around the powerhouse. As required for dam safety, vegetation near dam structures and on the embankments of the canal is either mowed, weed whacked, or annually herbicide is applied by a contractor. The vegetation along the dirt road to York dam is maintained to allow access. Therefore, trees are only trimmed or removed if they impede vehicle access on the road or are causing a safety hazard (are likely to fall in the road). Vegetation is managed at the boat ramp to allow continued use for recreation including mowing and/or weed whacking as needed during the summer along the perimeter of the parking area, access driveway, and boat ramp.

2.6.2 Project impacts on terrestrial resources

The projects operate in run of river and therefore would not affect upland vegetation and plant species while riparian vegetation are adapted to water level fluctuation and periodic inundation which may occur during periods of unusually high river discharge or precipitation. The wildlife species residing in the vicinity of the project areas would be well adapted to human activity due to the residential/commercial uses in the area therefore the activities associated with hydropower operations are unlikely to have any additional effect on terrestrial wildlife in the area.

2.6.3 Protection, Mitigation, and Enhancement Measures

2.6.3.1 Agency recommended mitigation

We are not aware of any agency recommended mitigation measures related to terrestrial plants, wildlife, or invasive plants in the project areas.

2.6.3.2 Application proposed mitigation

The Applicant is not recommending any mitigation measures associated with terrestrial plants, wildlife, or invasive plants in the project areas.

2.7 Threatened and Endangered species

2.7.1 Affected environment

The NH natural heritage bureau (NH NHB) maintains a database of known occurrences and locations of rare, threatened, and endangered species in NH. The following is a list of species of concern in NH with records of occurrence in the vicinity of the project areas. It should be noted that some of the known locations are outside of the project boundaries but are included here because they are known to occur near the projects as indicated in the table below. The NH NHB report includes a remark that the most recent report of known occurrence for long-leaved pondweed and sessile-fruited arrowhead was more than 20 years ago.

Scientific Name	Common Name	New Hampshire Status	Federal Status	Known occurrence location
Invertebrate Species:				
Gomphus quadricolor	Rapids Clubtail	Special Concern	N/A	Within 1 mile of project boundary PUF & RC
Plant Species:				
Potamogeton nodosus	Long-leaved pondweed	Threatened	N/A	Within PLF project boundary Within 1 mile of project boundary PUF & RC
Sagittaria rigida	Sessile-fruited arrowhead	**Endangered**	N/A	Within 1 miles of project boundary PLF & PUF Shores of Merrimack River
Vertebrate Species:				
Anguilla rostrate	American Eel	Special Concern	N/A	Within project boundary PLF, PUF & RC
Haliaeetus leucocephalus	Bald Eagle	Special Concern	Delisted	Within 1 mile of project boundaries PLF, PUF, & RC
Emydoidea blandingii	Blanding's Turtle	**Endangered**	N/A	Approximately 1 mile from project boundary RC only

Heterodon platirhinos	Eastern Hognose Snake	Endangered	N/A	Approximately 1 mile from project boundary RC only
Bufo fowleri	Fowler's Toad	Special Concern	N/A	Within 1 mile of project boundaries PUF & PLF
Rana pipiens	Northern Leopard Frog	Special Concern	N/A	Within 1 mile of project boundaries
Clemmys guttata	Spotted Turtle	Threatened	N/A	Within 1 mile of project boundaries
Glyptemys insculpta	Wood Turtle	Special Concern	N/A	Within project boundary RC

In addition to the species listed above, the mussel survey study found a population of brook floater (*Alasmidonta varicose*) mussels which is a state endangered species in NH. The mussel survey is discussed in section 2.5.1.2 above and the complete mussel survey report is included in section 2.13 of this Exhibit.

A verification of the USFWS IPaC database for the area including all three project areas and immediate vicinity listed the following species as potentially affected by activity in this area:
Northern long-eared bat – Threatened (proposed status update to endangered March 2022 – proposed rule pending)
Monarch butterfly – Candidate
Small whorled Pogonia – Threatened

In addition to the three species listed above, USFWS proposed to list the tricolored bat as an endangered species in September 2022. The range of the tricolored bat includes New Hampshire however, the proposed rule is still pending.

There are no critical habitat at this location.

2.7.2 Project Impacts on Threatened and Endangered species
Briar Hydro knows of no information suggesting that the current operations or maintenance of the three projects are adversely affecting threatened and endangered species in the vicinity of the Project.

The only NH NHB records on occurrence within the project boundaries are long leaved pondweed at PLF and Wood turtle at RC. The long-leaved pondweed record is outdated and current presence is uncertain. The wood turtle occurrence was near the penstock bypass at Rolfe Canal project. This bypass has a 5 cfs bypass flow and we propose to maintain this constant 5 cfs bypass flow. Maintaining current operation would not negatively affect this species. Project operations and maintenance would not negatively affect the species listed below that are known to occur outside of the project boundaries.

Small whorled pogonia typically occurs in dense tree and underbrush forested areas covering a large tract. The only significant area of forest in the immediate vicinity of any of the projects is the undeveloped portion of the island between the Rolfe canal and the York bypass. This forested area is located outside of the project boundary therefore not affected by project operations. Hydropower operations use and maintain an existing access road to York dam and do not otherwise access or impact the forested area. Since the access road is existing and already a disturbed area it is unlikely that small whorled pogonia would occur near the road.

The primary threat to the northern long eared bat and the tricolored bat is white-nose syndrome. Other factors negatively affecting bats is climate change and habitat fragmentation. As a renewable energy facility, hydropower is part of the solution to climate change. We are not proposing any new construction or development at these projects that would contribute to habitat fragmentation. The only maintenance activity that could impact local bats is tree clearing. We only remove trees if required for dam safety, if they fall and block necessary access, or are creating a safety hazard. Since the only tree cutting undertaken as part of our maintenance activities is specifically for safety purposes (dam safety, under overhead powerlines, or staff/public safety) our operations and maintenance activities do not risk unjustifiably affecting bats.

The primary drivers affecting the health of the two North American migratory populations of monarch butterflies are changes in breeding, migratory, and overwintering habitat (due to conversion of grasslands to agriculture, urban development, widespread use of herbicides, logging/thinning at overwintering sites in Mexico, unsuitable management of overwintering groves in California, and drought), continued exposure to insecticides, and effects of climate change. We are not proposing any new activities or changes to operations that would affect monarch butterflies or their habitat. Ongoing vegetation management practices at these projects that may affect monarch butterfly habitat are described in section 2.6.1.5. Generally, mowing and limited herbicide applications done by a contractor are only done in areas necessary to maintain dam safety and access therefore we are not likely to be significantly affecting monarch butterfly habitat.

2.7.3 Protection, Mitigation, and Enhancement Measures

2.7.3.1 Agency recommended mitigation measures

The applicant is not aware of any mitigation measures related to threatened and endangered species recommended by the agencies.

2.7.3.2 Applicant recommended mitigation measures

The applicant is not recommending any mitigation measures related to threatened or endangered species.

2.8 Recreation and Land Use resources
2.8.1 Affected environment

Recreation
Penacook Lower Falls

The Penacook Lower Falls project constructed and currently maintains a parking area and boat launch facility in a cove on the southern shore of the Contoocook River approximately 700 feet downstream of the powerhouse free of charge to visitors.

The boat launch area provides access to the Merrimac River and is widely used by local fishermen, daytime boaters and by local kayak clubs. Moderate levels of angling have been observed in the project's impoundment and on the southern bank of the tailrace during the years of project operation. Access is gained to the southern bank of the tailrace immediately downstream of the powerhouse or from property surrounding the boat launch ramp.

Parking at the boat launch is available in a cleared dirt area approximately 100 ft by 100 ft which does not have striped parking spaces. If we assume that only half of that area is available for parking (5,000 sq ft) with the remaining space for drive and turnaround lanes and that the parking space per vehicle is 250 sq ft (10ft x 25ft), we can estimate there is enough space to park upwards of 20 vehicles. Since the parking is haphazard and some vehicles may have trailers the actual parking capacity may be less than that estimate in practice. See Figure E.14 for a map of the boat launch and closer aerial view of the parking area.

Figure E.14 Map showing the location of Penacook Lower Falls Boat Ramp and closer aerial view of the parking area.

Penacook Upper Falls

In conjunction with the City of Concord, Briar helped to develop a recreational facility known as the Penacook Downtown River Park (aka Riverside Park) (see Figure E.15 and Figure E.16). The park borders and overlooks the project's impoundment area and has two focal points; the first, a stone structure on site which is used as a theater and stage, and the second, the Contoocook River

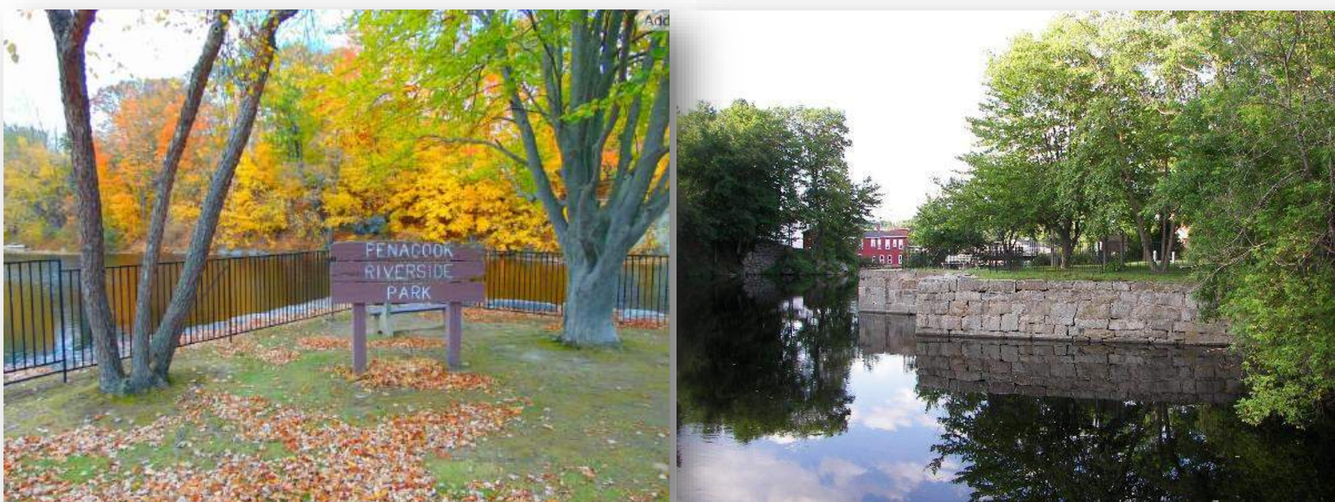


Figure E.15 Photos of Riverside Park located near Penacook Upper Falls project.

itself, the major emphasis of the park being the benches and grassy areas which allow visitors to enjoy the visual and audio aspects of the river. The park is open year round and is provided free of charge to visitors.

The City of Concord has proposed developing a new park on the eastern shore of the river immediately upstream of Penacook Upper Falls. Briar Hydro is collaborating with the City of Concord on this project by providing easements and input on the park. The City and Briar Hydro are discussing including interpretive educational signage on the topic of hydropower.

Figure E.16 Aerial image showing the location of Penacook Upper Falls dam, existing park and proposed new park.

Rolfe Canal

The Project provides limited recreational opportunities due to insufficient shorelands ownership by Briar Hydro. The City of Concord owns a large tract of forested land that is located immediately downstream of the intake to the Rolfe Canal and between the York bypass and the canal. Although the City has identified this land as a potential location for a park, no formal development has yet occurred, and the area is primarily used for hiking and serves as access for angling.

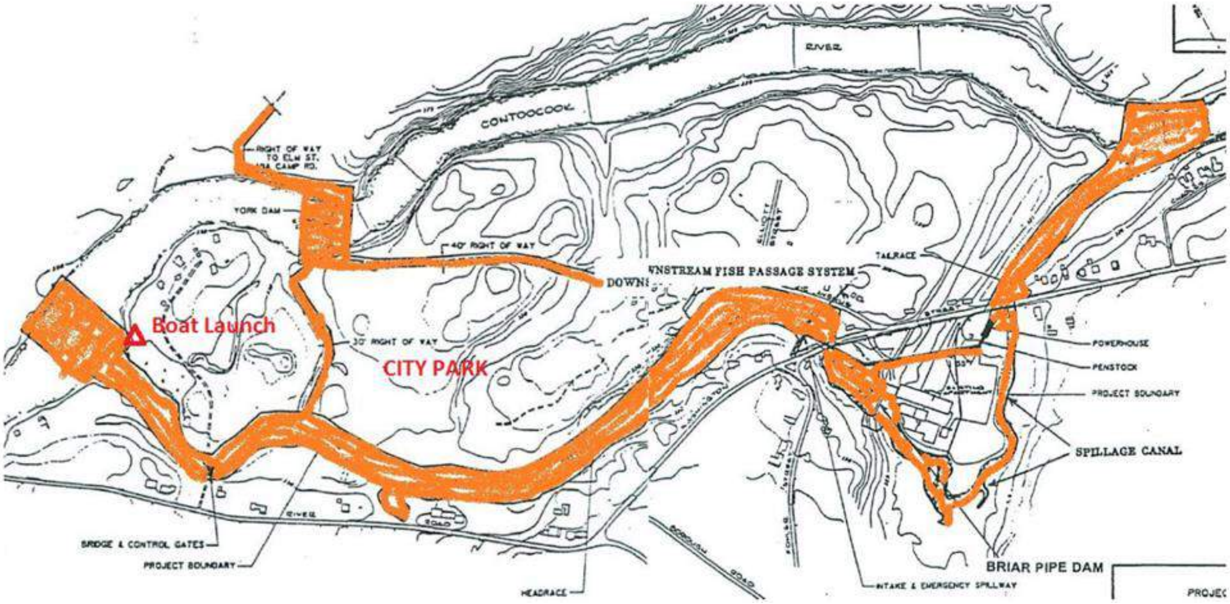


Figure E.17 Map of Rolfe Canal Project Lands and Recreation Access

Prior to Project development, the City of Concord maintained a boat launch (See Figure E.18) on the riverbank at the canal inlet. The license indicated that BRHA would protect the City's existing boat launch during Project construction and operation; however, unsafe currents were identified during a FERC inspection in 1990 and an order was issued requiring the BRHA to relocate the boat launch. FERC subsequently issued an order on January 22, 1993 approving a redesign with the launch remaining in the original location but with a breakwater to create a slack-water area for safe launching. The order requires the completion of a study within nine months to determine the maximum safe velocity for use of the launch with gating off of the launch when velocities exceed the safe level. FERC approved the boat launch operation plan by letter order dated June 24, 1993. The license does not require development of a recreation plan.

The current boat launch has an unpaved parking area approximately 70ft by 35 ft sufficient for approximately 6 or 7 head-in parking spaces. There is also additional space for parking along the access from Island road to the ramp that is suitable for vehicles with trailers (approximately 2-3) see figure E.18.

During the original licensing process, the USFWS recommended that the Applicant provide access across project lands for angling opportunities, especially as related to increased pressure once salmon and shad are restored. Briar Hydro does not consider its limited ownership of lands in the area conducive to such use. Standard Article 18 of the license requires free public access for public outdoor recreation, including hunting and fishing, except where such use would conflict with project operations or present a risk to public safety.

Figure E.18 Picture of Rolfe Canal Boat Launch and aerial view of the parking area.

2.8.1.2 Non-Recreational Land Use and Management within the Project Boundary
Within each project boundary, the area which includes the major Project works (including dam, powerhouse, intake canal, fish lift, etc.) is fenced and only used for non-recreational uses for safety. The remainder of the area located within the Project boundary, including the impoundment, is used and managed for both non-recreational and recreational uses.

2.8.1.3 Recreational and Non-Recreational Land Use and Management Adjacent to the Project Boundary
Other than boating access and public park facilities specifically mentioned in section 2.8.1, there are no other public recreation site or facilities adjacent to the project areas.

2.8.1.4 Regionally or Nationally Important Recreation Areas
There are no regionally or nationally important recreation areas located within or in the vicinity of the project areas.

2.8.1.5 Existing Shoreline Buffer Zones within the Project Boundary

Buffers along the Contoocook River are protected by the State of NH Shoreland and Water Quality Protection Act (SWQPA). The SWQPA protects vegetated buffers within 50 ft of the reference line and provides additional protections for the shoreland (within 250 ft of the reference line). Vegetated buffer coverage within the project boundary is variable due to the existing land use in the area.

2.8.1.6 Description of Project Lands in Relation to the National Wild and Scenic River System, Trails System, or as a Wilderness Area

The project boundaries are not located in a designated area or under study for inclusion in the National Wild and Scenic River System.

To our knowledge, no immediate project lands of the Rolfe Canal, PUF and PLF projects are under study for inclusion in the National Trails System or as a Wilderness Area.

2.8.2 Project Impacts on Recreation and Land Use Resources

The existing boat ramps located upstream of Rolfe Canal and downstream of Penacook Lower Falls give boating access to the impoundment upstream of York and Rolfe Canal dams as well as the Merrimack river. There is little area of river between Rolfe canal and Penacook Upper Falls and between Penacook Upper Falls and Penacook Lower Falls. In addition, there is no area appropriate for boating access within the project boundary at PUF.

Briar Hydro has previously collaborated with the City of Concord and will continue to do so to develop public park facilities adjacent to project lands. This collaborative approach allows for the appropriate balance of public access and enhanced recreation opportunities with public safety in proximity of the projects.

No impacts on recreational resources are expected as a result of the proposed operation of the projects. The projects operate in run of river mode with no use of impoundment storage and, as such, maintains a relatively constant pond level. Operations or maintenance of the projects to date has not caused any adverse effects on recreation and land use in the vicinity of the projects.

2.8.3 Protection, Mitigation and Enhancement Measures

2.8.3.1 Current or future Recreation Needs from Existing State or Regional Plans

The Statewide Comprehensive Outdoor Recreation Plan (SCORP) does not identify recreation needs at the local level. Generally, outdoor recreation is popular and important to the economy of NH. The City of Concord of Town of Boscawen provide diverse and plentiful recreation opportunities for residents and visitors to the area. Briar Hydro is not aware of an existing or expected future recreation need not currently being adequately met.

2.8.3.2 Agency Recommended Mitigation

Briar Hydro has not received any agency proposed PM&E measures related to recreation and land use resources.

2.8.3.3 Applicant Proposed Mitigation

The applicant is not proposing any new PM&E measures related to recreation and land use resources. We do propose to continue to maintain existing recreation facilities including the boat launch areas at PLF and Rolfe Canal.

2.9 Aesthetic Resources

2.9.1 Affected Environment

Some components of each project are visible to passersby on local roads. PLF is visible from the Canal street bridge, PUF is visible from the Village Street bridge, and the Rolfe Canal power house is visible from Washington Street. York dam from downstream is a pleasant view with some of the minimum flow going over the spillway. This view of York dam is observable from the public hiking trails on City owned forested land near the project. Pleasant views of the impoundments are also accessible from some local roads and parks.

None of the roads in the area are designated state of federal scenic byways or highways and the Contoocook River is not currently classified considered for inclusion as a Wild and Scenic River.

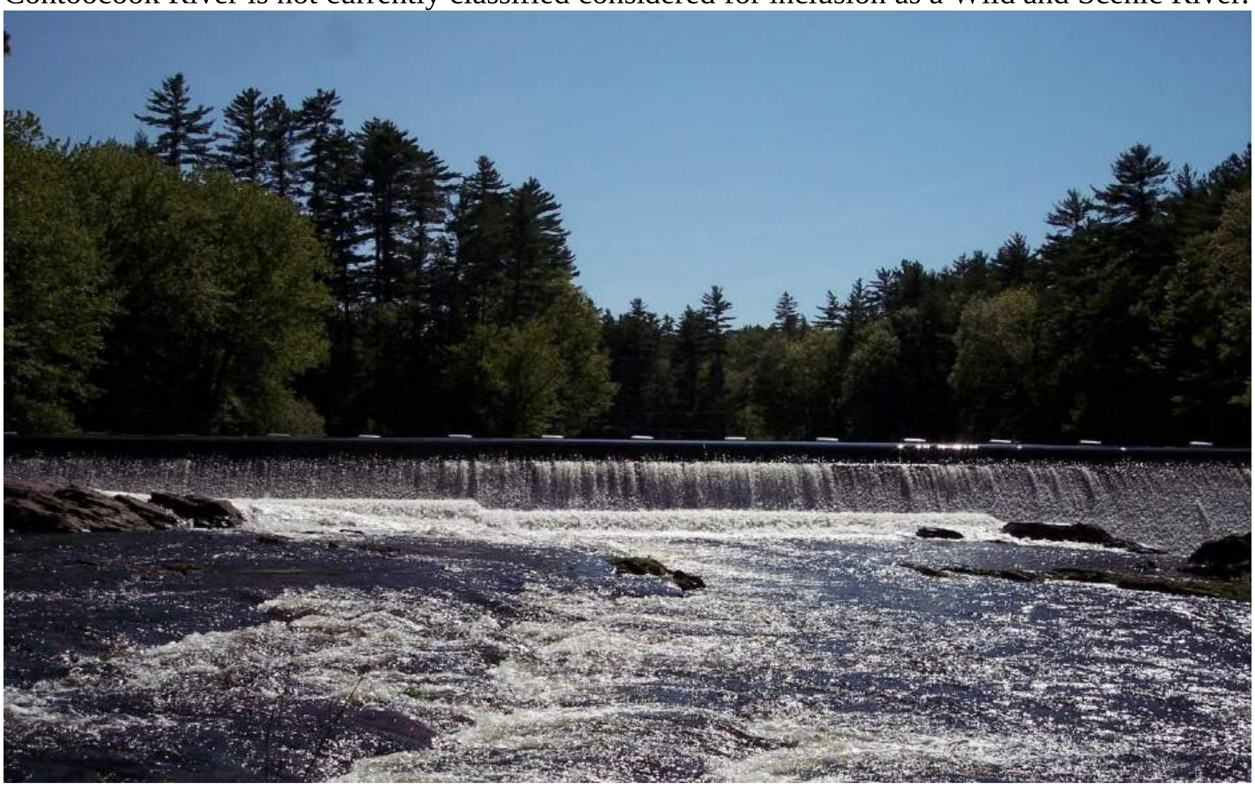


Figure E. 19 Photo showing a view of York Dam

2.9.2 Project Impacts on Aesthetic Resources

Briar Hydro proposes to operate and maintain the three projects as currently licensed. Briar Hydro is not planning any construction activity that would affect existing land use and aesthetics resources in the project areas. Therefore, the applicant expects there to be no adverse impact on and aesthetic resources in the next license terms that would result from maintenance and operation of the Rolfe Canal, PUF, and PLF projects.

2.9.3 Protection, Mitigation, and Enhancement Measures

Continued operation of the projects is not expected to adversely affect aesthetic resources in the project vicinities. As such, no protection, mitigation and/or enhancement measures are being proposed by Briar Hydro for the relicensing of the three projects.

2.9.3.1 Agency Recommended Protection, Mitigation, and Enhancement Measures

Briar Hydro is not aware of any agency proposed PM&E measures related to aesthetic resources.

2.9.3.2 Applicant Recommended Protection, Mitigation, and Enhancement Measures

Briar Hydro is not proposing any PM&E measures related to aesthetic resources.

2.10 Cultural Resources

2.10.1 Affected Environment

As was determined by the Project's exemption from licensing granted in September 1981, there are no significant historic and/or archeological sites in the Penacook Lower Falls area. Consultation with the New Hampshire Department of Resources and Economic Development in 1981 confirmed that no sites of historic and/or archeological significance

BRHA submitted a Request for Project Review to the New Hampshire Division of Historical Resources ("NHDHR") and provided a boundary map encompassing both the Penacook Upper and the Penacook Lower Project boundaries. On February 9, 2010 the NHDHR confirmed that there are no historic properties affected by the projects. Another request was made for review by NHDHR of the Penacook Lower Falls due to dam repair work requiring permitting and in October 2020 NHDHR again concluded there was no historic properties affected.

In 2017 BRHA also submitted a Request for Project Review to the New Hampshire Division of Historical Resources ("NHDHR") and provided a boundary map encompassing the Rolfe Canal Project boundaries. The NHDHR determined there was no potential to cause effect but noted a historic mill might be downstream and the York dam might be eligible for a National Register listing. NHDHR noted if modifications were proposed action would be necessary. No modifications are planned for the Rolfe Canal project at this time.

About one quarter of a mile downstream from the Penacook Lower Falls site is a one acre island at the confluence of the Contoocook and Merrimack Rivers which is the location of the Hannah Dustin Monument. This statue was erected in 1874 and is the first publicly-funded statue in New Hampshire. It commemorates the escape of Hannah Duston, who was captured in 1697 in Haverhill, Massachusetts during the French and Indian War. The site is potentially eligible for the National Register of Historic Places. A short walk from the parking area brings visitors to a picnic spot on the shore of the river. Project operations do not cause any adverse impacts upon this historic site.

Consultation with NH DHR staff revealed that there are two known pre-contact native American archeological sites near the vicinity of the projects. One is located in the wooded area downstream of York dam and likely outside of the project boundary. The other is located between Penacook Upper Falls and Penacook Lower Falls near the upstream end of the PLF project boundary on land to the south of the river. We are uncertain of the exact location of the site but it was identified during the development of a residential development located on shoreline drive so it is in the vicinity of those structures. If the area of potential effect is the same as the project boundaries, we do not think there are any known archaeological sites within the project boundaries.

In addition, there are 4 buildings in Boscawen and 1 building in Penacook that are listed on the National Register of Historic Places. Those are the Boscawen Academy, Boscawen Public Library, First Congregational Church of Boscawen, and Morill-Lassonde House in Boscawen as well as Rolfe Barn in Penacook. None of these structures are located particularly near the river or any of the three projects. The closest being Rolfe Barn located 0.35 miles from Penacook Lower Falls. The closest Boscawen historical structure to one of the projects is Boscawen Academy located 0.45 miles from Penacook Upper Falls.

During the development of the study plan and during review of the proposed study plan, there were no studies requested related to cultural, historical, archeological, or architectural resources. Therefore, there have been no discovery measures undertaken at any of the three project's sites for the purposes of locating, identifying, and assessing the significance of historical or archeological resources.

2.10.2 Project Impacts on Cultural Resources

To the best of our knowledge there are no known Indian tribes that may attach religious or cultural significance to historic properties in the boundary or vicinity of the three projects.

NHDHR responses to review of the project areas have revealed that either there are no historic properties affected or that there are no concerns of impact on historic properties under current conditions and that only if modifications are proposed at Rolfe canal project would further survey or review be necessary. Therefore, we conclude that there is no current or likely future project impact on Cultural resources under new licenses.

2.10.3 Protection, Mitigation, and Enhancement Measures

2.10.3.1 Agency Recommended PM&E Measures

Briar Hydro is not aware of any agency recommended PM&E measures related to cultural resources.

2.10.3.2 Applicant proposed PM&E Measures

The applicant is not proposing any PM&E measures related to cultural resources as no impact is expected.

2.11 Socio-economic Resources

The projects are located in Merrimack County, NH. Located in the south central portion of the state, equidistant from both the Maine and Vermont borders. Merrimack County includes the City of Concord, the state capitol, which is tucked into a bend in the Merrimack River. The county takes its name from the Merrimack River, whose name was adapted from an Abnaki Indian word meaning "deep." The county was formed in 1823 from towns in Hillsborough and Rockingham counties.
Merrimack County contains 934.1 square miles of land area and 22.3 square miles of inland water area. Based on the 2010 Census population, the population density is 156.8 persons per square mile. Merrimack County includes two cities, Concord and Franklin, and 25 towns. The county seat is Concord.

The population of Merrimack County according to the 2020 US Census is 153,808. Merrimack County has long been the third largest county in population, and is about equal in square miles of land to Carroll County. It is, however, the fourth most densely populated county, with less than half the population density of Strafford County, the third highest. Population in Merrimack County increased at about the same rate for three consecutive decades from 1960 to 1990, with population growth rates of 19.4 percent, 21.5 percent, and 22.3 percent. Since then the rate of growth has slowed, increasing by 13.3 percent between 1990 and 2000, 7.5 percent between 2000 and 2010 and 3.4 percent between 2010 and 2019.

The population of Merrimack County is predominantly white with a median annual household income of $77,937 and 9.8% in poverty. The largest employers in Merrimack County are the State of NH, Capital Region Health Care, and Merrimack County Nursing Home and Jail. The top 10 largest employers in the county are shown in the table below (source NH Employment Security).

Largest Businesses	Community	Product/Service	Employees
State of New Hampshire	Concord	Government	6,069
Capital Region Health Care	Concord	Health care services	3,050
Merrimack County Nursing Home & Jail	Boscawen	Nursing home, correctional facility	827
Concord School District	Concord	Education	818
GE Aviation	Hooksett	Jet engine parts	800
Southern NH University	Hooksett	Education	700
Pats Peak	Henniker	Ski area	622
City of Concord	Concord	Government	602
New London Hospital	New London	Health care services	520
United Healthcare	Hooksett	Health insurance services	500

Environmental Justice

To assist staff in complying with Executive Order 14008 Tackling the Climate Crisis at Home and Abroad and Executive Order 12898 Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations, we are providing the following new information as requested by Commission Staff.

According to the data presented in the table below, there were no environmental justice communities based on the presence of low-income populations identified in the census block groups that are within 1 mile of the project boundaries. Each census block group percent population below the poverty level (4.3 to 7.8 %) were lower than the reference population of Merrimack County (9.8%). The total percent minority population for tract 443 group 3 which is within a mile of the Rolfe Canal project boundary is 15.4% and is more than 10% greater than the reference population of Merrimack county is 12.5% which would make this population an environmental justice community according to the "meaningfully greater analysis method".

The other census group blocks considered had significantly lower minority populations than the reference population and therefore do not qualify as environmental justice communities. The minority population in tract 443 group 3 were African American (8%), Asian (2%), and Hispanic or Latino (5%).

We are not proposing any new project-related construction, therefore project-related construction would not risk affecting the identified environmental justice community. There are no anticipated project related impacts on any environmental justice communities.

We have not done outreach explicitly to environmental justice communities. All neighboring communities and abutters have been notified of this application as required. No comments have been received from environmental justice communities or organizations that represent them. We are not aware of significant non-english speaking groups within the geographic scope of the analysis therefore our communications regarding this application have been provided in English.

	Race and ethnicity data										Low-income data	Project
Geography	Total Population	White alone not Hispanic	African American	Native American/ Alaska Native	Asian	Native Hawaiian & other pacific islander	Other race	Two or more races	Hispanic or Latino	Total minority %	Below Poverty level %	
NH State	1,377,529	1,200,649	20,127	3,031	35,871	453	24,102	77,742	59,454	16.0	7.2	
Merrimack County	153,808	137,252	2,650	362	3,026	64	1,336	7,916	3,880	12.5	9.8	
Tract 327.06 group 1	1,308	1,279	0	0	29	0	0	0	0	2.2	4.3	Lower and Upper
Tract 380 group 3	1,414	1,414	0	0	0	0	0	0	0	0.0	7.8	Lower and Upper
Tract 327.01 group 1	1,392	1,310	8	0	33	0	0	22	19	5.9	5.7	Rolfe
Tract 443 group 3	2,087	1,765	163	0	44	0	0	15	100	15.4	4.4	Rolfe

2.11.1 Project effect on socio-economic resources

The three projects have a positive effect on local socio-economic resources by creating employment, economic activity in the form of revenue for local vendors, and tax revenue for the municipalities where the projects are located and the state of NH. These positive effects would be expected to be similar under the term of new licenses.

2.11.2 Protection, Mitigation, and Enhancement Measures

2.11.2.1 Agency Recommended PM&E Measures

Briar Hydro is not aware of any agency recommended PM&E measures associated with Socio-economic resources.

2.11.2.2 Applicant proposed PM&E Measures

The Applicant is not proposing any PM&E measures associated with socio-economic resources.

2.12 Compliance with FERC Recognized Comprehensive Plans

Section 10(a)(2)(A) of the Federal Power Act (FPA), 16 United States Code (USC) § 803(a)(2)(A), requires FERC (the Commission) to consider the extent to which a project is consistent with federal or state comprehensive plans for improving, developing, or conserving a waterway affected by the project. FERC Order No. 481-A, issued on April 27, 1988, established that the Commission will accord FPA Section 10(a)(2)(A) comprehensive plan status to any federal or state plan that:

- is a comprehensive study of one or more of the beneficial uses of a waterway or waterways;
- specifies the standards, the data, and the methodology used; and
- is filed with the Secretary of the Commission.

Based on the Commission's August 2022 revised list of comprehensive plans for the New Hampshire, 21 of the 43 listed comprehensive plans pertain to the Merrimack River watershed. In general, the plans have identified water quality and habitat loss as the primary factors affecting aquatic resources, as well as management objectives for New Hampshire wetlands, rivers, and outdoor recreation. The Project's continued run-of-river operation and the associated environmental protection, mitigation, or enhancement measures (i.e., maintaining existing minimum flows) contained in the Applicant's proposal will ensure continued consistency with the uses outlined in the plans listed below.

- Atlantic States Marine Fisheries Commission. 1999. Amendment 1 to the Interstate Fishery Management Plan for shad and river herring (Report No. 35). April 1999.
- Atlantic States Marine Fisheries Commission. 2000. Interstate Fishery Management Plan for American eel (Anguilla rostrata) (Report No. 36). April 2000.
- Atlantic States Marine Fisheries Commission. 2000. Technical Addendum 1 to Amendment 1 of the Interstate Fishery Management Plan for shad and river herring. February 9, 2000.

- Atlantic States Marine Fisheries Commission. 2008. Amendment 2 to the Interstate Fishery Management Plan for American eel. Arlington, Virginia. October 2008.
- Atlantic States Marine Fisheries Commission. 2009. Amendment 2 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. May 2009.
- Atlantic States Marine Fisheries Commission. 2010. Amendment 3 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. February 2010.
- Atlantic States Marine Fisheries Commission. 2013. Amendment 3 to the Interstate Fishery Management Plan for American eel. Arlington, Virginia. August 2013.
- Atlantic States Marine Fisheries Commission. 2014. Amendment 4 to the Interstate Fishery Management Plan for American eel. Arlington, Virginia. October 2014.

The above eight plans are focused on American eels. See section 2.4 for a summary of study reports on upstream and downstream eel passage at the three projects and current upstream eel passage facility at PUF, and proposed PM&E measures related to American eel passage.

- Merrimack River Policy and Technical Committees. 1990. Strategic plan for the restoration of Atlantic salmon to the Merrimack River, 1990 through 2004. Concord, New Hampshire. April 1990.

Atlantic salmon restoration efforts in the Merrimack river watershed were suspended therefore Briar Hydro is not proposing any PM&E measures associated with Atlantic Salmon restoration.

- National Park Service. The Nationwide Rivers Inventory. Department of the Interior, Washington, D.C. 1993.

The National Rivers Inventory lists the segment of the Contoocook River from Contoocook to Penacook as having the following resources: “Fish-(River is an historic Atlantic Salmon fishery.) Historic-(Segment includes two covered bridges which are being nominated to the National Register of Historic Places.) Recreation-(Significant diversity of flow gradients ranging from slackwater to rapids of Class IV gradients.)”.

As mentioned above the Atlantic Salmon restoration efforts in Merrimack River watershed including tributaries like the Contoocook River has been suspended. The covered bridges mentioned are far upstream of the projects and would not be affected by the projects. The project impoundments contribute to the diversity of flow gradients mentioned by creating slackwater reaches.

- New Hampshire Office of State Planning. 1977. Wild, scenic, & recreational rivers for New Hampshire. Concord, New Hampshire. June 1977.

See section 2.7 for detailed description of current recreation and public access offered by the projects.

- New Hampshire Office of State Planning. 1989. New Hampshire wetlands priority conservation plan. Concord, New Hampshire.

This plan does not include specific listing or concern of the Contoocook River in the vicinity of the projects beyond mentioning that the Contoocook River is a designated river under the NH Rivers Management and Protection Act.

- New Hampshire Office of Energy and Planning. New Hampshire Statewide Comprehensive Outdoor Recreation Plan (SCORP): 2008-2013. Concord, New Hampshire. December 2007.
- New Hampshire Office of State Planning. 1991. Public access plan for New Hampshire's lakes, ponds, and rivers. Concord, New Hampshire. November 1991.

See section 2.7 for detailed description of current recreation and public access offered by the projects.

- New Hampshire Office of State Planning. 1991. Upper Merrimack River corridor plan-volume 2: management plan. Concord, New Hampshire. March 1991.

This plan and the most updated version (2007) are focused on a section of the mainstem Merrimack River and do not contain specific goals or objectives related to tributaries including the Contoocook River.

- Policy Committee for Anadromous Fishery Management of the Merrimack River Basin. 1985. A strategic plan for the restoration of Atlantic salmon to the Merrimack River Basin, 1985 through 1999. Laconia, New Hampshire. May 1985.

Atlantic salmon restoration efforts in the Merrimack river watershed were suspended therefore Briar Hydro is not proposing any PM&E measures associated with Atlantic Salmon restoration.

- State of New Hampshire. 1991. New Hampshire rivers management and protection program [as compiled from NH RSA Ch. 483, HB 1432-FN (1990) and HB 674-FN (1991)]. Concord, New Hampshire. State of New Hampshire. 1991. New Hampshire rivers management and protection program: (1) 1994 Contoocook and North Branch Rivers, river corridor management plan; (2) 1994 Swift River corridor management plan; (3) 1999 Piscataquog River management plan; (4) 2006 Ashuelot River management plan; (5) 2007 Lamprey River management plan; (6) 2008 Lower Merrimack River corridor management plan; (7) 2009 Cold River watershed management plan; (8) 1994 Saco River corridor management plan; (9) 1999 Exeter River corridor and watershed management plan; (10) 2001 Pemigewasset River corridor management 73 plan; (11) 2006 Souhegan River watershed management plan; (12) 2007 Upper Merrimack River management and implementation plan; and (13) 2008 Isinglass River management plan. Concord, New Hampshire.

The Contoocook and North Branch Rivers corridor management plan was most recently updated in 2011. The plan lists several goals and objectives that the Rolfe Canal, PUF, and PLF projects help achieve. For example, the public access and recreation opportunities created at the projects help achieve goal Goal #5 “Maintain and encourage safe and responsible public access and use of the rivers’ resources.” The proposed continuation of operation in run of river mode and bypass flows at Rolfe Canal help to protect water quality, quantity, and stable flow patterns. The plan does not mention specific goals or objectives related to dams or hydropower generation.

- Technical Committee for Fishery Management of the Merrimack River Basin. 2021. Merrimack River Watershed Comprehensive Plan for Diadromous Fishes.

See section 2.4 for summary of fish passage study reports and proposed PM&E measures related to fish and fishery resources.

- U.S. Fish and Wildlife Service. 1989. Atlantic salmon restoration in New England: Final environmental impact statement 1989-2021. Department of the Interior, Newton Corner, Massachusetts. May 1989.

Atlantic salmon restoration efforts in the Merrimack river watershed were suspended therefore Briar Hydro is not proposing any PM&E measures associated with Atlantic Salmon restoration.

- U.S. Fish and Wildlife Service. 2010. A Plan for the Restoration of American Shad: Merrimack River Watershed. Concord, New Hampshire. 2010.
- U.S. Fish and Wildlife Service. n.d. Fisheries USA: the recreational fisheries policy of the U.S. Fish and Wildlife Service. Washington, D.C.

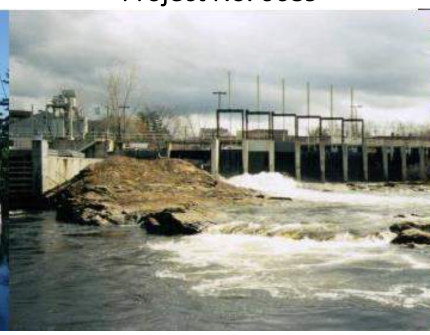
See section 2.4 for summary of fish passage study reports and proposed PM&E measures related to fish and fishery resources.

2.13 Study Reports

Water Quality Study

Briar Hydro Associates

Penacook Lower Falls Hydroelectric Project Project No. 3342	Penacook Upper Falls Hydroelectric Project Project No. 6689	Rolfe Canal Hydroelectric Project Project No. 3240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February 2022

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1 Introduction and Background

The goal of this Briar Hydro Associates (Briar Hydro or Licensee) is in the process of relicensing the Rolfe Canal (FERC No. 3240), Penacook Upper Falls (PUF; FERC No. 6689), and Penacook Lower Falls (PLF; FERC No. 3342) Hydroelectric Projects (Project; collectively, Projects) with the Federal Energy Regulatory Commission (FERC or Commission). The Projects are located on the Contoocook River in Boscawen and Concord, New Hampshire. PLF sits at river mile 0 of the Contoocook River, above the confluence with the Merrimack River. The Upper Penacook and Rolfe Canal Projects are located upstream at river miles 1.0 and 2.0, respectively.

The current Project licenses were issued by the Federal Energy Regulatory Commission (FERC or Commission) in accordance with the Commission's delegated authority under the Federal Power Act on November 17, 1982 (PLF) and December 5, 1984 (Rolfe Canal and PUF). By FERC order the original April 17, 2018 license expiration for PLF was extended from October 31, 2022 to November 30, 2024 and matching the expiration for the Rolfe Canal and PUF Projects. Briar Hydro is pursuing a new license for the three Projects through the Commission's Traditional Licensing Process (TLP).

In response to requests provided by the resource agencies as part of the TLP process, Briar Hydro prepared a Preliminary Study Plan (PSP). The intent of the PSP was that the goals, methodology, scope, and schedule would be refined in consultation with interested stakeholders, as necessary. Briar Hydro distributed a copy of the PSP to representatives from the representatives from the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFGD) and the New Hampshire Department of Environmental Services (NHDES) on December 14, 2020. Following receipt and consultation related to comments on the PSP, Briar Hydro prepared a Revised Study Plan (RSP) which was finalized in March 2021 and filed with FERC on July 6, 2021.

NHDES is the agency responsible for establishing and administering surface water quality standards for New Hampshire and is the agency responsible for issuing 401 Water Quality Certification (WQC). The Projects will be required to obtain a 401 WQC as a condition of the FERC license and will therefore need to demonstrate that Project operations will comply with state water quality standards. A Sampling and Analysis Plan (SAP) was developed in response to the NHDES PAD and PSP comments and study requests and was developed consistent with the Revised Study Plan (RSP) dated March 23, 2021. The SAP was developed in coordination was NHDES and was determined acceptable by NHDES as communicated in an email dated July 16, 2021. The water quality study presented in this report was completed in accordance with the SAP to the extent practicable.

2 Goals and Objectives

The goal of this study was to determine the spatial and temporal effects of operation of each of the three Projects on water quality and to compare results to state surface water quality standards. Specific objectives for this study (at each Project) were:

- Collect water temperature, dissolved oxygen (DO), pH, nutrients, chlorophyll-a and Secchi disk data under various conditions of river flow, temperature and Project operating conditions;
- Determine the spatial and temporal effects of Project operations on water quality; and
- Determine compliance with New Hampshire surface water quality standards (Env-Wq 1700 and RSA 485-A:8).

3 Study Area

The study area encompassed the Project impoundments, dam/powerhouse structures, bypasses, tailwater areas, and riverine reaches below the confluence of Project tailwaters and bypasses. Further information on each project is provided below.

4 Rolfe Canal

The Rolfe Canal Project operates in a run-of-river mode and diverts water from an impoundment in the Contoocook River created by the York Dam into the Rolfe Canal which conveys water to the penstock intake structure. The drainage area at the Rolfe Canal diversion is approximately 760 square miles. A reservoir created by the York Dam has negligible storage and a surface area of 50 acres with a normal water surface elevation of 346.0 feet (NGVD). York Dam is a 300-foot-long, 10-foot-high diversion dam above an approximately 4,000 foot bypass reach. Currently, Briar Hydro releases 100 cfs to the bypass reach below York Dam (or inflow if less) when not in spill conditions. Flow into the canal is controlled by an intake structure located at the Island Road Bridge. At the lower end of the canal, the Project headworks and intake are located at the Penstock Intake dam where generation flows are conveyed to the powerhouse by an underground penstock. The power canal is approximately 3,000 feet long, 75 feet wide, and 9-feet deep leading to a 130 foot long, 17 foot high granite block generation dam. The generation dam connects to a roughly 950-foot-long buried penstock. The entrance to the penstock is protected with trash racks that have 3 1/2 inch clear spacing. The historic canal channel extends another 2,000 feet beyond the generation dam and returns to the tailrace area. Briar Hydro currently maintains 5 cfs of flow to the historic canal channel. A 1,200 foot tailrace flows back from the powerhouse to the mainstem of the Contoocook River. The Rolfe Canal Project powerhouse houses a single horizontal shaft tube turbine with a capacity of 4,283 kW at 2,000 cfs and 22 feet of head.

5 Penacook Upper Falls

PUF is located one mile below the Rolfe Canal, operates in a run-of-river mode and consists of a dam on the mainstem of the Contoocook River, an approximately 250 foot bypass reach, a forebay, powerhouse, and tailrace that rejoins the mainstem. The drainage area at the PUF Dam is approximately 764 square miles. The reservoir has negligible storage capacity, a surface area of 11.4 acres and normal water surface elevation of 306 feet (NGVD). The dam structure consists of a timber stoplog dam with a concrete spillway 21 feet high and 187 feet long with 15 gates in the spillway. 6 gates are operable steel gates, 9.5 feet wide and 15.5 feet high, 7 gates are fixed timber stoplog gates, and two gates are operable (ice) gates, 12 feet wide and 3.5 feet high. A 15-foot long forebay with a 58-foot average width begins at the powerhouse intake and extends upstream in the Contoocook River. From the southwest corner of the powerhouse, a concrete, gated spillway extends 187 feet across the Contoocook River. The concrete powerhouse is 81 feet in length and 44 feet in width and located on the east river bank. The entrance to the turbine is protected with trash racks that have 3 1/2 inch clear spacing. The powerhouse houses one horizontal shaft tube turbine with a capacity of 3,020 kW at 2,000 cfs and 22 feet of head. The river banks upstream and downstream of the power house are contained by concrete retaining walls to bedrock. A tailrace with an average width of 47 feet begins at the draft tube exit of the powerhouse and extends downstream for approximately 350 feet where it rejoins the mainstem of the Contoocook River.

6 Penacook Lower Falls

PLF is located one mile below PUF and consists of a dam on the mainstem of the Contoocook River, a forebay leading to a powerhouse, an approximately 680 foot bypass reach, and tailrace that rejoins the mainstem of the river. The drainage area at the PLF dam is approximately 764 square miles. A reservoir is created above the Project dam with an 8.4-acre surface area, a useable storage capacity of 54 acre-feet, and a normal maximum water surface elevation of 272.0 feet (NGVD). The dam structure has a concrete diversion spillway with three 9.5 foot by 10.0 foot high timber gates and seven timber stop log gates, as well as a concrete gravity auxiliary spillway, 316 feet long, and a main concrete spillway, gated, and 106 feet long. The dam has no flashboards. A 50-foot wide forebay excavated from rock beginning at the powerhouse intake at an elevation of 236.52 feet (NGVD) extends upstream for a distance of 70 feet and terminates at an elevation of 261.00 feet (NGVD). Sideslope rock cuts of 1:6 slope with rockbolts comprise the sidewalls of the forebay. A concrete powerhouse containing a single, horizontal tube-type, 3 meter turbine encased in concrete is constructed to bedrock on the same alignment as the centerline of the river profile. The entrance to the turbine is protected with trash racks that have 3 5/8 inch clear spacing. The generating unit has an installed capacity of 4,600 kW at 2,000 cfs and 28 feet of head. The overall length of the powerhouse is 97.5 feet and the width perpendicular to the profile is 35 feet. A 55-foot wide rock filled access area connects the north face of the powerhouse to the north river bank. Upstream and downstream sides of the access area are contained by concrete retaining walls to bedrock. A 45-foot wide tailrace was excavated from rock beginning at the draft tube exit of the powerhouse at EL 224.90 feet (NGVD). The tailrace extends downstream for 700 feet and terminates at an elevation of 241.11 feet (NGVD). Sideslope rock cuts of 1:6 slope comprise the side walls of the tailrace.

7 Methodology

A water quality SAP was developed in response to the NHDES comments to the PAD and study requests from September 28, 2020, later addressed in the PSP submitted on December 16, 2020 and modified in a RSP. In the February 11, 2021 comments to the PSP, NHDES referenced the NHDES document "Sampling Guidance #1 for Hydropower Studies (Dissolved Oxygen, Temperature, pH, Nutrients, Chlorophyll-a, Secchi Disk and Flow)" last revised 02/05/2021 for guidance in developing a water quality study in support of NH 401 water quality certification for the Projects. The SAP (Normandeau, 2021) was developed in accordance with NHDES requests and conforms to the NHDES hydropower studies guidance document and was accepted by NHDES as communicated in an email dated July 16, 2021. The water quality study presented in this report was completed in accordance with the SAP to the maximum extent practicable with generally minor deviations from the SAP. Any variances of consequence are discussed in Section 7.

The water quality study consisted of continuous monitoring of temperature, dissolved oxygen, and pH using deployed water quality data loggers at fourteen locations in the Project area, including an upstream reach, Project impoundments, bypass reaches, tailrace areas, and in the Rolfe Canal and historic Rolfe Canal Channel. Continuous data was supplemented with recurring water quality profiles and Secchi Disk depth measurements in the deep spot of each impoundment and at the Rolfe Canal Project intake to determine changes in water quality with depth and assist with trophic state determination. In addition, water quality samples were collected for laboratory analysis of nutrients and chlorophyll-a in each of the Project impoundments and the Rolfe Canal Project intake. The field study was completed between July 28, 2021 and September 23, 2021, a period of nine weeks, and included periods of high water temperature and low river flows, as well as during flows supportive of a range of generating conditions including high flows with spill conditions. Water surface elevations in the impoundments are monitored as part of Project operations and inflows to the Projects were estimated using the nearest available USGS gage data. Inflow was determined by scaling the available USGS gage data using watershed areas and outflows were determined from the inflow and generation data. The data have been summarized in a spreadsheet and are included as Appendix A.

8 Continuous Water Quality Data Sonde Measurements

The water quality study included near-continuous water quality monitoring with deployed instruments (Onset Hobo U26-001 DO & temperature logger, Onset Hobo MX2501 pH and temperature logger, and Onset Hobo U20-001 water level logger (used for barometric pressure reference, see SAP for specifications) at fourteen locations in the vicinity of the Projects as presented in Table 4-1 and Figures 4-1 and 4-2. The monitoring locations included the deep spot of each impoundment and at the Rolfe Canal intake structure, a riverine section upstream of the York Dam/Rolfe Canal impoundment which is not influenced by Project operations, in the tailraces of the Rolfe Canal and PUF, in the bypass reaches of each of the three Projects (including two stations in the York Dam/Rolfe Canal bypass reach), in two locations in the historic canal channel that bypasses the penstock and powerhouse at the Rolfe Canal Project, and downstream of the confluence of the tailrace and bypass reach below the PLF.

The Rolfe Canal bypass stations were selected to represent two locations in the bypass reach including a pool/run location in the upper third of the bypass reach and at a run location above the confluence with the Rolfe Canal Project tailrace. The Rolfe Canal historic canal channel monitoring stations were selected to represent two locations along the approximately 2,000 foot long channel. The upper monitoring location (RC-HCC1) is a pool area below the flow diversion structures and the lower monitoring location (RC-HCC2) is in a low gradient section near the end of the reach.

Instruments were generally deployed with an anchor and buoy system and located in a mid-depth location in the water column, with the exception of the monitoring locations in the three Project impoundments and the Rolfe Canal where the instrument depths were determined according to the presence or absence of vertical stratification. Under unstratified conditions, the instruments were located no shallower than one meter above the 25% depth and under stratified conditions, the instruments were located no shallower than one meter above the bottom of the epilimnion. Deployed instruments collected water quality data at 15 minute interval and were retrieved weekly to download data and to maintain, clean, and calibrate the instruments. A handheld water quality instrument (YSI ProDSS, also used for vertical profiles) was used for independent calibration checks of the continuously deployed instrumentation. Calibration of the deployed sondes occurred weekly using commercially produced calibration standards for pH and 100% water saturated air for dissolved oxygen. The barometer used for determining oxygen saturation values at calibration and for calculating oxygen saturation values in the data record (i.e. from oxygen concentration values) was a water level pressure logger dry-mounted at the site. Calibration of the handheld QC meter was conducted prior to use.

9 Vertical Profiles (Dissolved Oxygen and Temperature)

Water quality measurements taken as a vertical profile through the water column were completed during the weekly site visits in the Project impoundment monitoring stations (RC-IMP, PUF-IMP, and PLF-IMP) and Rolfe Canal penstock intake monitoring station (RC-INT). In order to determine the location of the Project impoundment stations, the deep spot was located at each impoundment and the Rolfe Canal Project intake. A bathymetric survey was completed using a fish finder to locate the deep spot at each station. Depth readings were taken at regular intervals along a zigzag or grid pattern from the buoy line above each dam upstream sufficiently far to determine the deepest areas. The depths at each station were confirmed with a weighted tape measure and the station position was marked with a GPS.

A YSI ProDSS multi-parameter water quality sonde was used to measure dissolved oxygen and water temperature as a vertical profile at 0.1 meter below the surface, 0.5 meters below the surface, then every 0.5 meters down to 0.5 meters above the bottom. Prior to and following weekly profile collections, the YSI ProDSS used for profile sampling was calibrated following manufacturer guidelines and using the water saturated air method for DO calibration (temperature measurements used the default factory calibration). Upon completion of the task, the field data sheets were processed manually and the data was electronically stored in a project database.

10 Laboratory Analysis (Nutrients and Chlorophyll-*a*)

Water samples were collected at the Project impoundment monitoring stations (RC-IMP, PUF-IMP, & PLF-IMP) as well as the Rolfe Canal intake station (RC-INT) and analyzed for chlorophyll-a, total phosphorus

(TP), nitrate + nitrite nitrogen, and total Kjeldahl nitrogen (TKN). Samples were collected one to two times per week (with a minimum two day separation between samples) for a six week period from 8/5/21 through 9/14/21. Samples were collected from the Rolfe Canal station (RC-INT) once per week for a total of six samples. A single field replicate sample was also collected at each of the four stations on 8/30/21 and analyzed for each of the above parameters. When thermal stratification was not present, all samples were collected from the near-surface (25% of total depth), with the exception of chlorophyll-*a* which was collected as a water column composite sample for the upper 2/3 of the water column. When thermal stratification was present, nitrogen and phosphorous samples were collected from the middle of the epilimnion with an additional phosphorous sample was collected from the middle of the hypolimnion. Under stratified conditions, chlorophyll-*a* was collected as a water column composite sample from the water surface to the middle of the thermocline. Discrete depth samples were collected with a Kemmerer sampler. Integrated core samples were collected by lowering a weighted tube through the water column, crimping the tube at the water surface, then extracting the water column sample and transferring to a mixing container before distributing to sample bottles. All sampling equipment were cleaned with potable water, and pre-rinsed with sample water prior to use. All samples were preserved, stored, handled, and delivered to the participating analytical lab according to lab specifications.

11 Secchi Disk Depth

Secchi disk depth was measured at the Project impoundments monitoring stations (RC-IMP, PUF-IMP, & PLF-IMP) and Rolfe Canal intake station (RC-INT) concurrent with chlorophyll-*a* sampling and vertical profiles. An underwater viewer was used to view the Secchi disk. The Secchi disk depth was taken as the average of the visible depth while lowering and raising the disk.

12 Flow and Operations Data

Operations data for the Project, including impoundment water surface elevation at each of the three Project dams and Rolfe Canal, flows diverted to the Rolfe Canal historic channel, outflow from the turbines, and power generation at each generating unit are presented. Flow through the turbines was determined from power output and established power-flow regressions at each Project. Impoundment water surface elevations were measured continuously with pressure sensors deployed in the Project impoundments and Rolfe Canal. Water levels are logged at fifteen minute intervals using Druck model 1835 pressure sensors (at RC and PLF) and Rosemount model 1151 pressure transmitters (at PUF).

Flow records were developed for the study period and will include inflow to each impoundment, outflow through the turbines and into each Project tailrace, and estimated flows to the bypass reaches and through the Rolfe Canal historic channel. Turbine outflow was assumed to equal outflow to the tailrace at each Project and was determined from power output of individual turbine units and established power-flow regressions. The power-flow equations developed for each turbine unit are empirical equations developed by the turbine manufacturer. During commissioning of the turbines index testing was completed to verify turbine performance. The Winter-Kennedy method (1933) was used to estimate flows through the turbines based on pressure differences in tap pairs located in radial sections of the spiral casings. Turbine flows estimated from index testing were consistent with the power-flow equations determined by the turbine manufacturers and the regressions are believed to be accurate. Power-flow regressions were developed for the Projects as follows:

Penacook Lower Falls:

If power output < 2131 KW, then flow (cfs) = power (KW) * 0.3285 + 250

If power output 2131-3118 KW, then flow (cfs) = power (KW) * 0.3382 + 228.43

If power output > 3118 KW, then flow (cfs) = power (KW) * 0.378 + 104.24

Penacook Upper Falls:

If power output < 675 KW, then flow (cfs) = power (KW) * 0.4237 + 85

If power output 675-1442 KW, then flow (cfs) = power (KW) * 0.5474 + 1.442

If power output 1443-2183 KW, then flow (cfs) = power (KW) * 0.476 + 103.89

If power output > 2183 KW, then flow (cfs) = power (KW) * 0.4738 + 108.54

Rolfe Canal:

If power output < 1000 KW, then flow (cfs) = power (KW) * 0.365 + 77

If power output 1000-3561 KW, then flow (cfs) = power (KW) * 0.3676 + 74.31

If power output 3562-4406 KW, then flow (cfs) = power (KW) * 0.4561 - 240.84

If power output > 4406 KW, then flow (cfs) = power (KW) * 0.3662 + 155.13

As an example, if PLF is running at 2,500 KW, then flows to the PLF tailrace are:

Turbine Flow at PLF = 2,500 KW * 0.3382 + 228.43 = 1,074 cfs

Inflow was developed for each Project impoundment by area-adjusting the 15 minute data obtained from the nearest USGS gages in the watershed. Two gages upstream of the Projects were used for developing inflow - USGS 01085500 Contoocook River below Hopkinton Dam at West Hopkinton, NH and USGS 01086000 Warner River at Davisville, NH. Flow data were accessed from the USGS Waterwatch website (https://waterwatch.usgs.gov) and complied in a spreadsheet. Flows from the two gages were summed for each 15 minute timestamp during the study period to produce a total gaged flow record in the watersheds upstream of the Projects. The total gaged flow was then multiplied by a drainage area conversion factor to produce estimated inflow at each Project. The drainage area conversion factor is the Project drainage area (760 square miles at RC, 764 square miles at PUF, and 764 square miles at PLF) divided by the total gaged drainage area (573 square miles). While the USGS gages are located 10-18 miles upstream of the Projects, the time of travel (lag time) from the USGS gages to the Project was not explicitly accounted for in determining inflow to the Projects. This decision was justified because lag time is not easily or reliably calculated for the Project without continuous flow monitoring or hydraulic modeling, which are beyond the scope of this study. Flows to bypass channels were assumed to be equal to inflow less outflow through the turbines at each Project (less diversion flow to the historic Rolfe Canal channel at the Rolfe Canal Project). It was also assumed that minimum flows were always maintained whenever a Project was generating. If a Project was not generating, then outflow to the bypass was assumed to equal inflow (less diversion to the historic Rolfe Canal). It was not possible to develop hydraulic estimates of flow to the bypass channels due to the number and unknown dimensions of each of the outflow control structures and leakage through the flashboards.

Diversion flows to the historic Rolfe Canal were determined from standard hydraulic calculations using the impoundment water surface elevation. The diversion gate is kept fully open and a 7.15 inch diameter flow orifice installed next to the valve is used to regulate flows through the diversion pipe. Therefore, flows to the historic Rolfe Canal are a function of head from the Rolfe Canal water surface at the Project intake to the centerline of the diversion pipe. Diversion flows are targeted for 5 cfs at a normal water surface elevation of 342.46 feet (NGVD) and may vary slightly as the water surface changes. Flow through the diversion orifice is calculated using the orifice flow equation:

Flow = CA √(2gh)

Where C is the coefficient of discharge, A is the area of the orifice, g is acceleration due to gravity, and h is head at the horizontal line of the orifice.

The diversion pipe has a 7.15 inch diameter orifice (0.279 ft^2 area) and horizontal line elevation of 331.67 ft (NGVD). The coefficient of discharge is 0.61 based on standard values for a thin sharp edged orifice plate.

As an example, if the Rolfe Canal surface elevation is 342.46 feet (the normal water surface elevation), then the flow to the Historic Rolfe Canal channel is calculated as:

Flow to RC-HCC = 0.61 * 0.279 ft^2 * [2 * 32.2 ft/s^2 * (342.46 ft – 331.67 ft)]$^{0.5}$ = 4.49 cfs

Please note: previous calculations determined a 5 cfs discharge at the normal pond elevation of 342.46 feet; however, a calculation error was just recently discovered upon review. Once current high flows recede and it is safe to do so, the project owners will verify the actual present conditions including orifice diameter and head to verify minimum flow discharge to the historic Rolfe Canal channel.

As a method to validate the estimates of inflow based on the USGS gage data, three transects were established for the periodic collection of flow measurements during the water quality study. Transects were established in the historic Rolfe Canal channel, in the Rolfe Canal/York Dam bypass reach, and downstream of the confluence of the Penacook Lower Falls Project tailrace and bypass channel. Flow data from the transects were collected on five occasions (approximately once per week) from 8/11/21 through 9/13/21. Discharge below PLF was measured immediately above Station PLF-TR at a point capturing the full outflow from the Projects. Flow measurements utilized an acoustic Doppler current profiler (ADCP) tethered to an appropriate watercraft at PLF-TR and utilized a current meter and conventional gaging techniques at Stations RC-HCC2 and RC-BP1.

The three Projects are located within two river miles of each other with estimated watershed areas of 760 square miles (RC), 764 square miles (PUF), and 764 square miles (PLF), that would result in a 0.5% flow increase (based on area) from the RC Project to the PLF Project. Therefore, inflow differences between Projects can be considered negligible and a single flow gaging station is sufficient for validating the inflow estimates at each Project. In addition to the five flow gaging measurements that were taken at PLF-TR, a water level logger was installed at that station to continuously measure water level during the study. The logger was deployed at a fixed depth using a section of slotted PVC pipe with an endcap attached to steel rebar and bolted vertically to a section of bedrock on the right bank. The logger was deployed from 8/11/21 to 9/28/21 and retrieved weekly to download data. Water depth to the top of the PVC pipe (and offset to the sensor) was measured weekly at the time of deployment/redeployment using a folding yard stick or tape measure. The water level logger and companion barometric pressure logger were Onset HOBO U20 level loggers as described in Section 4.1. A stage/discharge regression was developed for the water level and stream gaging data at PLF-TR and a flow record for the study period was developed from the water level data. Given that there were only five gaging measurements in the rating curve, the accuracy of the flow estimates is limited and confined to a range of 498-1635 cfs, which are the lowest and highest flow measurements obtained from gaging. Flow estimates outside of this measured range are presented (estimated flow ranges from <200 to >9000 cfs during the study period) with the understanding it is an estimate with no validation. Generally, flow estimates were comparable between the USGS inflow estimates and level logger estimates, particularly during periods of consistent power generation. Flow estimates during periods with intermittent power generation tended to be less correlated between the two methods.

13 QA/QC Protocols

Prior to deployment, redeployment, or use for spot measurements, water quality meters were cleaned, inspected for fouling, damage, or other performance affecting conditions, and calibrated according to manufacturer recommendations and established best practices. A log of calibration data was maintained to establish a project record of instrument performance history (included as Appendix B). Calibration acceptance criteria is presented in Table 4-2.

A single field replicate sample was collected at each station during the study and submitted for laboratory analysis of each of the parameters in Table 4-3. The field replicates provide a QC assessment of field sampling methods and any potential sampling errors. Acceptance criteria for measurement differences between field replicate samples is presented in Table 4-3.

Instrument QA/QC data may indicate need for filtering, flagging, or correction of continuous data records due to instrument drift and fouling effects on sensor readings or other instrument performance issues. Instrument performance was first evaluated using the side-by-side QC readings between deployed meters and a handheld meter as described previously. The acceptance criteria for simultaneous measurement differences between instruments is presented in Table 4-4, below. A summary table that includes the relative percent difference and absolute difference values from side-by-side QC reading data pairs is included as Appendix C. Generally, instrument performance was acceptable and met the criteria in Table 4-4; regardless, all deployed instruments were recalibrated during weekly site visits and the pre- and post-calibration data were reviewed to evaluate instrument performance.

In the SAP it was stated that data corrections would be applied to instruments that failed to meet side-by-side QC readings and fouling/drift error QC criteria. However, none of the QC checks indicated data correction was necessary or appropriate for the water quality data collected. In some instances, data was flagged as suspect data that could not be corrected with a weighted linear correction as specified in the SAP. Suspect data are presented in the time series figures (presented and identified as suspect data) but are not included in statistical summaries.

Table 7–1. Monitoring station locations

Monitoring Station	Description	Latitude	Longitude
RC-US	Mainstream Contoocook River upstream of influence of York Dam/Rolfe Canal	43°14'3.51"N	71°42'28.15"W
RC-IMP	York Dam/Rolfe Canal Impoundment deep spot	43°16'5.55"N	71°36'53.18"W
RC-INT	Rolfe Canal upstream of the penstock intake dam	43°16'21.47"N	71°36'23.27"W
RC-TR	Rolfe Canal tailrace	43°16'30.14"N	71°36'15.36"W
RC-BP1	York Dam/Rolfe Canal bypass reach pool/run habitat in upper bypass reach	43°16'20.16"N	71°36'43.29"W
RC-BP2	York Dam/Rolfe Canal bypass reach run habitat above the confluence with Rolfe Canal Tailrace	43°16'37.17"N	71°36'21.56"W
RC-HCC1	Rolfe Canal Historic Canal channel pool habitat below flow control structures	43°16'22.18"N	71°36'14.19"W
RC-HCC2	Rolfe Canal Historic Canal channel low gradient run habitat above confluence with tailrace	43°16'28.52"N	71°36'12.65"W
PUF-IMP	PUF Impoundment deep spot	43°16'53.33"N	71°36'5.71"W
PUF-BP	PUF bypass reach	43°16'58.22"N	71°36'4.55"W
PUF-TR	PUF tailrace	43°17'0.41"N	71°36'3.50"W
PLF-IMP	PLF impoundment deep spot	43°17'7.04"N	71°35'48.67"W
PLF-BP	PLF bypass reach	43°17'6.27"N	71°35'43.13"W
PLF-TR	PLF below confluence of tailrace and bypass	43°17'11.12"N	71°35'38.13"W

Table 7–2. Field Meter Calibration Method, Frequency, and Acceptance Criteria

Parameters	Frequency of Calibration	Calibration Acceptance Criteria
Dissolved Oxygen	Instantaneous readings Prior to each measurement Datasonde Deployments Datasonde must be calibrated before deployment and at least every two weeks (or more frequently if meter fouling is likely to occur) for deployments lasting more than two weeks.	Instantaneous readings Record the calibration value in % saturation and after one-minute record the % saturation reading and compare to the calibration value. The dissolved oxygen % saturation reading should be ± 5.0% of dissolved oxygen % saturation calibration value. Datasonde Deployments After the datasonde is calibrated, record the datasonde instantaneous mg/L reading immediately after calibration and the Oxygen Solubility in Water Value based on concurrent water temperature and barometric conditions. The difference between the datasonde instantaneous reading immediately after calibration and the Oxygen Solubility Water Value must be no greater than ± 0.2 mg/L. If the difference is greater, recalibrate. Datasonde Retrieval After removal from water, set up the datasonde so that it is under 100% saturated air conditions. After dissolved oxygen readings have stabilized, record the datasonde instantaneous mg/L reading and the Oxygen Solubility in Water Value based on concurrent water temperature and barometric conditions. The difference between the datasonde instantaneous reading immediately after calibration and the Oxygen Solubility Water Value from Table 4 must be no greater than ±0.5 mg/L). If the datasonde is going to be redeployed, and it hasn't been more than 2 weeks since the last calibration, recalibrate if the difference is greater than ±0.2 mg/L. If it has been 2 weeks since the last calibration, recalibrate regardless of the difference.
Temperature	Not Applicable	Not Applicable
pH	Instantaneous readings Two-point calibration prior to each measurement (4.00 and 7.00 are the preferred calibration standards)	Instantaneous readings Record calibration slope prior to each measurement. Slope should be between 95% - 105%. If slope is out of range, the meter should be recalibrated. During each day of sampling the handheld meter should measure a standard not used in the calibrations (i.e. 6.00 pH standard). Meter should read ± 0.3 pH units from the standard. If the difference is greater, it may indicate a contaminated standard or faulty meter. Try again

Parameters	Frequency of Calibration	Calibration Acceptance Criteria
	Datasonde Deployments Datasonde must be calibrated before deployment and at least every two weeks (or more frequently if meter fouling is likely to occur) for deployments lasting more than two weeks.	with a fresh standard. If it is still out of range, the meter may be faulty. Datasonde Deployments After two-point calibration (4.00 and 7.00 are the preferred calibration standards) record the datasonde reading of the two standards used. Reading should be ± 0.05 pH units from both calibration standards. If the difference is greater, recalibrate. Datasonde Retrieval Datasonde should measure the two standards used in the calibration. Datasonde readings should be ± 0.3 pH units from both calibration standards. If the datasonde is going to be redeployed, and it hasn't been more than 2 weeks since the last calibration, recalibrate if the difference is greater than ± 0.3 pH units. If it has been 2 weeks since the last calibration, recalibrate regardless of the difference.

Table 7–3. Field Replicate Frequency and Acceptance Criteria

Parameters	Frequency of Field Replicates	Precision (RPD Based on Field Replicates)
Total Phosphorus	Once every site visit or once every 10 samples, whichever is greater	RPD < 20%
Total Kjldahl Nitrogen	Once every site visit or once every 10 samples, whichever is greater	RPD < 20%
Nitrite + Nitrate Nitrogen	Once every site visit or once every 10 samples, whichever is greater	RPD < 20%
Chlorophyll-*a*	Once every site visit or once every 10 samples, whichever is greater	RPD < 20%

Table 7–4. Data QC Acceptance Criteria

Parameters	Frequency of Measurement Checks*	Acceptance Criteria (i.e., maximum difference between the handheld and datasonde measurements)* RPD – Relative Percent Difference ABS – Absolute Difference

Dissolved Oxygen	Handheld measurements should be taken at the time of datalogger deployment, once a week throughout the deployment and at the time the datalogger is removed. Handheld measurements should be taken as close as possible to the location of the datalogger.	RPD between handheld measurement and datalogger should be ≤ 10%. If RPD is > 10% the absolute value of the difference between the handheld measurement and the datalogger measurement should be ≤ 0.4 mg/l or ≤ 4% saturation.
Temperature	Same as above	RPD between handheld measurement and datalogger should be ≤ 10%. If RPD is > 10% the absolute value of the difference between the handheld measurement and the datalogger measurement should be ≤ 0.5 °C.
pH	Same as above	The absolute value of the difference between the handheld measurement and the datalogger measurement should be ≤ 0.3 pH units
Specific Conductance	Same as above	± 5 µS/cm or ± 3% of the measured value, whichever is greater

*Adjacent measurements with the handheld meter are taken at same location and depth as the datasonde.

** The relative percent difference (RPD) is equal to the following:

$$RPD = \frac{|x_1 - x_2|}{\frac{x_1 + x_2}{2}} \times 100\%$$

Where: χ_1 is the original sample concentration, and
χ_2 is the replicate sample concentration

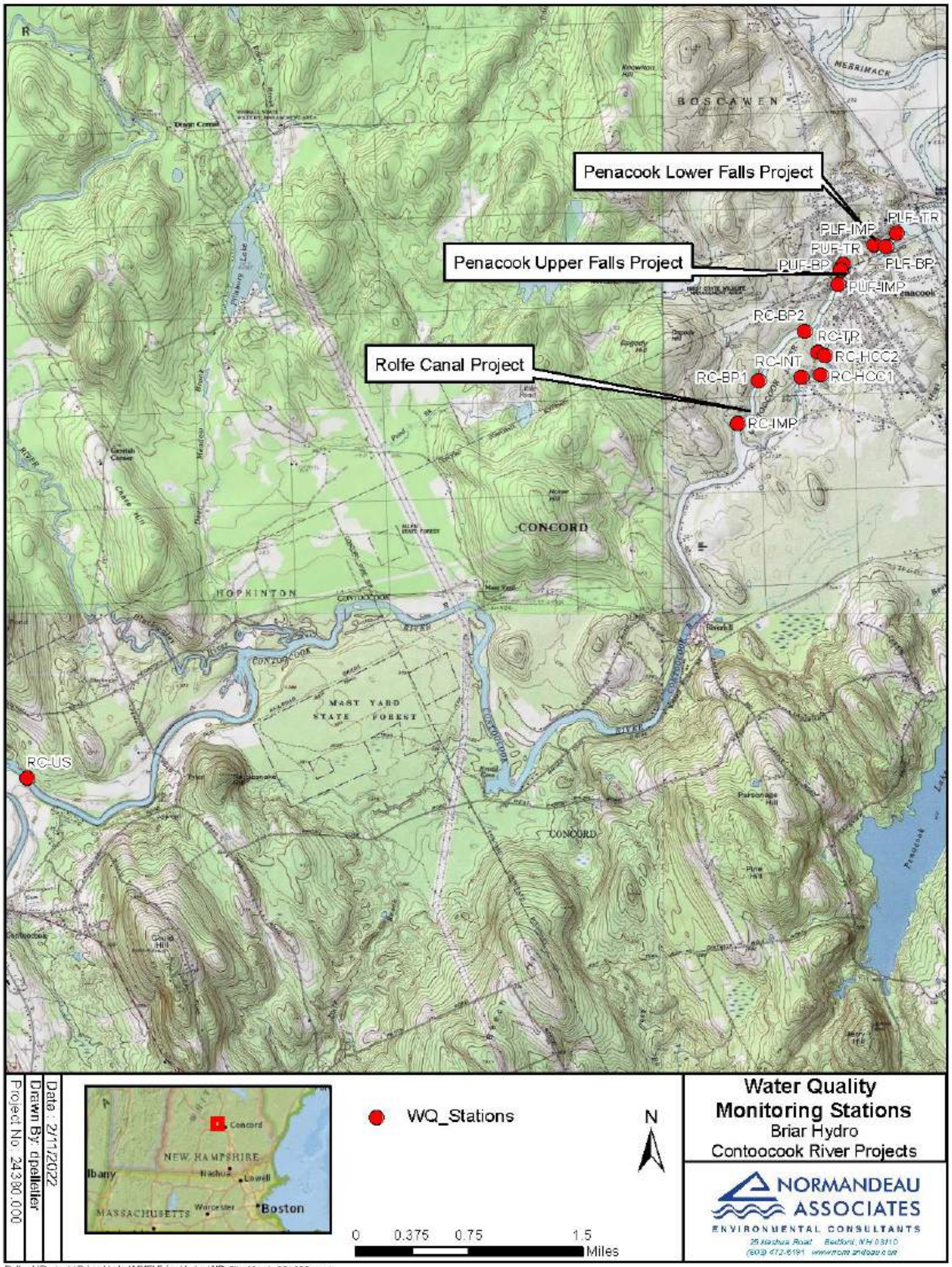


Figure 7–1. Site map of sampling locations.

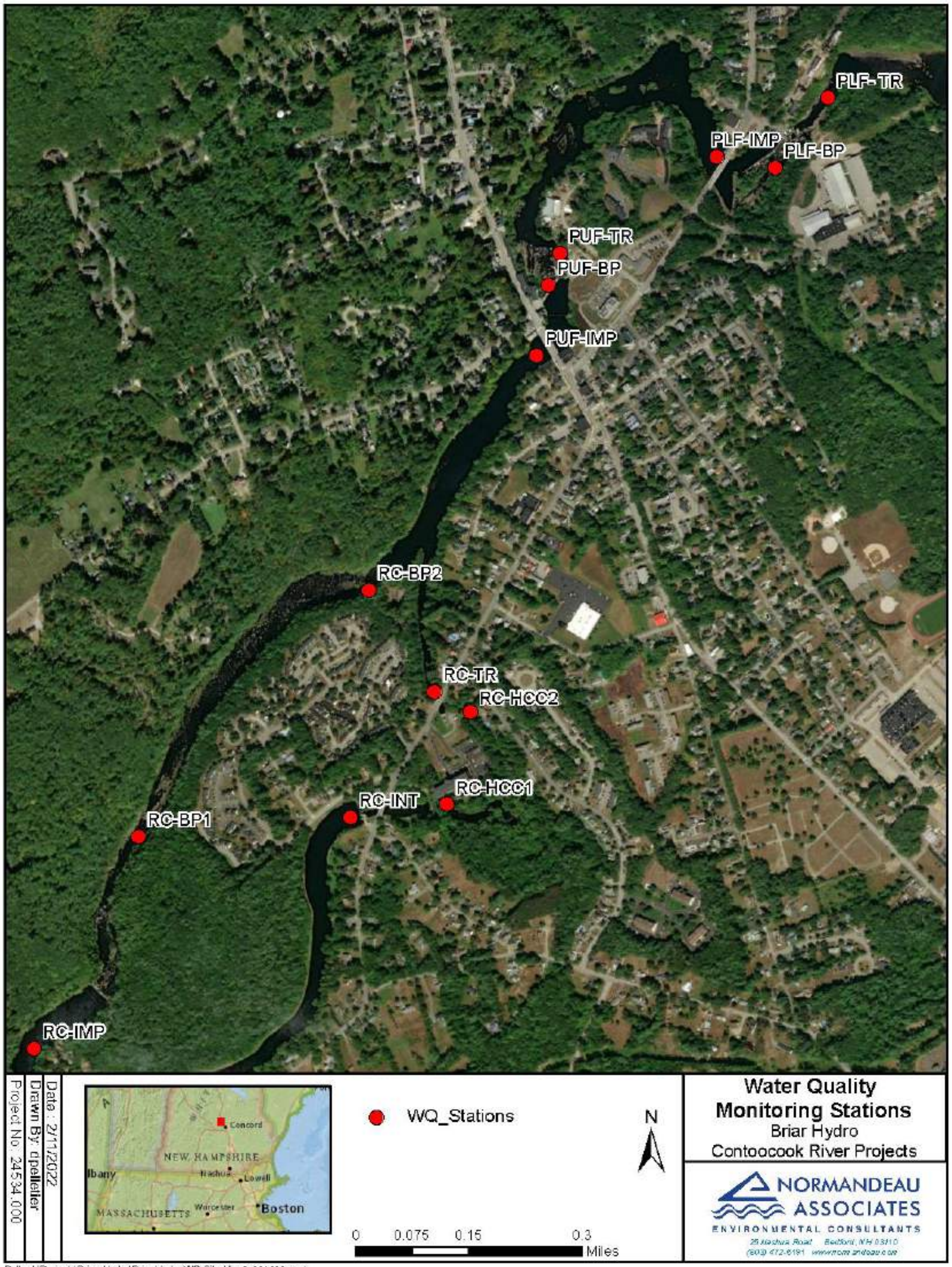


Figure 7–2. Detail map of sampling locations.

14 Results

The water quality study was completed in accordance with the SAP to the extent practicable and the results of the continuous monitoring, vertical profiles, laboratory analyses, and flow measurements are presented in this section. Time series plots for river and operational conditions are provided in Appendix D.

15 Continuous Water Quality Data Sonde Measurements

Continuous monitoring of temperature, DO, and pH was completed between 7/28/21 and 9/23/21. Loggers were deployed on 7/28/21 at Stations RC-INT, RC-HCC1 PLF-IMP and PLF-BP; on 7/29/21 at Stations RC-US and RC-IMP; on 8/2/21 at Stations RC-BP1, RC-BP2, RC-TR, and PUF-IMP; on 8/4/21 at Stations PUF-TR and PLF-TR; on 8/12/21 at Station RC-HCC2; and on 8/13/21 at Station PUF-BP. Loggers were removed on 9/20/21 at Stations RC-BP1, RC-BP2, RC-HCC1, RC-HCC2, and PLF-BP; on 9/21/22 at Stations RC-INT, RC-TR, PUF-IMP, and PLF-IMP; on 9/22/21 at Stations RC-US, RC-IMP, and PUF-TR; and on 9/23/21 at Stations PUF-BP and PLF-TR. Deployment periods for each Station are presented in Table 5-1 and results are presented in Figures 5-1 through 5-68 and Tables 5-2 through 5-6.

Table 14–1. Deployment periods and number of valid data points collected by station

Continuous Monitoring Station	DO/Temp Deployed	DO/Temp Retrieved	No. of Valid DO/Temp Data Points	pH Deployed	pH retrieved	No. of Valid pH Data Points
RC-US	7/29/2021	9/22/2021	5,263	7/29/2021	9/22/2021	4,991
RC-IMP	7/29/2021	9/22/2021	5,263	7/29/2021	9/22/2021	5,263
RC-INT	7/28/2021	9/21/2022	5,258	7/28/2021	9/21/2022	5,258
RC-BP1	8/2/2021	9/20/2021	4,597	8/2/2021	9/20/2021	4,597
RC-BP2	8/2/2021	9/20/2021	4,687	8/2/2021	8/12/2021	972
RC-HCC1	7/28/2021	9/20/2021	5,143	7/28/2021	9/20/2021	5,143
RC-HCC2	8/12/2021	9/20/2021	3,645	No pH	No pH	No pH
RC-TR	8/2/2021	9/21/2022	4,117	8/2/2021	9/21/2022	3,339
PUF-IMP	8/2/2021	9/21/2022	4,765	8/2/2021	9/21/2022	4,765
PUF-TR	8/4/2021	9/22/2021	4,084	8/4/2021	9/22/2021	2,188
PUF-BP	8/13/2021	9/23/2021	3,929	8/13/2021	9/23/2021	3,929
PLF-IMP	7/28/2021	9/21/2022	5,266	7/28/2021	9/21/2022	4,805
PLF-TR	8/4/2021	9/23/2021	4,763	8/4/2021	9/23/2021	4,763
PLF-BP	7/28/2021	9/20/2021	5,159	7/28/2021	9/20/2021	5,159

16 Water Temperature

Water temperatures during the study are presented in Figures 5-1 through 5-17 and Table 5-2 and the periods of deployment and number of valid measurements are highlighted in Table 5-1. Temperatures varied from 15.62 to 28.50 °C and were relatively consistent between each of the continuous monitoring stations and were on average lowest at the upstream riverine reach (RC-US, 21.2 °C mean temperature) and highest at the PUF tailrace reach (PUF-TR, 21.8°C mean temperature). Temperatures in the study area increased from ~18-19 °C at the beginning of the study on July 28 to a peak of >25 °C August 13/14, then remained in the lower 20s °C through the end of August and remained in the high teens to ~20 °C through the end of the study in September. Maximum water temperatures coincided with relatively low flow of <1,000 cfs inflow at Rolfe Canal, although moderately high water temperatures (>23 °C) did also coincide with inflow >5,000 cfs during a flow event on 8/25/21. A summary of the suspect data removed from the final data set is highlighted in Table 5-3.

Water temperatures varied on a daily warming/cooling cycle at all stations, with the largest daily variations recorded in the Rolfe Canal bypass stations and Rolfe Canal historic canal channel stations, as well as the PLF-BP station, where daily temperature changes of >3 °C were common, particularly at lower flows. The shallower water at these stations and lower flows (i.e. dependent on spill conditions in the bypass reaches and diversion flows in the historic canal channel) likely contributed to the greater daily temperature variations documented at these stations as compared to elsewhere in the study area. The short bypass reach at PUF-BP and the location of the data logger in a turbulent mixed area near the spillway likely explains why daily temperature variations of 1 °C or less were recorded at that station. Daily temperature variations were also relatively low in the impoundment stations and Rolfe Canal intake station (likely due to the deeper logger positions) and were typically on the order of 1 °C or less, even during low flow periods. The upstream riverine station (Station RC-US) and tailrace stations exhibited daily temperature cycles that were intermediate in magnitude between the impoundments and bypass reaches, with typical daily variations of >1 °C, especially during lower flow periods.

Temperature conditions in the Project study area were variable during the study period, and exhibited a seasonal pattern with a general warming trend early in the study followed by a general cooling trend after a mid-August peak with water temperatures in excess of 25 °C. Temperatures in the upstream reach, outside the direct hydraulic influence of the Project, were comparable to the other stations in the study area and all station temperatures were within ~3 °C or less of each other throughout the study. The temperature data collected in this study indicate that water temperatures in areas affected by the

Project generally follow a natural temperature regime that is comparable to areas outside the Project influence.

Table 14–2. Summary of continuous monitoring temperature data

	RC-US	RC-IMP	RC-INT	RC-BP1	RC-BP2	RC-HCC1	RC-HCC2	RC-TR	PUF-IMP	PUF-TR	PUF-BP	PLF-IMP	PLF-TR	PLF-BP
	Temperature (°C)													
Min	18.1	18.5	18.4	18.2	15.6	18.1	17.3	18.6	18.4	18.4	18.2	18.4	18.4	17.9
Max	25.8	25.9	26.2	27.2	28.5	27.2	27.3	26.2	26.4	26.3	26	26.2	26.2	27.9
Mean	21.2	21.3	21.5	21.7	21.8	21.7	21.5	21.8	21.6	21.8	21.3	21.4	21.6	21.7
Median	20.4	20.5	21.2	21.7	21.9	21.4	21.3	22.1	21.5	22.3	20.3	20.9	21.4	21.4

Table 14–3. Summary of suspect temperature and DO data removed from dataset

Continuous Monitoring Station	Suspect Data Period	Comment
RC-BP1	8/5/21 11:15 – 8/6/21 09:30	Logger was likely out of water
RC-HCC2	8/25/21 02:30 – 08/25/21 20:00	Unknown cause of errors
RC-TR	8/30/21 14:00 – 9/6/21 10:15	Calibration error at deployment on 8/30 and failed QC check on 9/6
PUF-TR	9/9/21 10:45 – 9/15/21 12:45	Deployment error (calibration cap left on instrument)

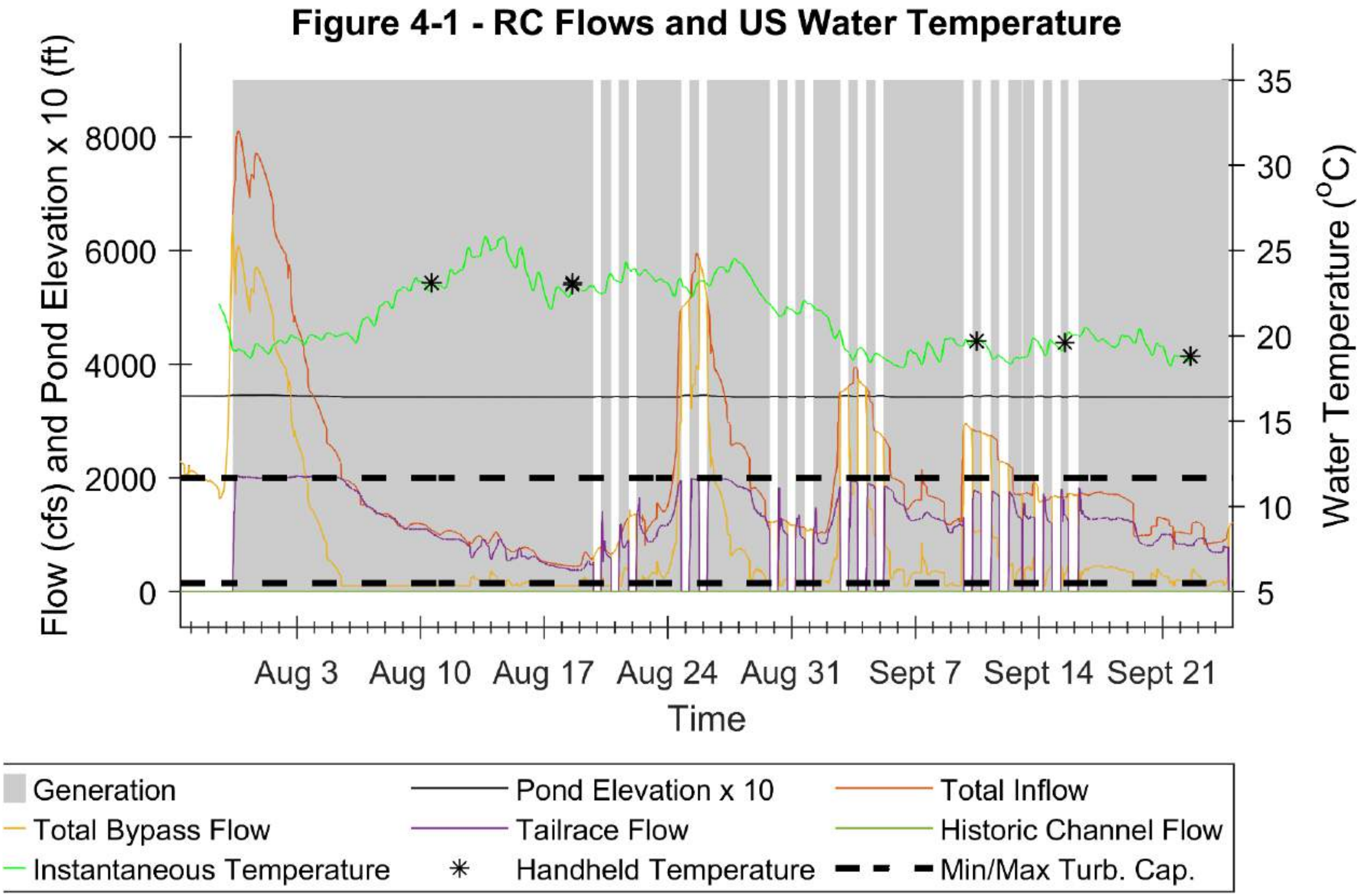


Figure 14–1. RC-US. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

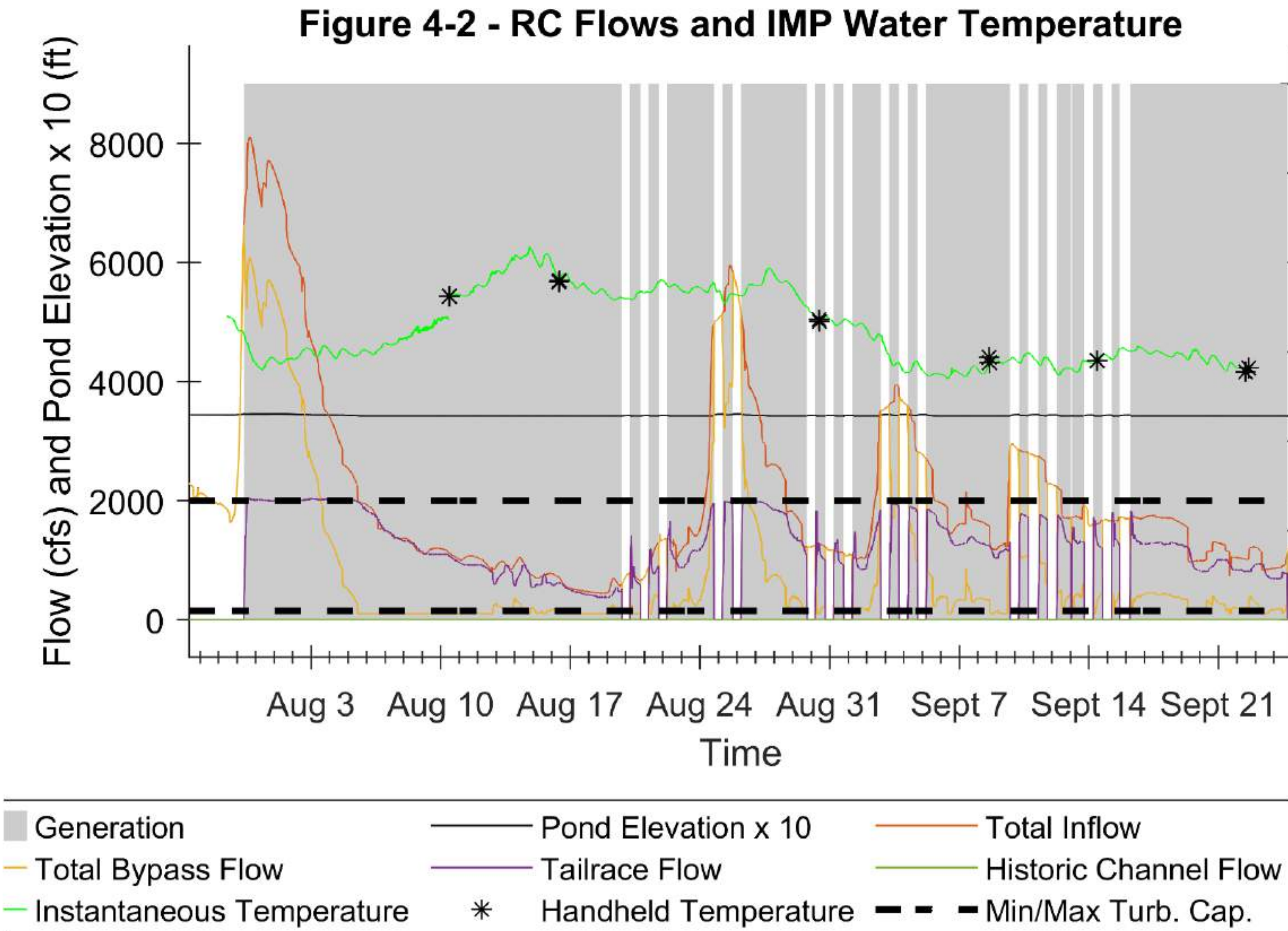


Figure 14–2. RC-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

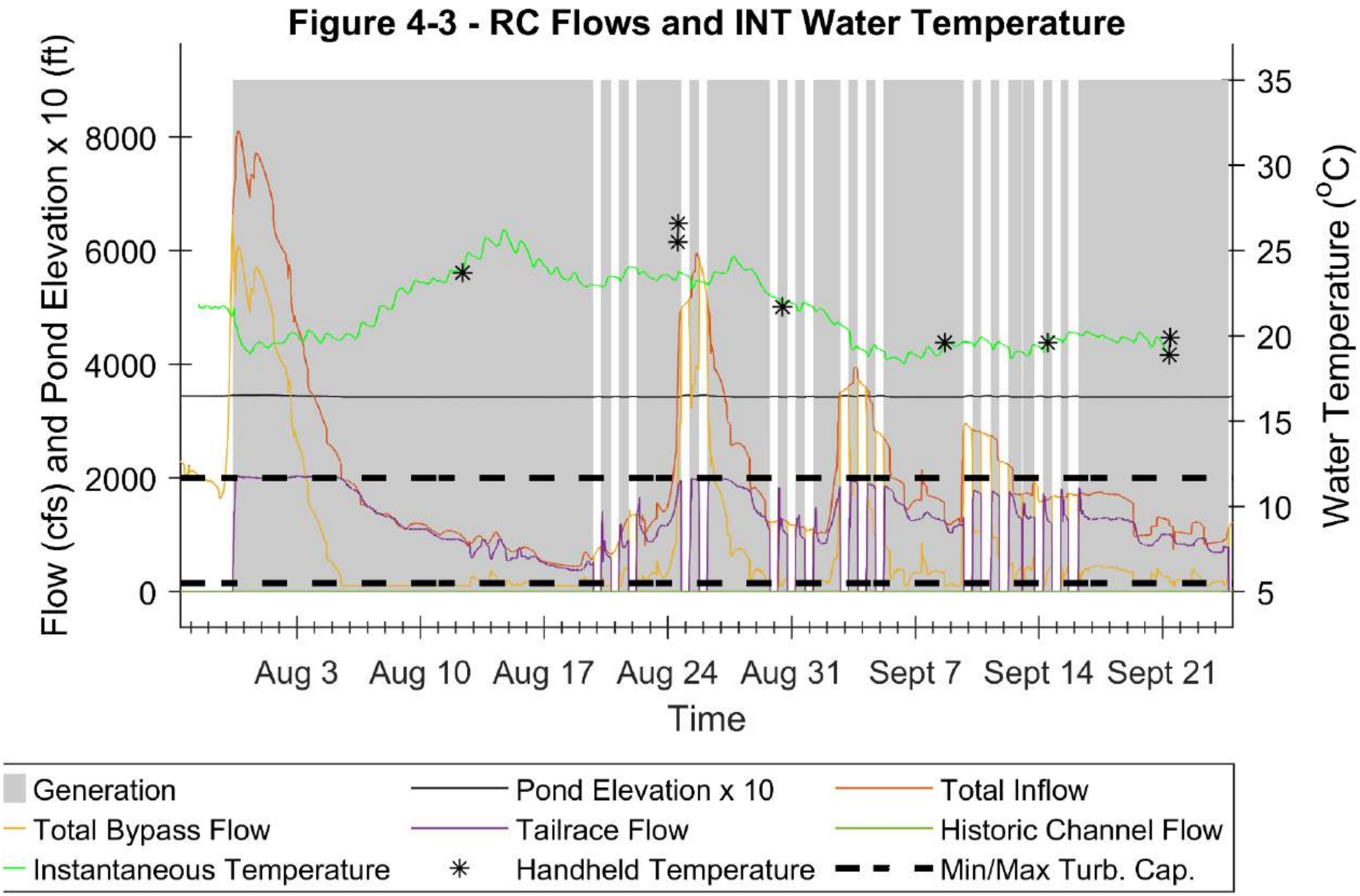


Figure 14–3. RC-INT. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

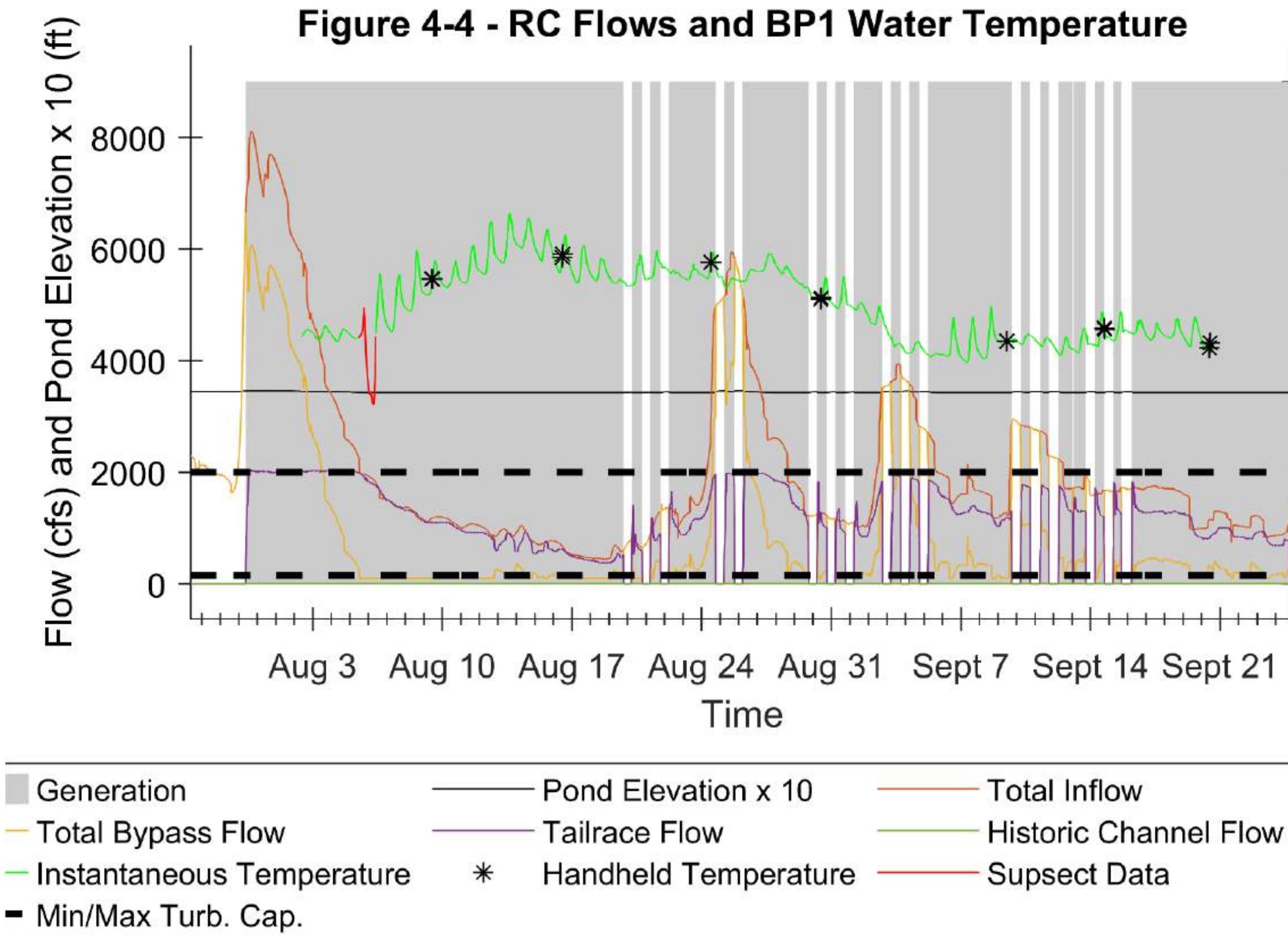


Figure 14–4. RC-BP1. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

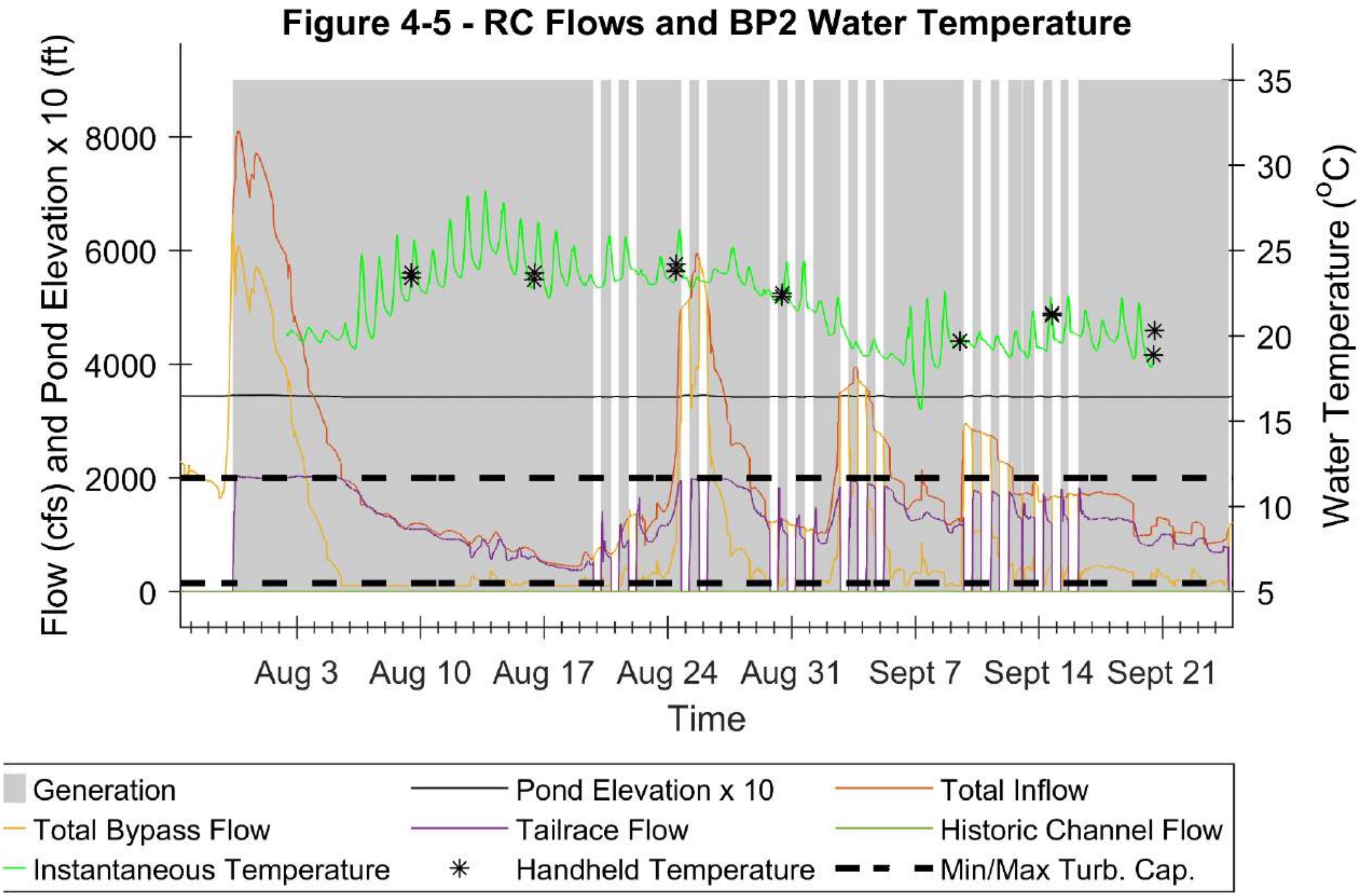


Figure 14–5. RC-BP2. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

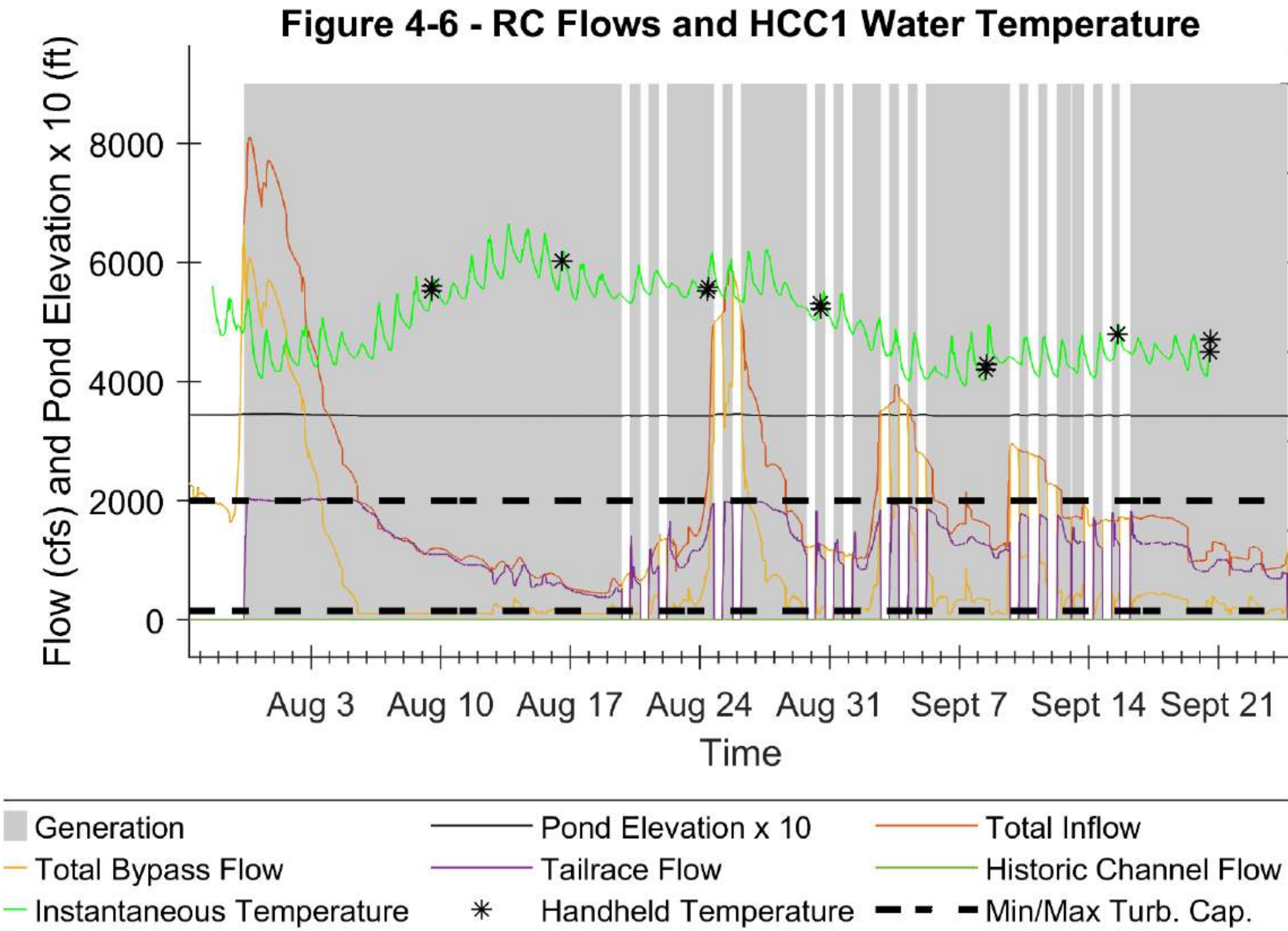


Figure 14–6. RC-HCC1. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

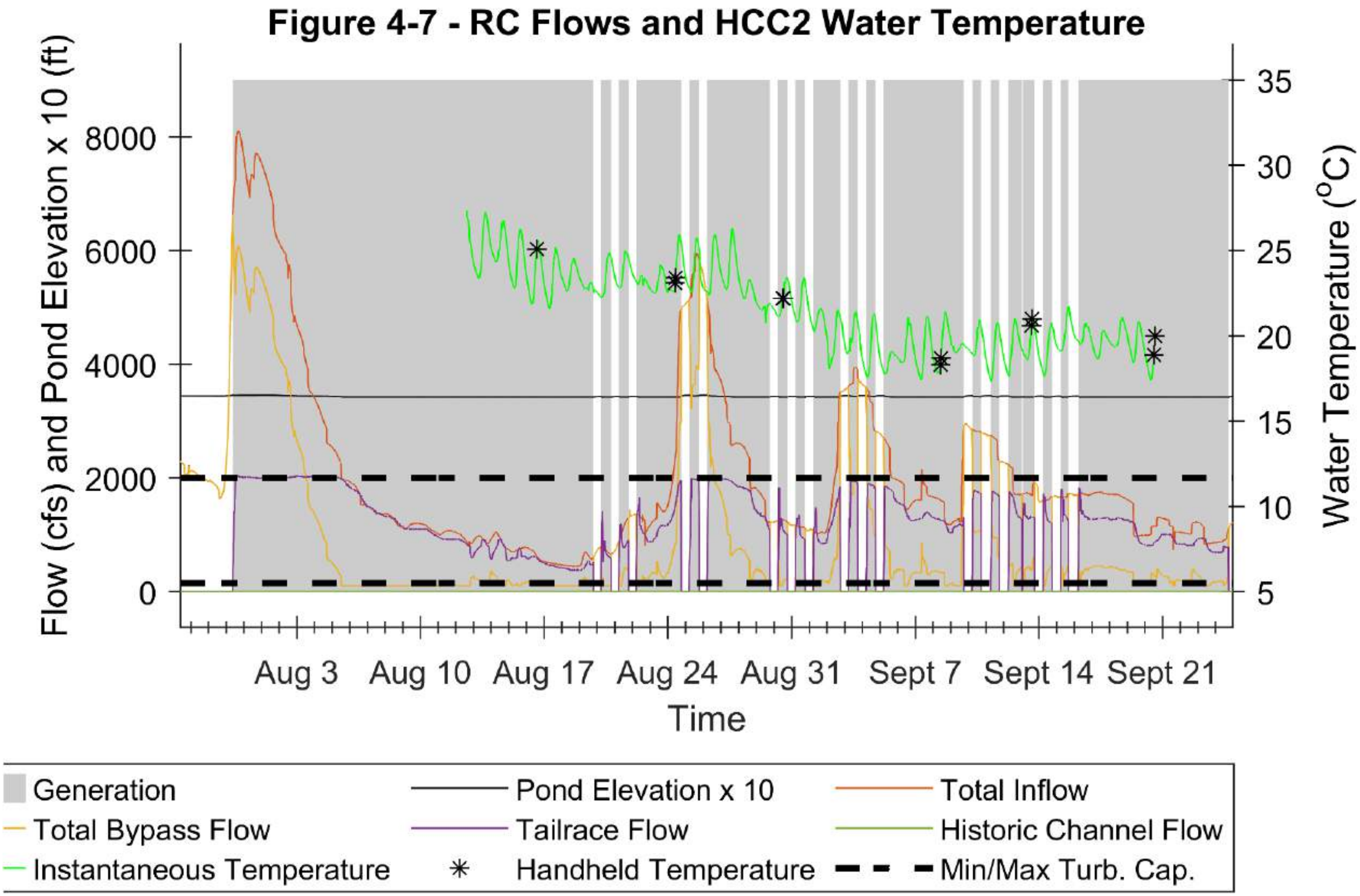


Figure 14–7. RC-HCC2. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

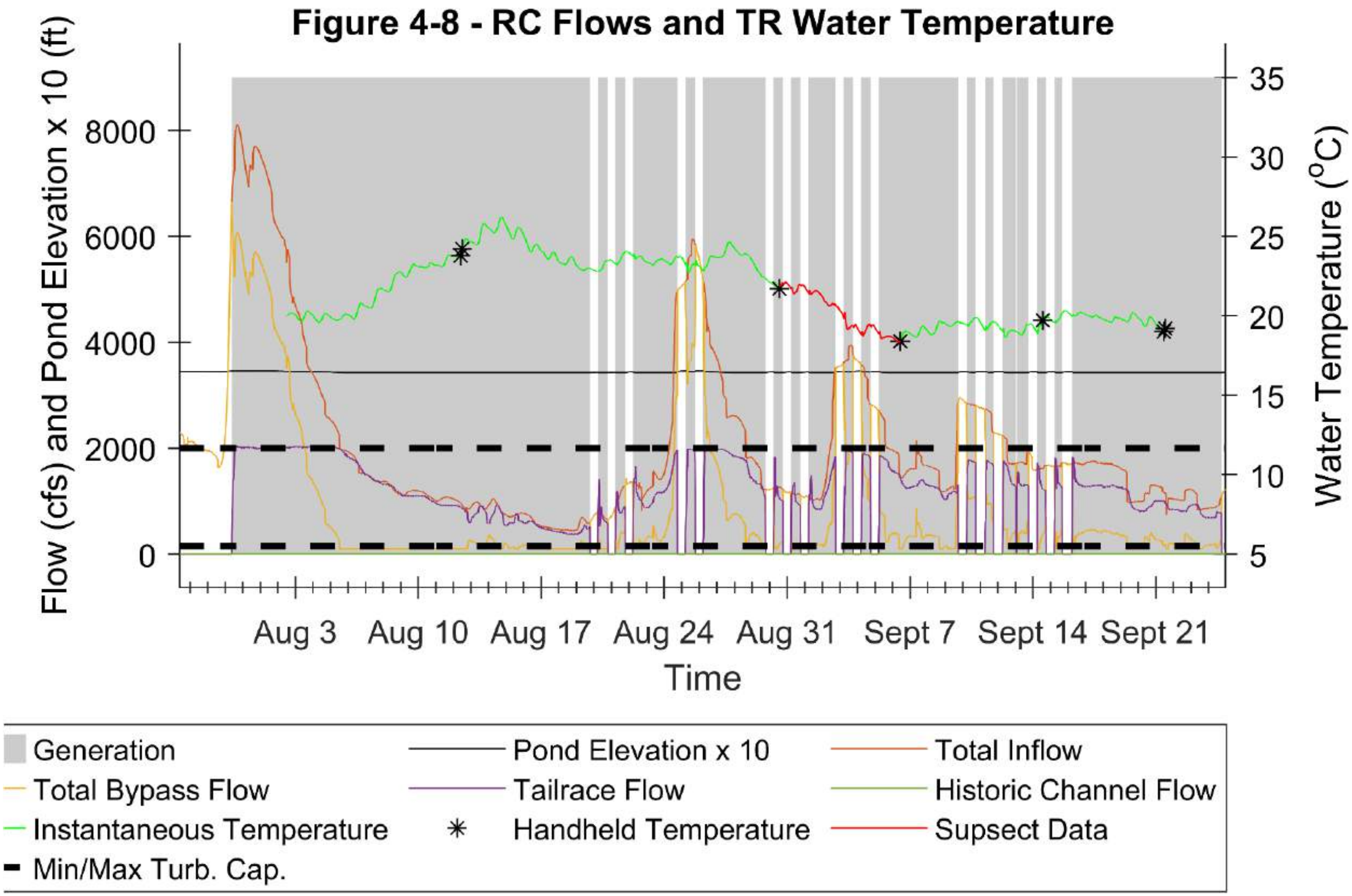


Figure 14–8. RC-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

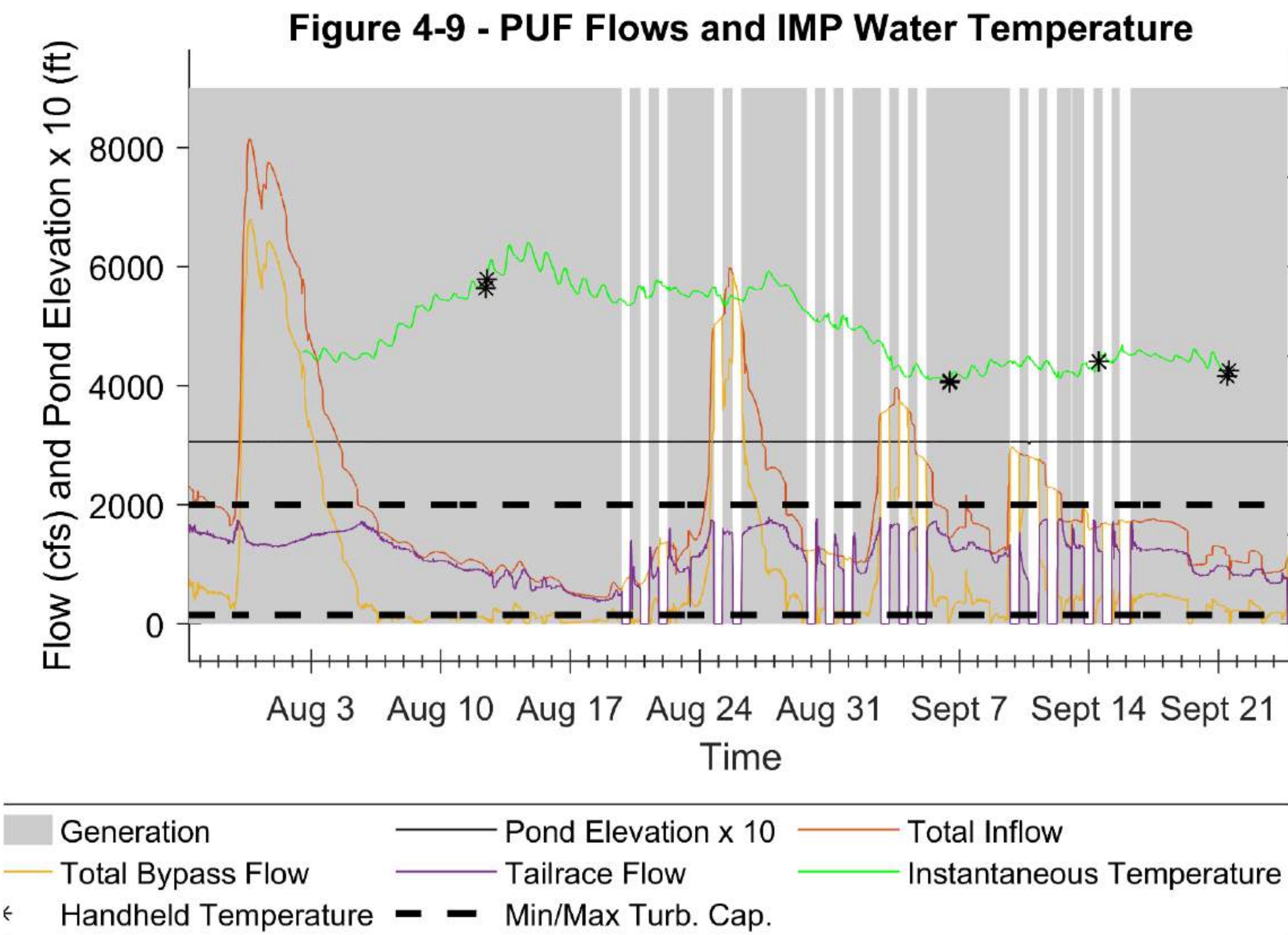


Figure 14–9. PUF-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

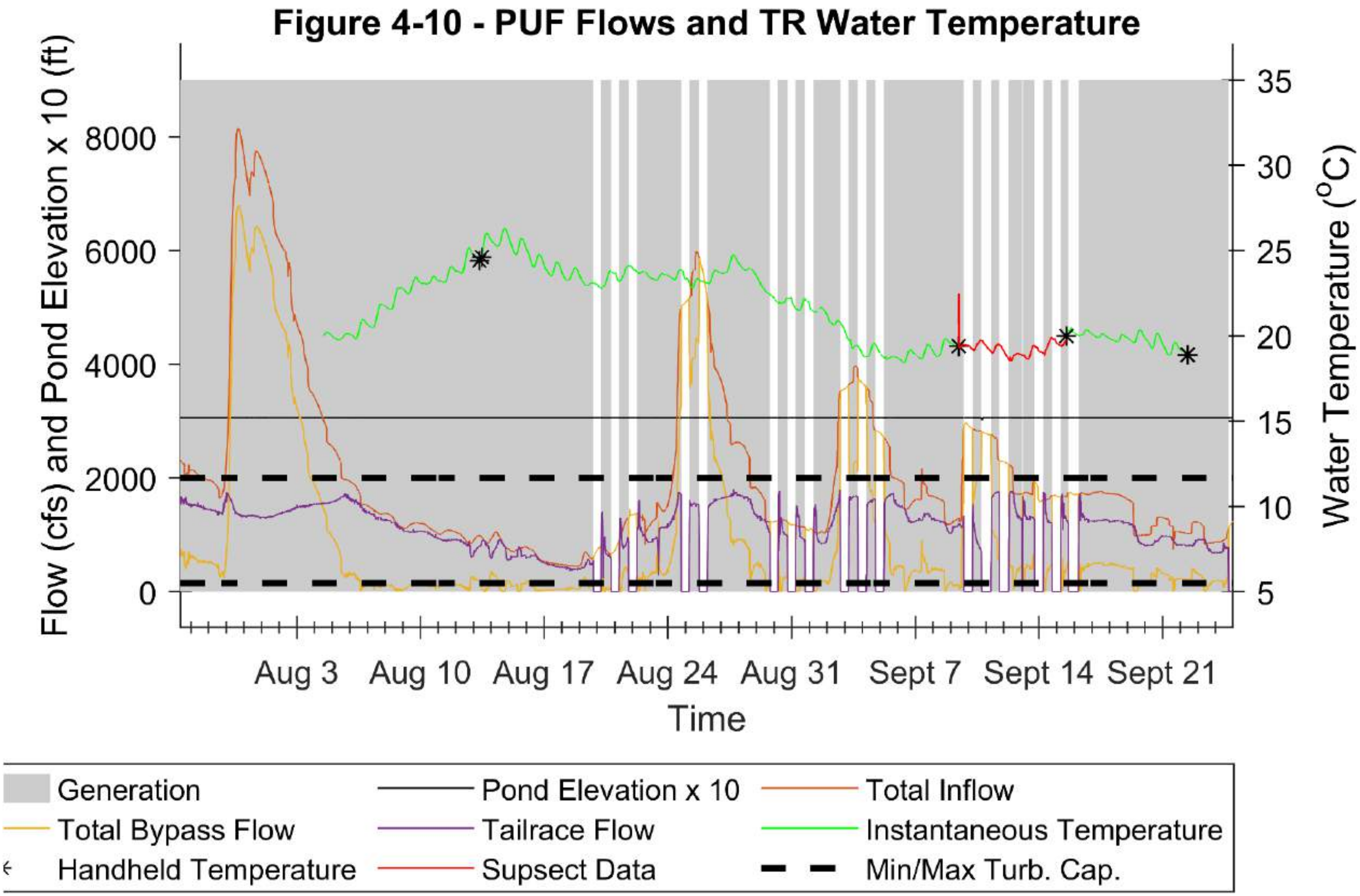


Figure 14–10. PUF-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

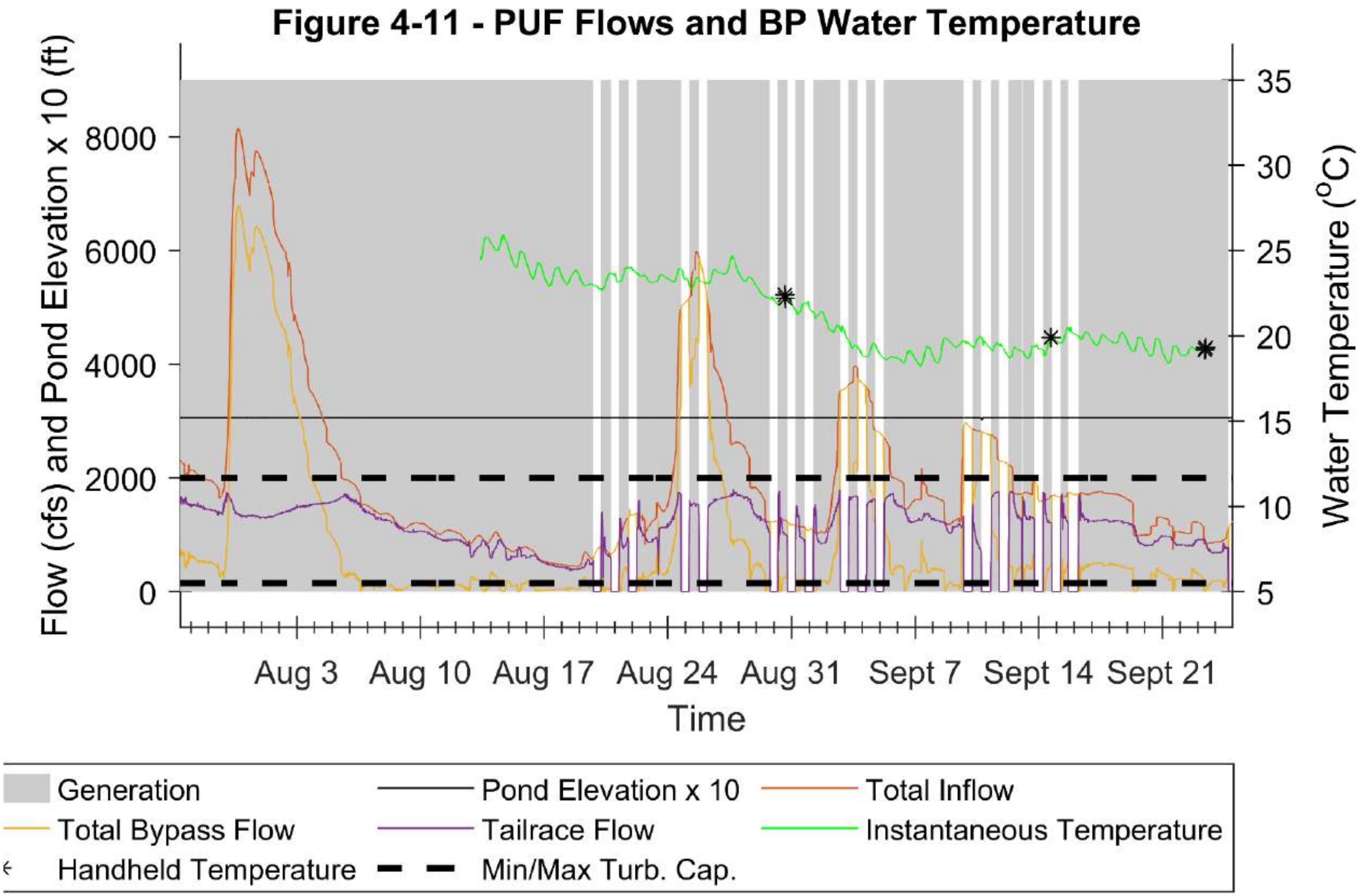


Figure 14–11. PUF-BP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

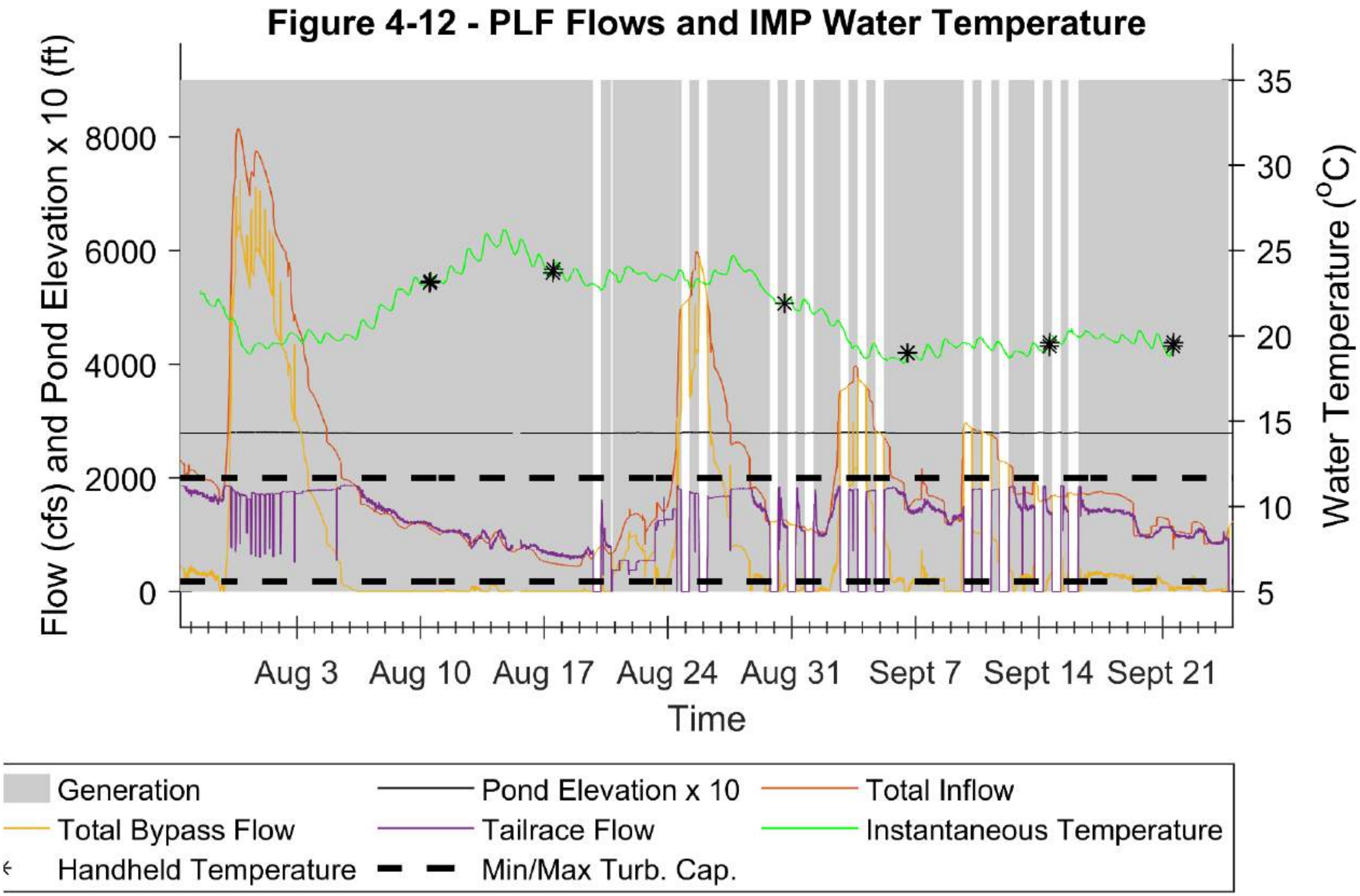


Figure 14–12. PLF-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

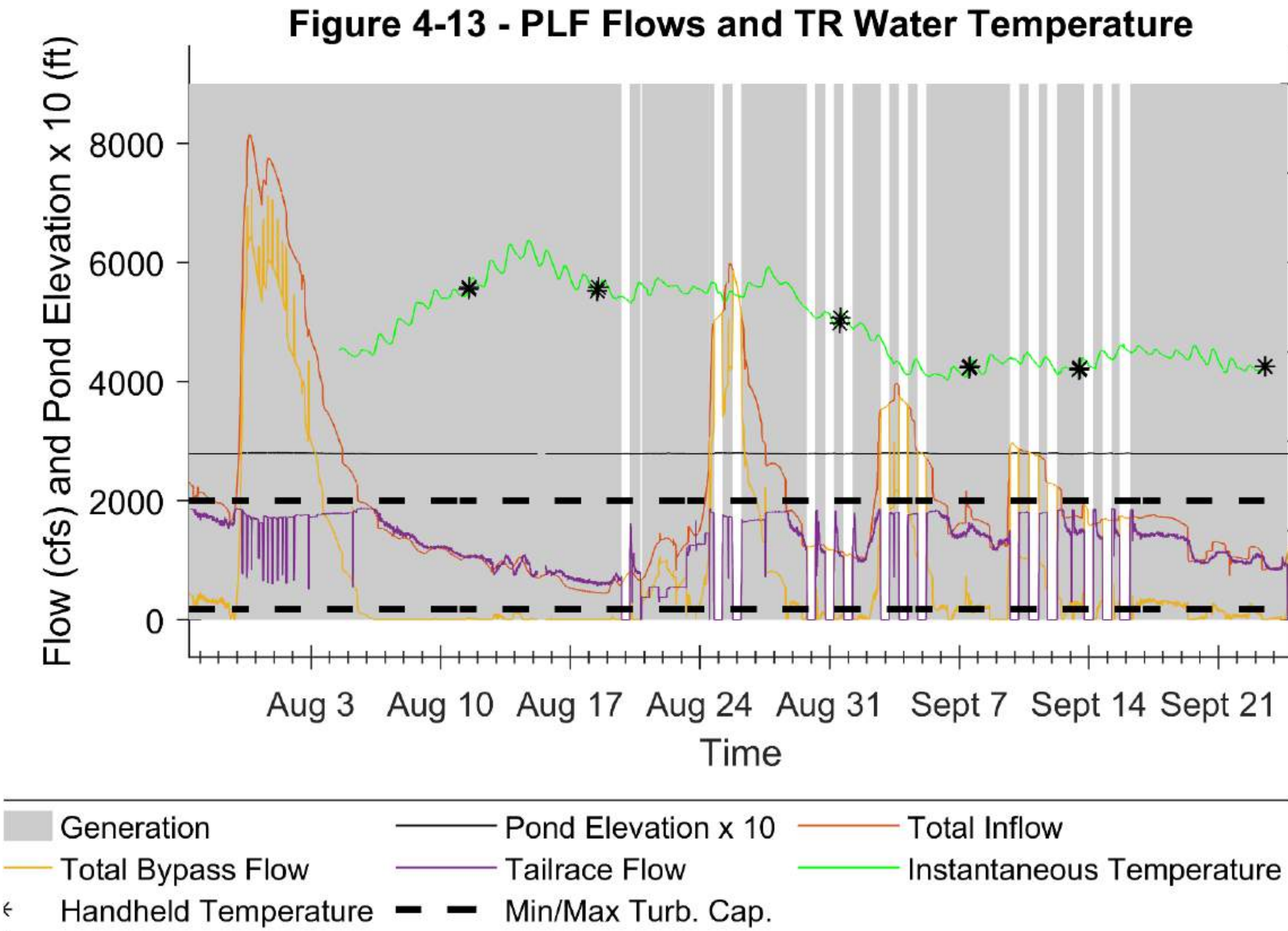


Figure 14–13. PLF-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

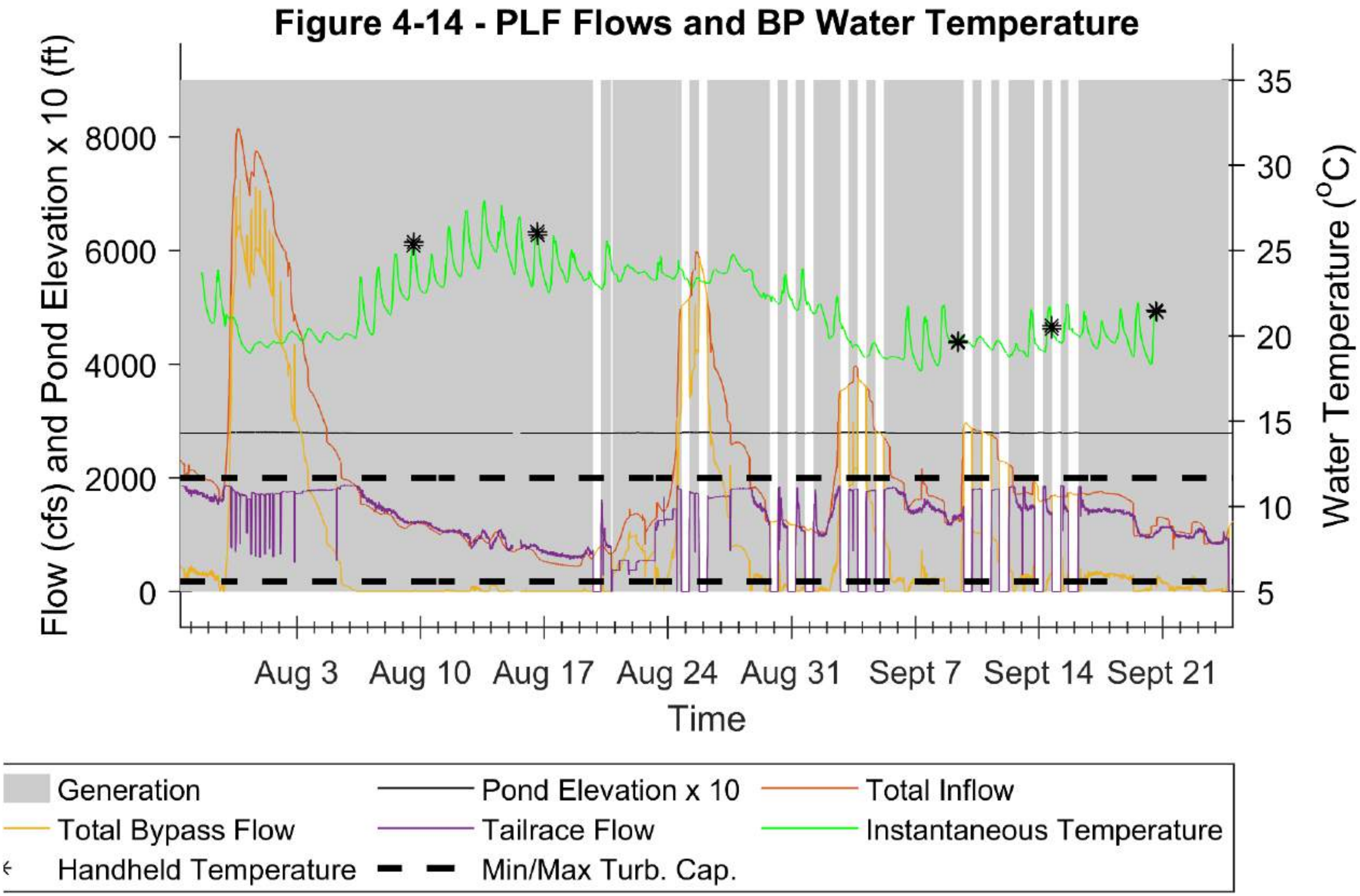


Figure 14–14. PLF-BP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde temperature (°C), and handheld meter temperature observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

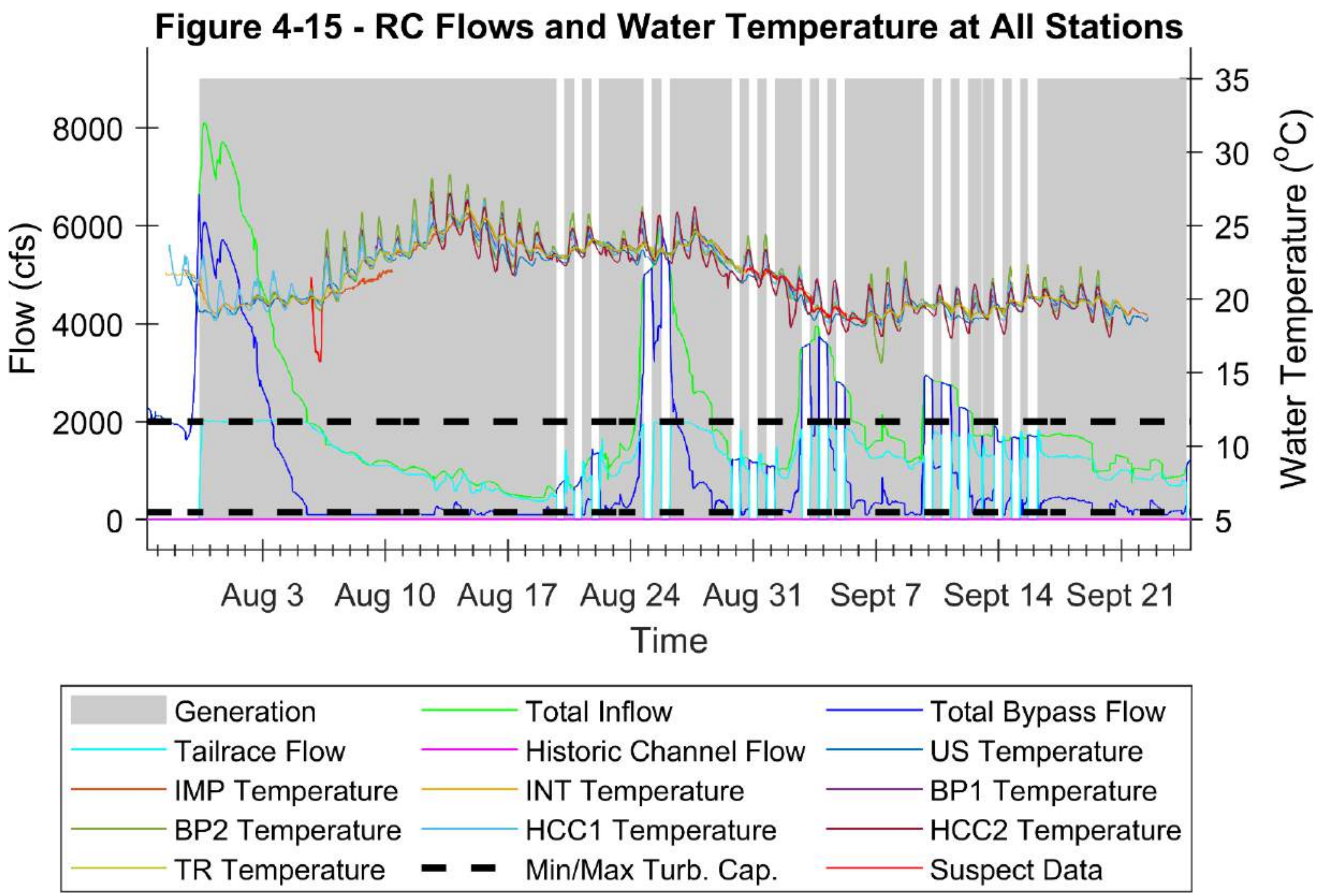


Figure 14–15. Rolfe Canal. Datasonde temperature (°C) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

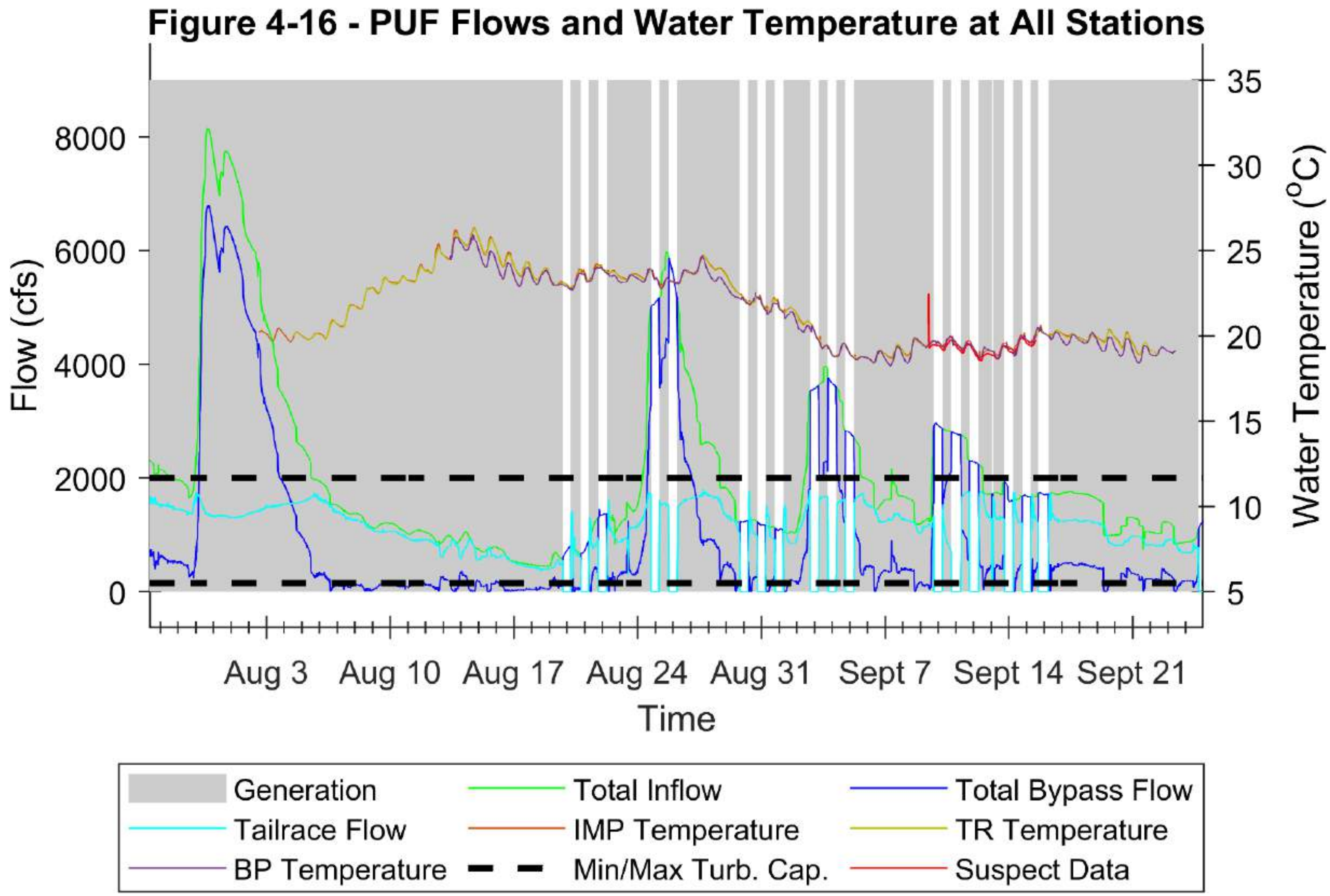


Figure 14–16. Penacook Upper Falls. Datasonde temperature (°C) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

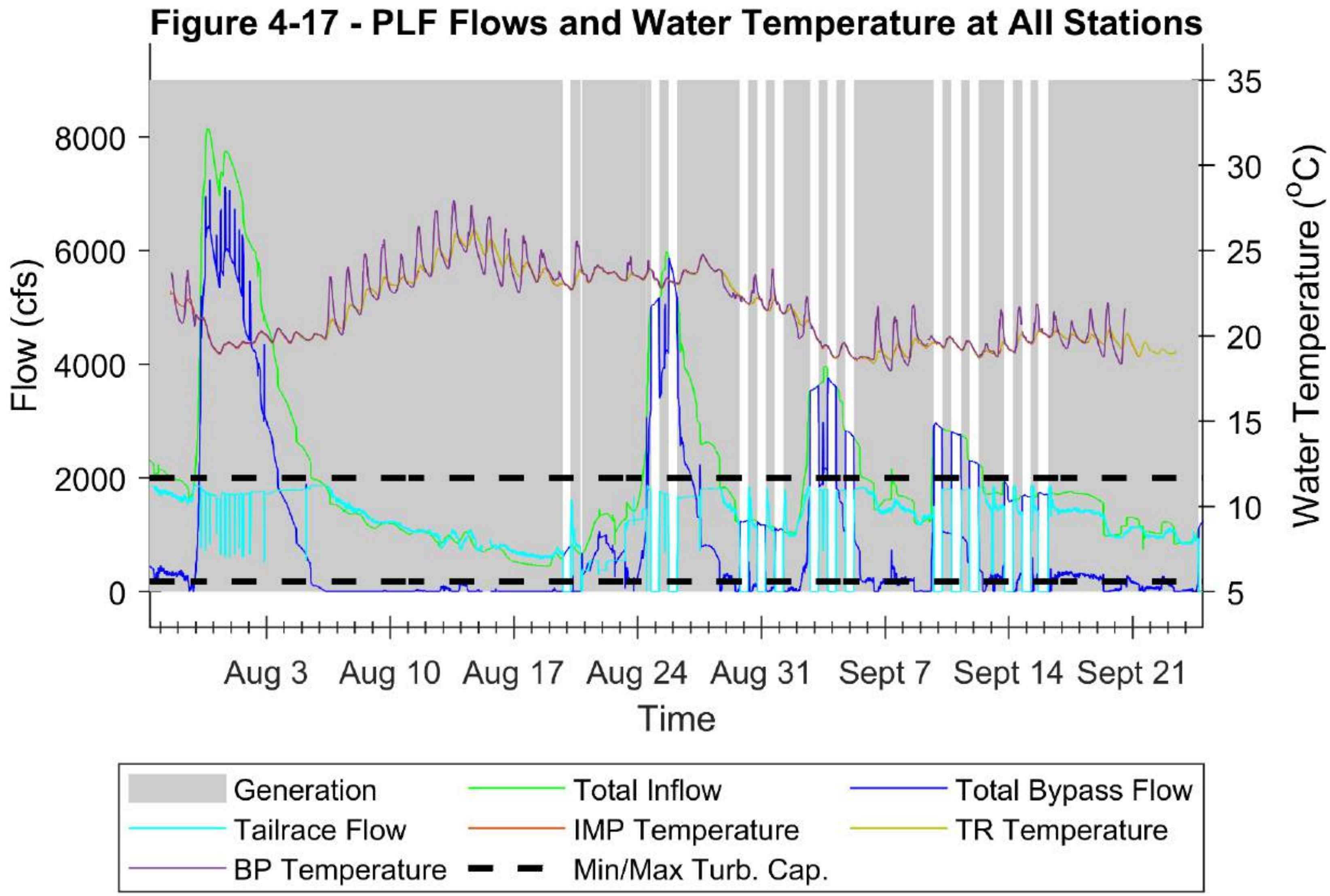


Figure 14–17. Penacook Lower Falls. Datasonde temperature (°C) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

17 Dissolved Oxygen

Dissolved oxygen was measured at each of the 14 continuous monitoring stations throughout the eight week study period and included periods of variable flow, temperature, and power generation conditions as presented in Figures 5-18 through 5-51 and Table 5-4. The periods of deployment and number of valid measurements are highlighted in Table 5-1. The DO loggers generally performed very well throughout the study and the deployment/post-deployment QC criteria were met with a few exceptions. There were four separate instances of instrument performance issues where DO/temperature data were flagged as suspect data and omitted from the final dataset. Suspect data are presented in the DO figures but are included as a separate time series for clarity (Suspect data are also presented in Appendix E). A summary of the suspect data removed from the final data set is highlighted in Table 5-3.

Dissolved oxygen was generally measured at high levels at all stations throughout the study and varied from a low of 4.81 mg/L (53.52% saturation) at RC-INT on 7/30/21 (during a period of low flow with no power generation) to a high of 10.73 mg/L (125% saturation) at PUF-TR on 8/26/21 (during a brief period of interrupted power generation and high inflow). There was only one period of exceedance of the DO standards documented at the continuous monitoring stations on 7/28/21 - 7/30/21 at Station RC-INT, otherwise all of the valid continuous monitoring data were well above the 5 mg/L standard and 75% saturation standard (as a daily average). DO values on average were highest in the bypass reaches with slightly lower values in the impoundments and tailrace reaches. The PLF-TR station, which represents outflow from all of the Projects, and RC-US, which was located upstream of the Project's hydraulic influence, had comparable median DO values during the study at 8.64 and 8.68 mg/L, respectively (although daily DO variations were much higher at PLF-TR). Lower DO values, below the 5 mg/L standard, were recorded during the study at lower water depths at the RC impoundment station, as presented in Section 5.2 – Vertical Profile results.

DO concentrations throughout the Project area generally decreased during the first two weeks of the study as high inflows receded and water temperatures increased to maximum values by August 14. DO concentrations then began an overall increasing trend that corresponded with decreasing temperatures and recurring periods of higher inflow. DO was positively correlated with inflow with DO concentrations and % saturation trending up and down with inflow. Absolute DO concentrations were also negatively correlated with temperature with higher DO concentrations generally corresponding with lower water temperatures and lower DO concentrations corresponding with higher water temperatures. DO % saturation tended to vary less over time at the bypass stations and historic canal channel stations compared to the other stations, likely due to the mixing conditions in the bypass reaches and the constant rate of inflow at the historic canal channel.

DO varied cyclically on a daily basis at each of the stations, similar to the documented daily variations in water temperature. The most pronounced daily DO variations were in the RC bypass reach and the PLF bypass reach where DO concentrations varied by 1 mg/L or more at times during the study and were typically well above 100% saturation during daily peaks. Daily variations of 0.5 mg/L or more were also documented at the other stations and were most pronounced during the receding limb of a flow event and low flows. At high flow there tended to be much less daily variation (i.e. as a daily cycle) in DO concentration, likely due to the mixing and generally higher DO levels associated with runoff events.

In addition to seasonal/temperature influences, inflow effects, and daily cycles, DO concentrations were affected by Project operating conditions, particularly in the tailrace reaches and the PUF/PLF impoundments which were directly affected by upstream operations.

The upstream reference station (RC-US) indicated a pattern of natural DO variations with daily cycles and longer trends affected by temperature and flow. Similarly, the RC-IMP station had comparable patterns of DO concentration and did not vary with power generation levels. At RC-INT where flows into the Rolfe Canal were dependent on generation levels, DO concentrations were affected by generating conditions to some degree. At the beginning of the study when inflows were low and no power was being generated, DO concentrations dropped to a study minimum of 4.81 mg/L at RC-INT, likely due to the lack of inflow and minimal mixing in the canal under these conditions. During generating periods, DO concentrations at the RC intake were similar to the RC impoundment as water was being diverted to the Canal for power production. When generating was interrupted there was a slight drop in DO concentration at RC-INT of up to approximately 0.5 mg/L, although this short-term variation in DO was similar in magnitude to daily cycles that occurred with prolonged uninterrupted power generation. In the RC bypass, DO concentrations were affected by spill versus minimum flow conditions with less daily DO variation under spill conditions and greater daily variation in DO of up to 1 mg/L or more under minimum flow conditions. When power generation was interrupted, resulting in spill to the bypass, DO concentrations increased slightly and/or stabilized at the bypass stations compared to the preceding minimum flow conditions. The historic Rolfe Canal channel stations did not show evidence of DO being affected by project operations, likely due to the minimum flow requirement to the historic canal channel and the mixing created by the diversion structures (with a cascade created at the minimum flow orifice and at the canal sluice). The RC tailrace station (RC-TR) recorded DO concentrations that increased slightly when power generation was interrupted and decreased by up to 0.5 mg/L, briefly (3 hours or less), when power generation resumed.

Water quality at the PUF stations was affected by operations at the Rolfe Canal Project and the PUF Project, particularly in the tailrace and impoundment stations. At the impoundment station (PUF-IMP), DO concentrations increased by up to 1 mg/L when power generation was interrupted and had a corresponding decrease of up to 1.2 mg/L when power generation resumed (i.e., generation at either RC and/or PUF) with DO concentrations at PUF-IMP similar to RC-TR during generating periods. DO increases/decreases associated with generation were greater than typical daily variations recorded during periods of sustained generation. DO changes associated with power generation were greatest at the tailrace station (PUF-TR) with increases of up to 1-2 mg/L associated with interrupted power generation and corresponding decreases of 1-2 mg/L associated with resumed generation. Changes in DO concentration associated with generation were much greater than the daily DO cycle documented during uninterrupted periods of generation. DO concentrations at PUF-TR were similar to concentrations at PUF-IMP during generation periods and during non-generation periods were anomalously high (e.g., up to 120+ % saturation) and were not comparable to conditions at other stations. At the PUF bypass station (PUF-BP), DO concentrations generally increased slightly (up to 0.5 mg/L) during interrupted power generation, although these variations were indistinguishable from daily variations during uninterrupted power generation periods.

Water quality at the PLF stations, located furthest downstream of the three Projects, was affected by operations at the upstream projects as well as operations at the PLF Project, particularly at the PLF-IMP and PLF-TR stations. At the PLF-IMP station, DO concentrations were directly affect by upstream operations, with DO increases of 0.8 – 1.4 mg/L occurring during interrupted power generation and corresponding similar decreases when upstream power generation resumed. The DO patterns at PLF-IMP were quite similar to PUF-TR and demonstrates the influence of upstream operations on downstream water quality. DO patterns at the PLF-TR station were also comparable to PLF-IMP, although the DO changes associated with generating and non-generating periods were greater than at PLF-IMP, likely due to the added influence of outflows from the lower Project. DO increases of 1.2 – 1.6 mg/L were documented at PLF-TR during interrupted power generation as were corresponding similar decreases when power generation resumed. DO saturation levels were well in excess of 100% during the non-generating periods. DO patterns at the PLF-BP station indicated minimal impact on DO from Project operations, with changes in DO due to Project operations being indistinguishable from daily cyclical changes in DO (typically 1 mg/l under minimum flow conditions). When power generation was interrupted, resulting in spill to the bypass, DO typically increased at PLF-BP by 0.5 - 1.0 mg/L. DO saturation was frequently in excess of 100% saturation at the PLF-BP station under both generating and non-generating conditions, although variability was highest under minimum flow conditions.

Table 14–4. Summary of continuous monitoring DO data

	RC-US	RC-IMP	RC-INT	RC-BP1	RC-BP2	RC-HCC1	RC-HCC2	RC-TR	PUF-IMP	PUF-TR	PUF-BP	PLF-IMP	PLF-TR	PLF-BP
	DO (mg/L)													
Min	7.09	6.14	4.81	8.04	7.37	8.01	7.31	6.41	6.89	6.85	7.67	6.83	7.16	7.5
Max	9.52	9.02	9.04	9.65	10.15	9.5	9.13	9.08	9.4	10.73	9.72	10.01	10.48	9.68
Mean	8.51	7.97	7.92	8.8	8.75	8.81	8.26	8.02	8.19	8.19	8.78	8.34	8.59	8.83
Median	8.64	8.16	8.02	8.78	8.74	8.79	8.33	8.04	8.36	8.16	8.9	8.39	8.68	8.85
	RC-US	RC-IMP	RC-INT	RC-BP1	RC-BP2	RC-HCC1	RC-HCC2	RC-TR	PUF-IMP	PUF-TR	PUF-BP	PLF-IMP	PLF-TR	PLF-BP
	DO % Saturation (daily mean data)													
Min	89	80	71	95	96	97	91	85	86	86	95	86	90	97
Max	102	99	97	104	104	103	96	96	100	105	103	104	110	103
Mean	95	90	89	100	99	100	93	91	93	93	99	94	97	100
Median	95	90	91	100	99	100	93	91	92	93	98	93	96	100
	RC-US	RC-IMP	RC-INT	RC-BP1	RC-BP2	RC-HCC1	RC-HCC2	RC-TR	PUF-IMP	PUF-TR	PUF-BP	PLF-IMP	PLF-TR	PLF-BP
	DO % Saturation (15 minute data)													
Min	86	70	54	89	90	96	86	75	83	83	88	83	87	91
Max	104	100	98	109	114	104	102	99	103	125	104	107	114	111
Mean	95	90	89	100	99	100	93	91	93	93	99	94	97	100
Median	96	90	90	100	100	100	92	91	93	92	98	93	95	101

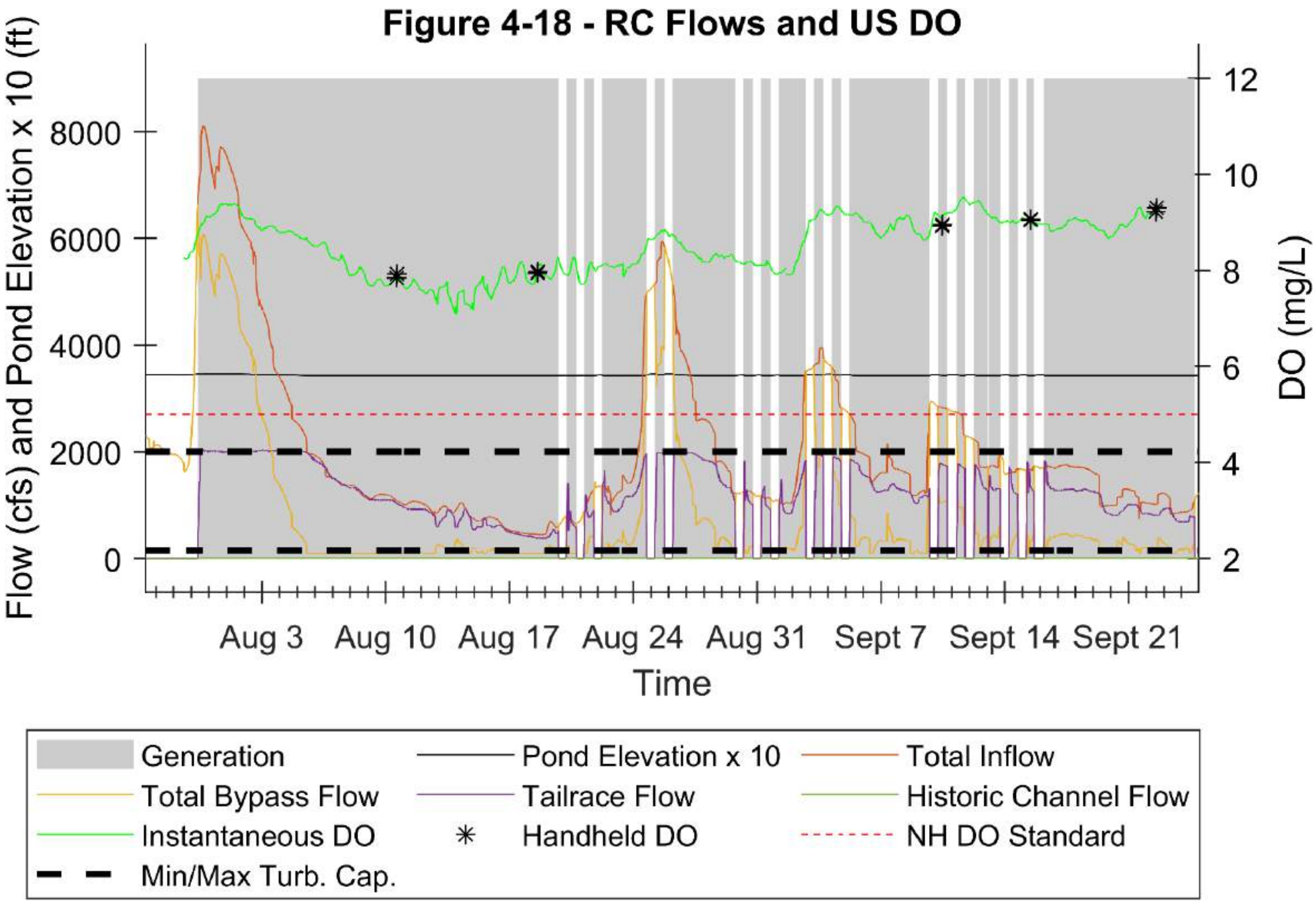


Figure 14–18. RC-US. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

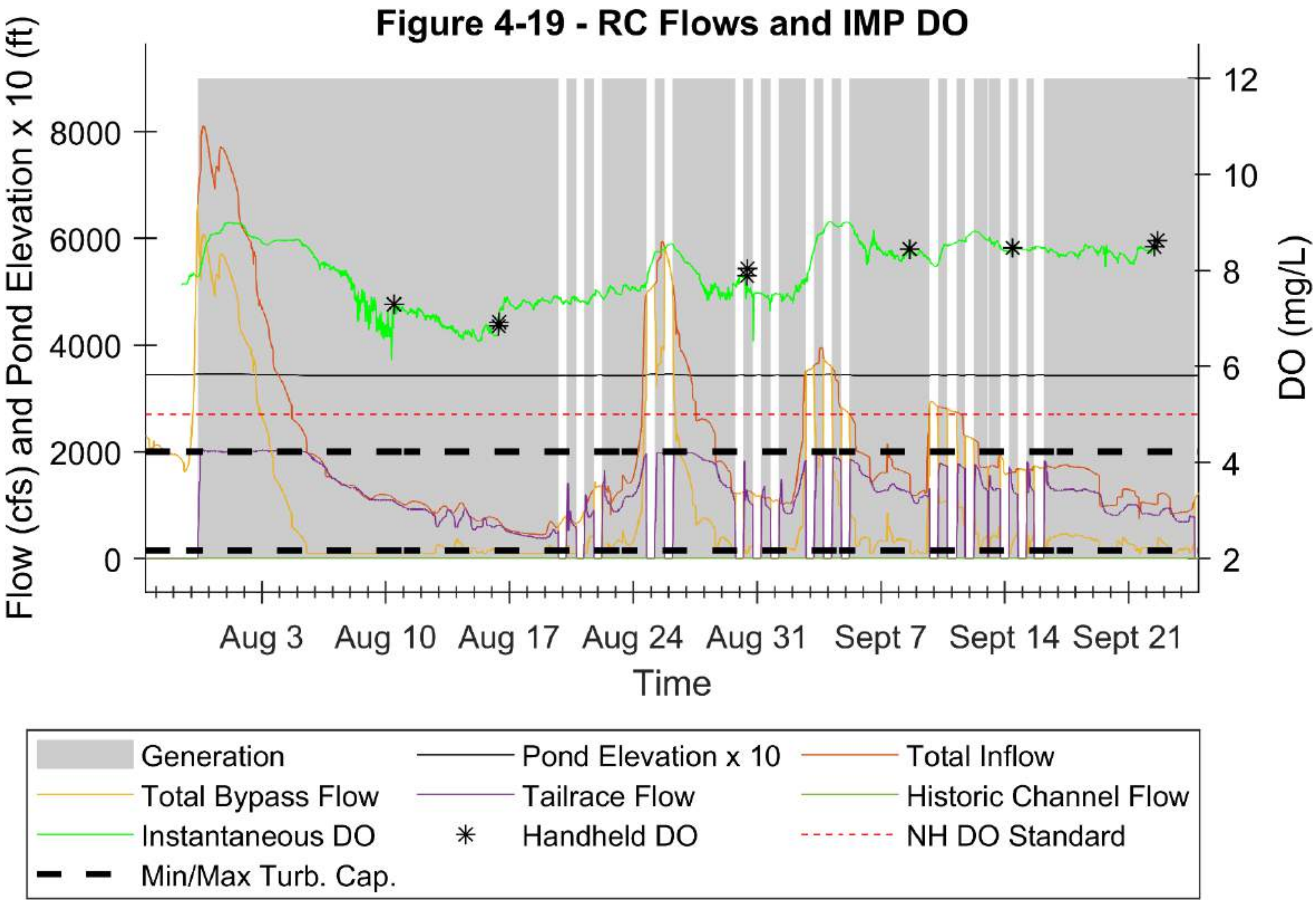


Figure 14–19. RC-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

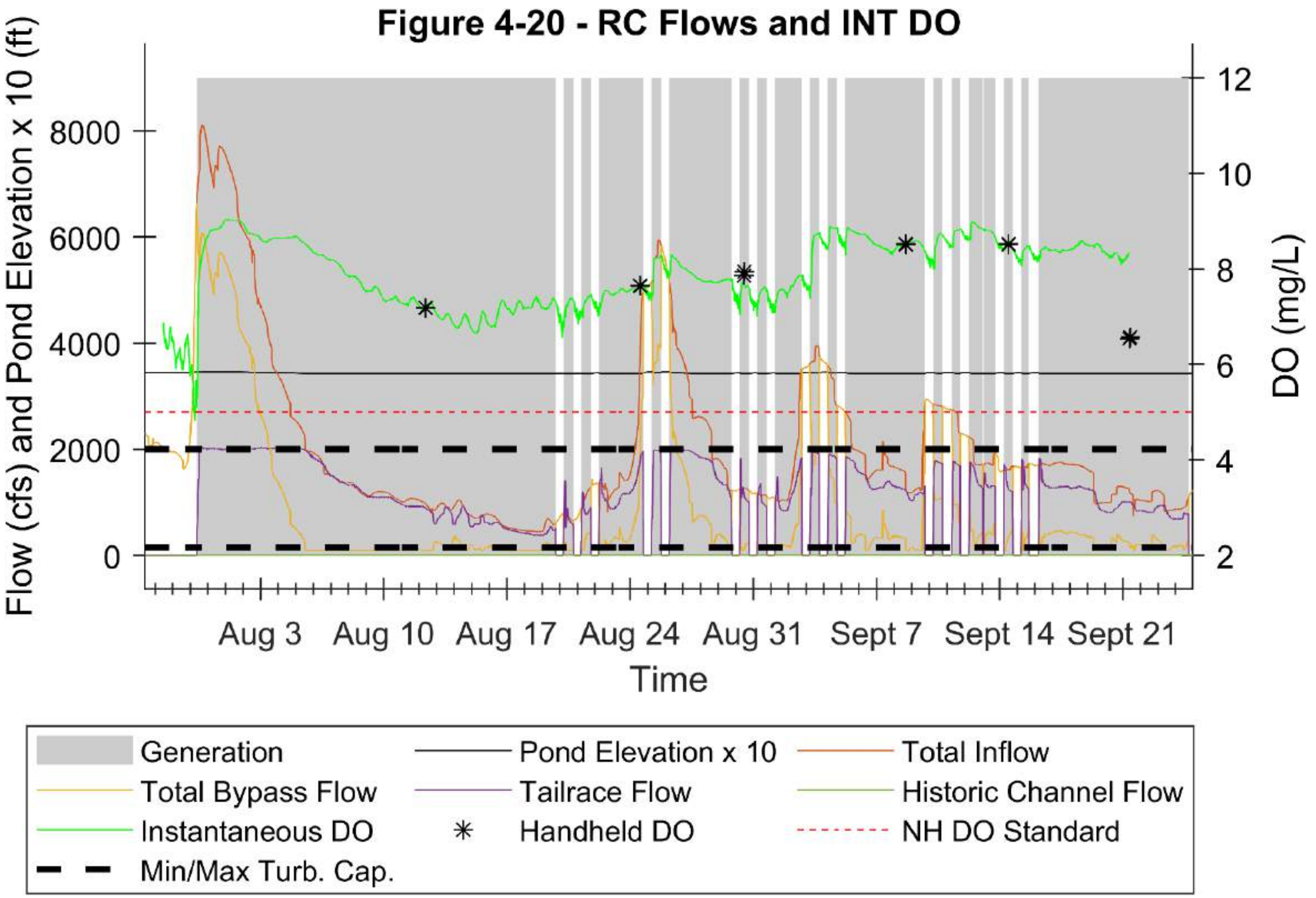


Figure 14–20. RC-INT. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

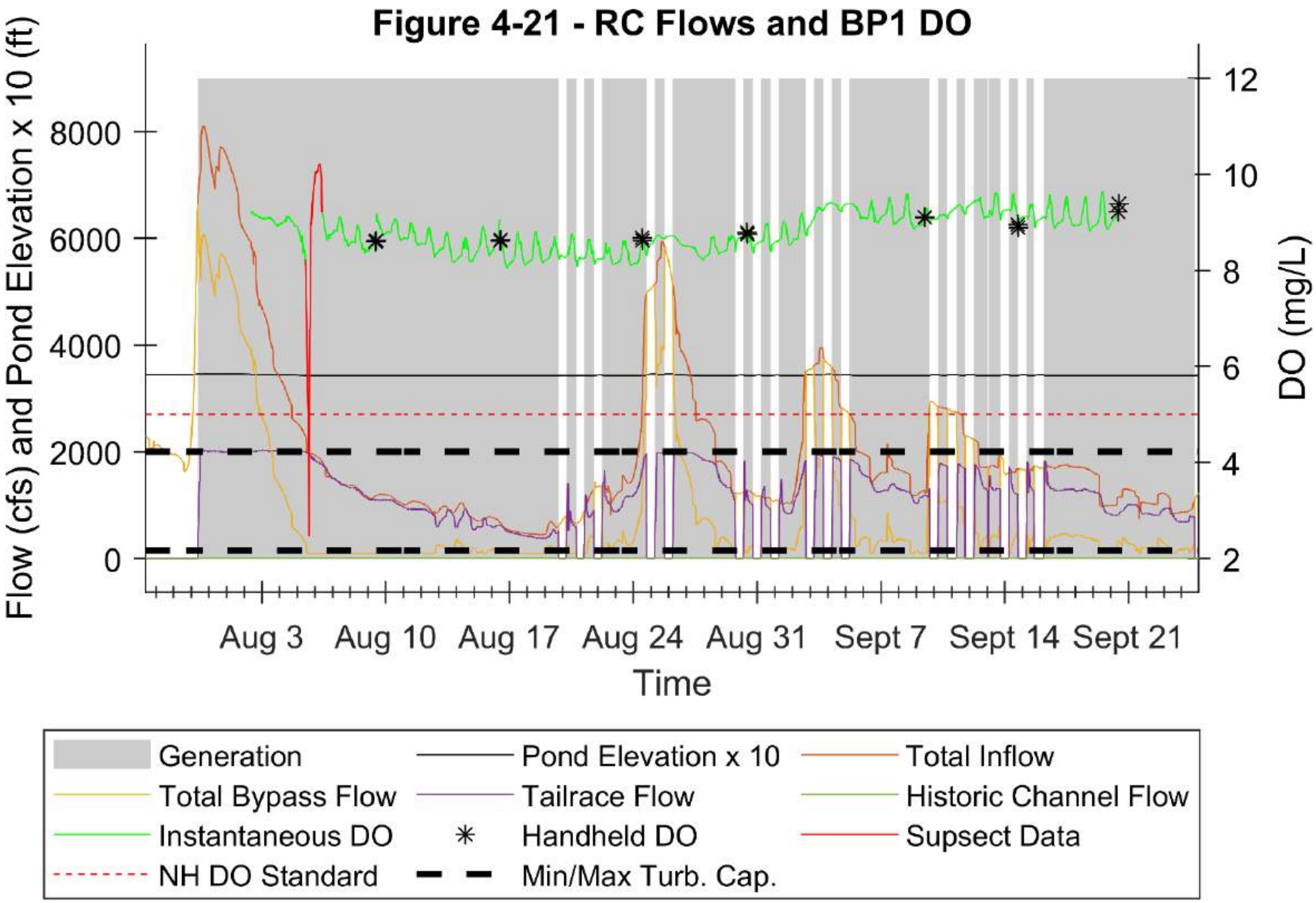


Figure 14–21. RC-BP1. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

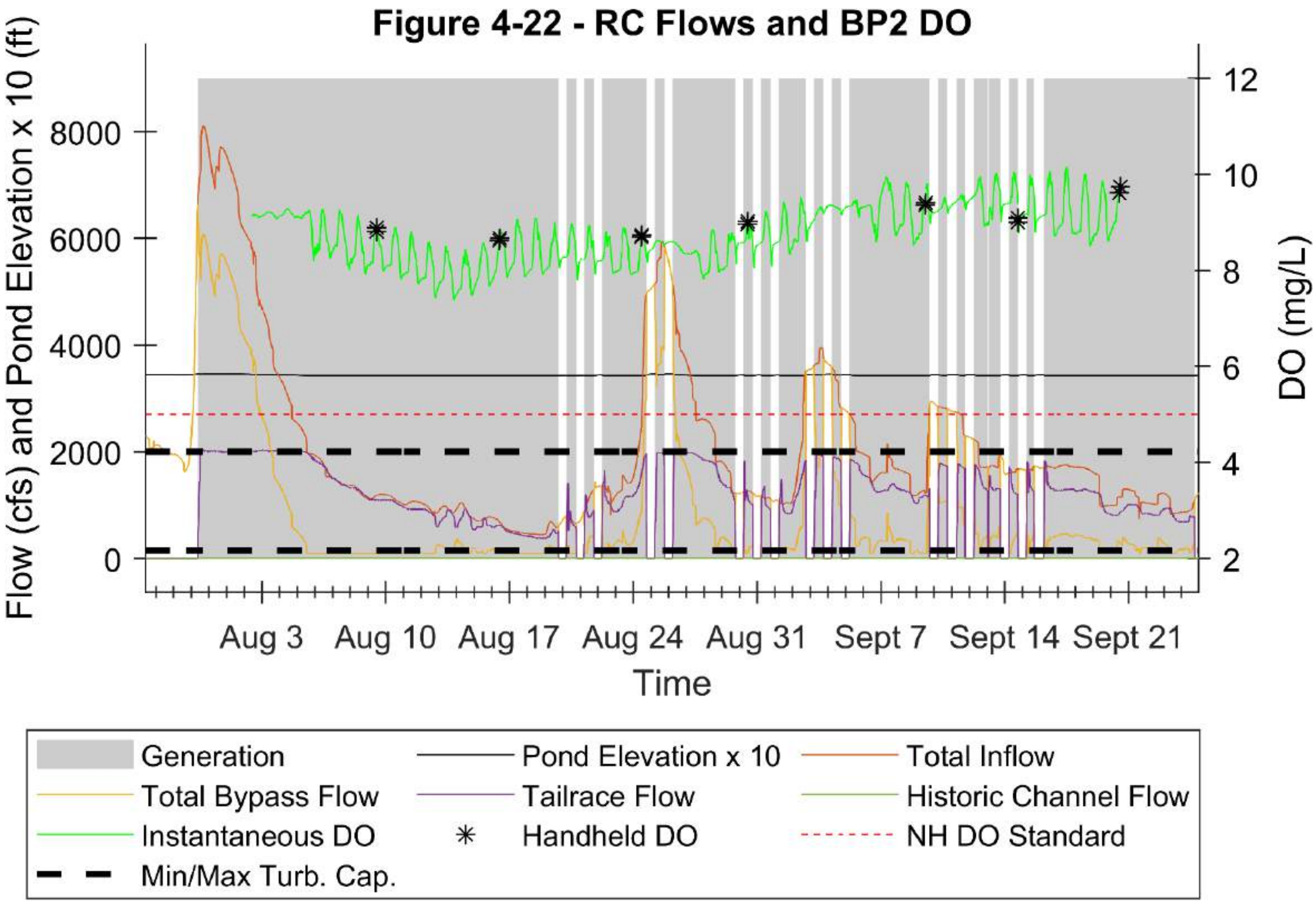


Figure 14–22. RC-BP2. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

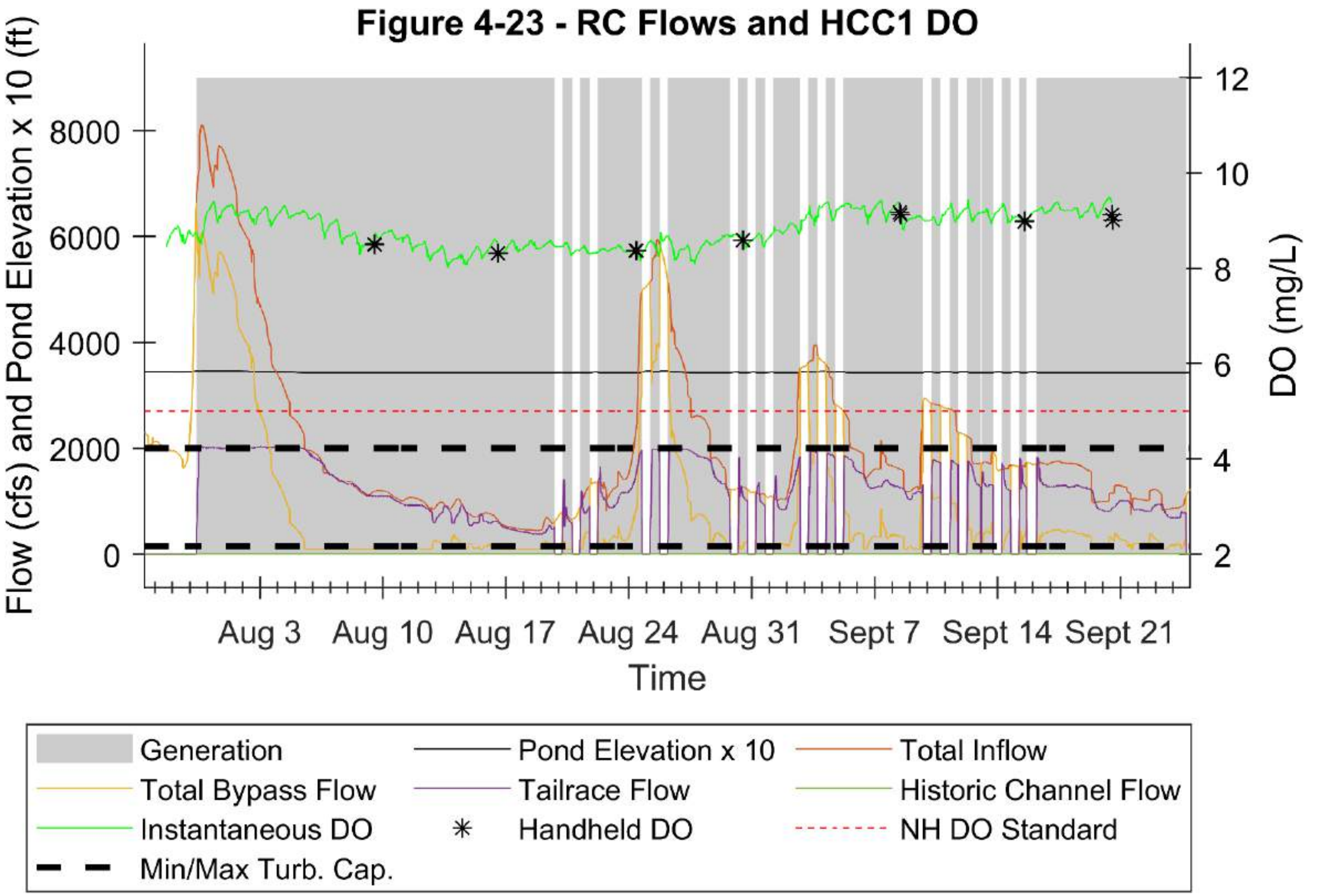


Figure 14–23. RC-HCC1. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

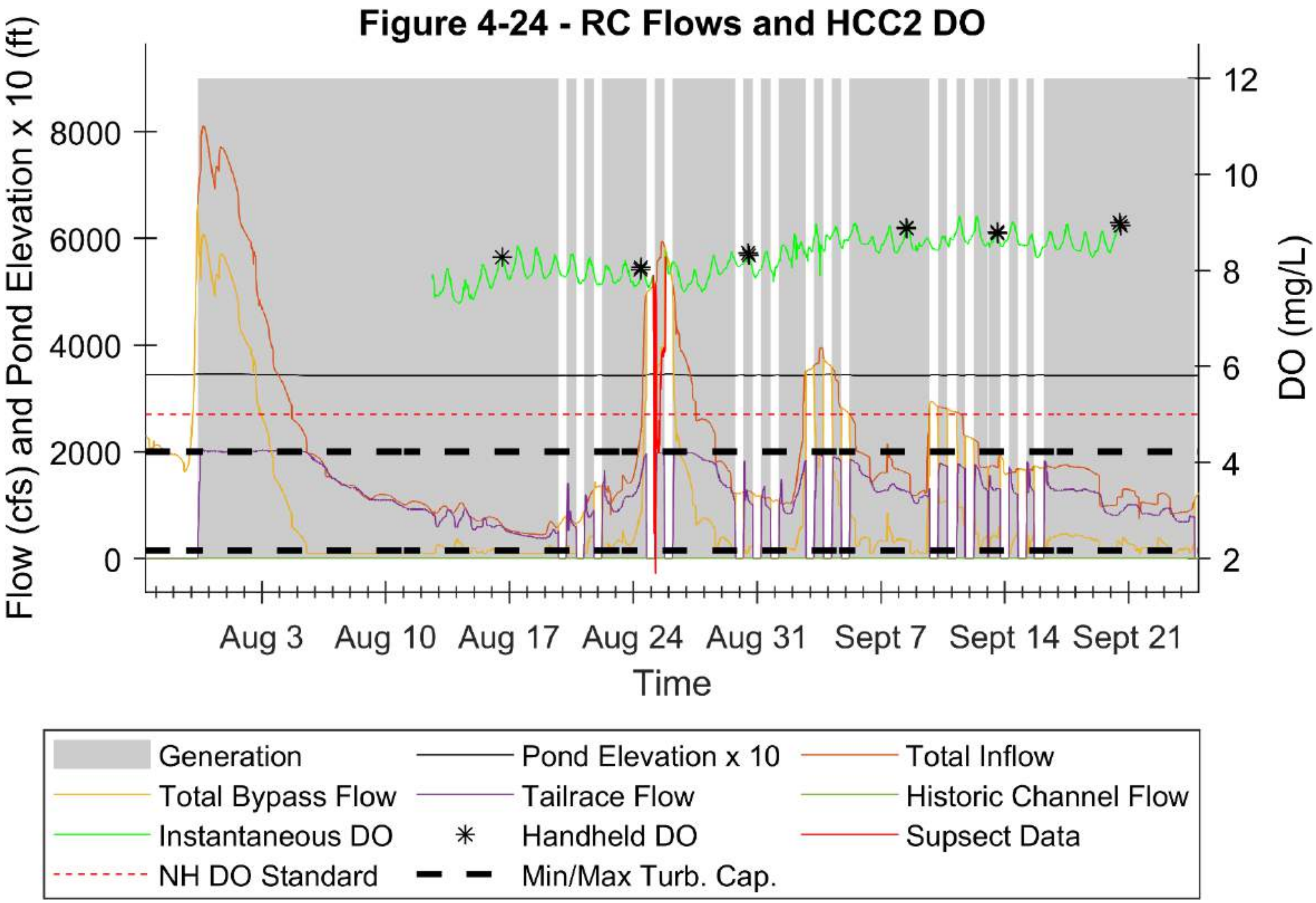


Figure 14–24. RC-HCC2. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

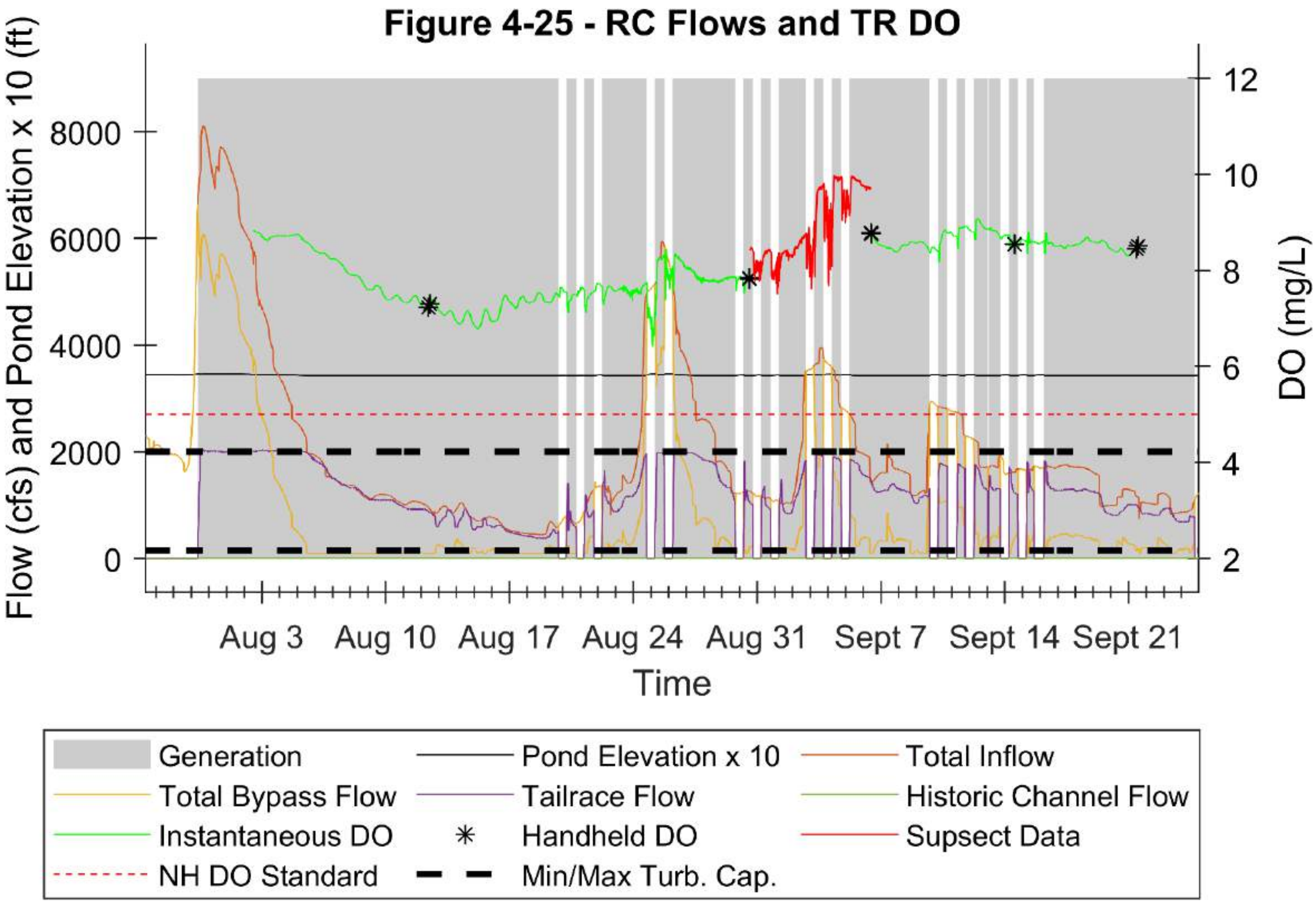


Figure 14–25. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

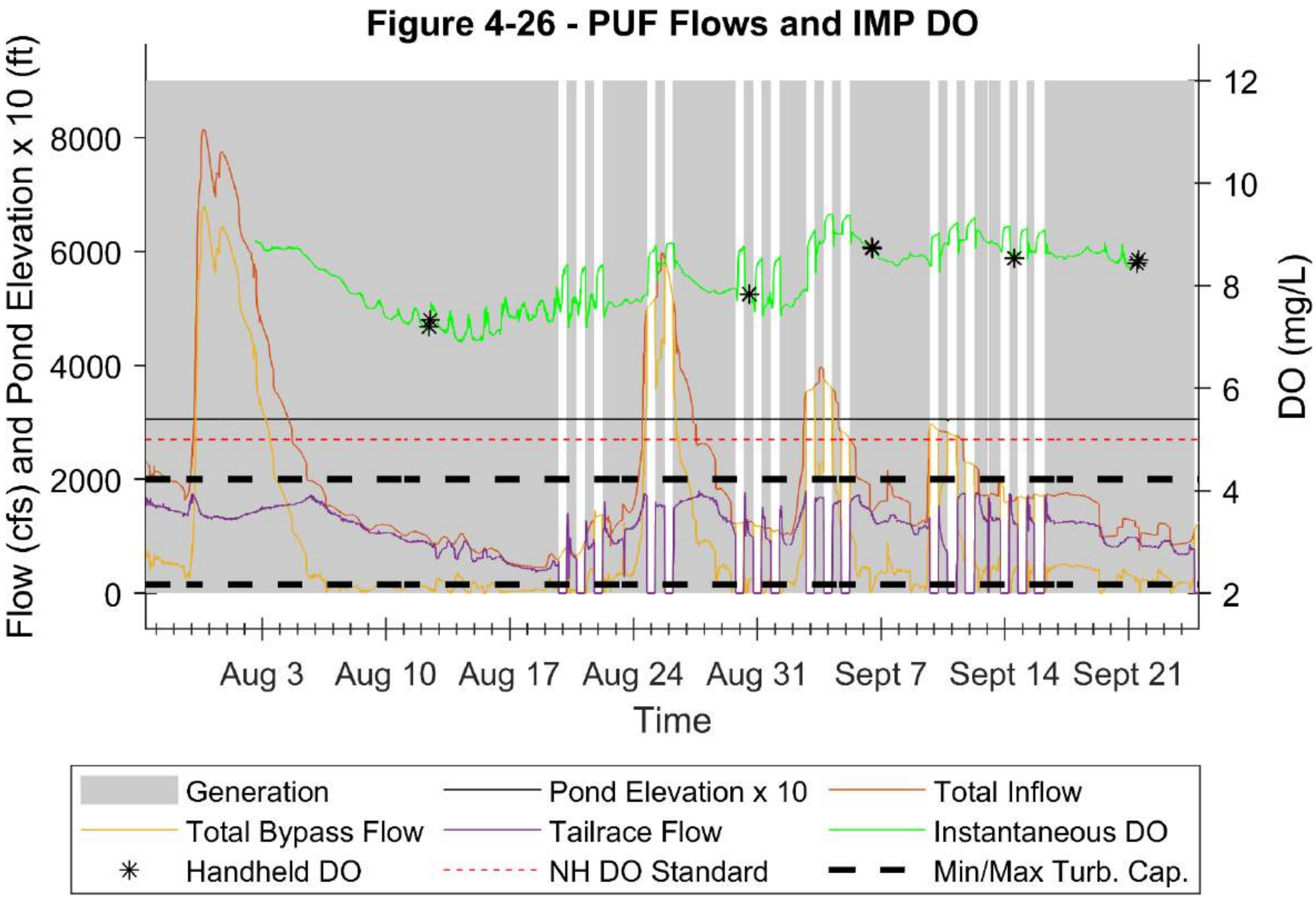


Figure 14–26. PUF-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

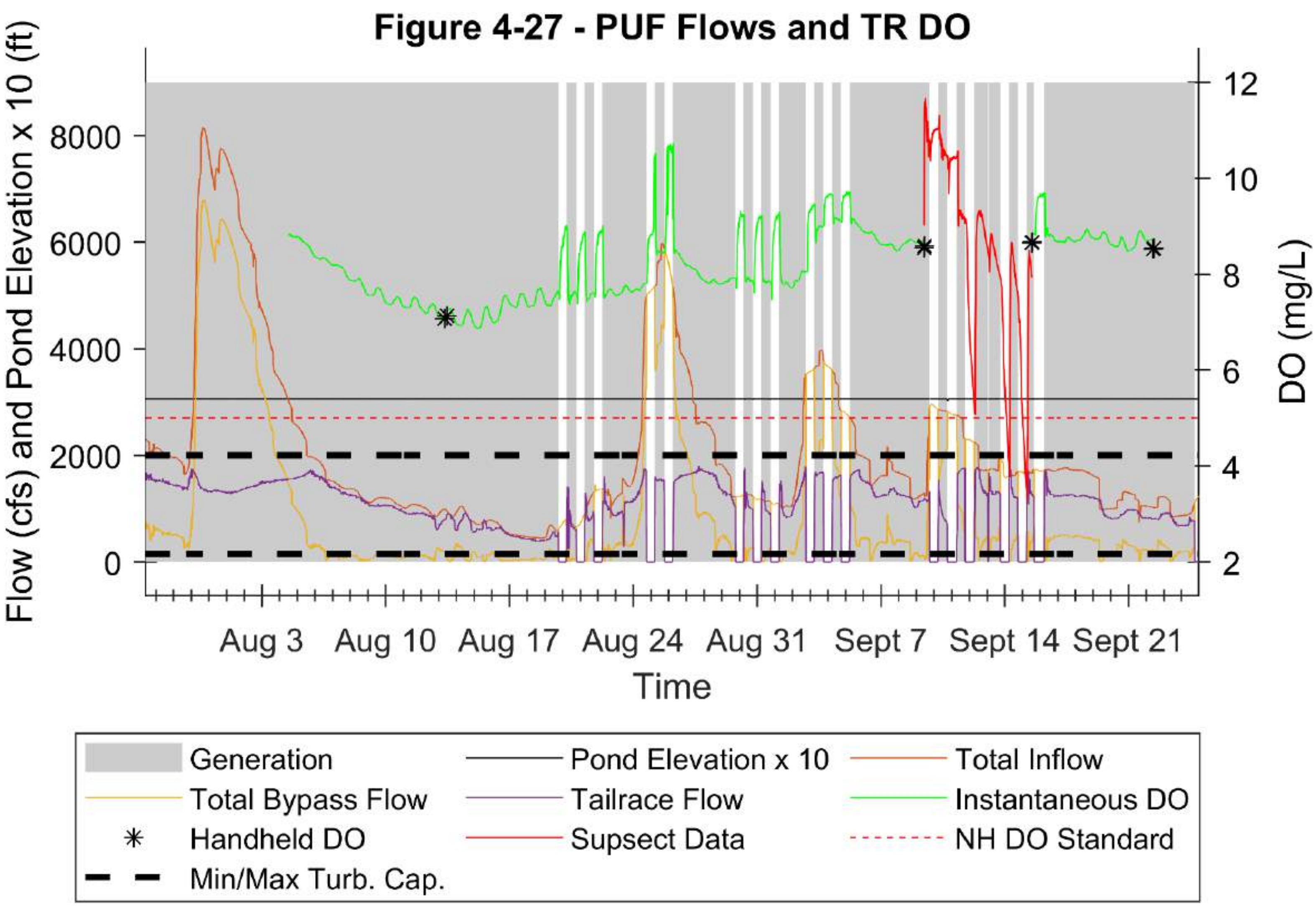


Figure 14–27. PUF-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

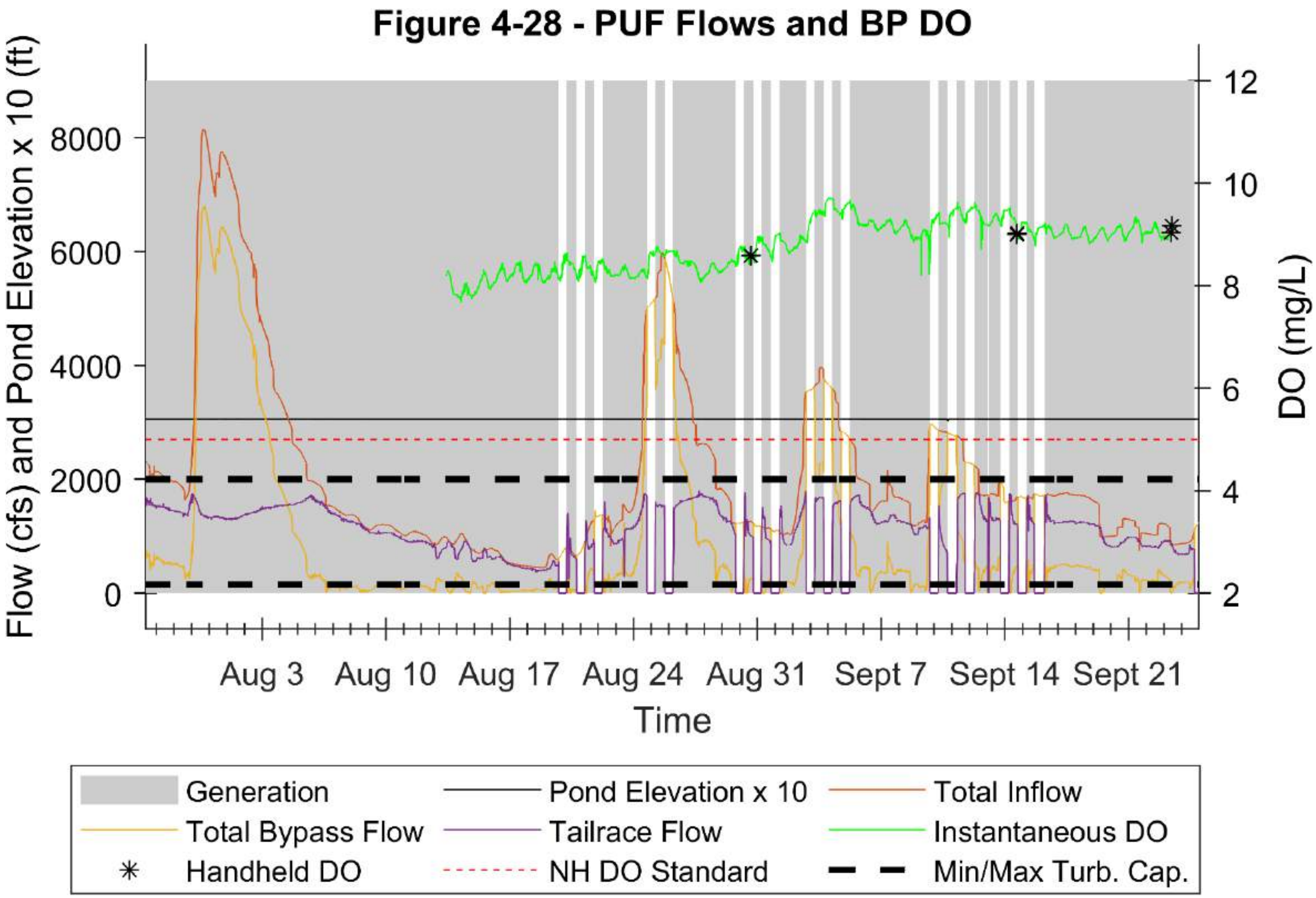


Figure 14–28. PUF-BP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

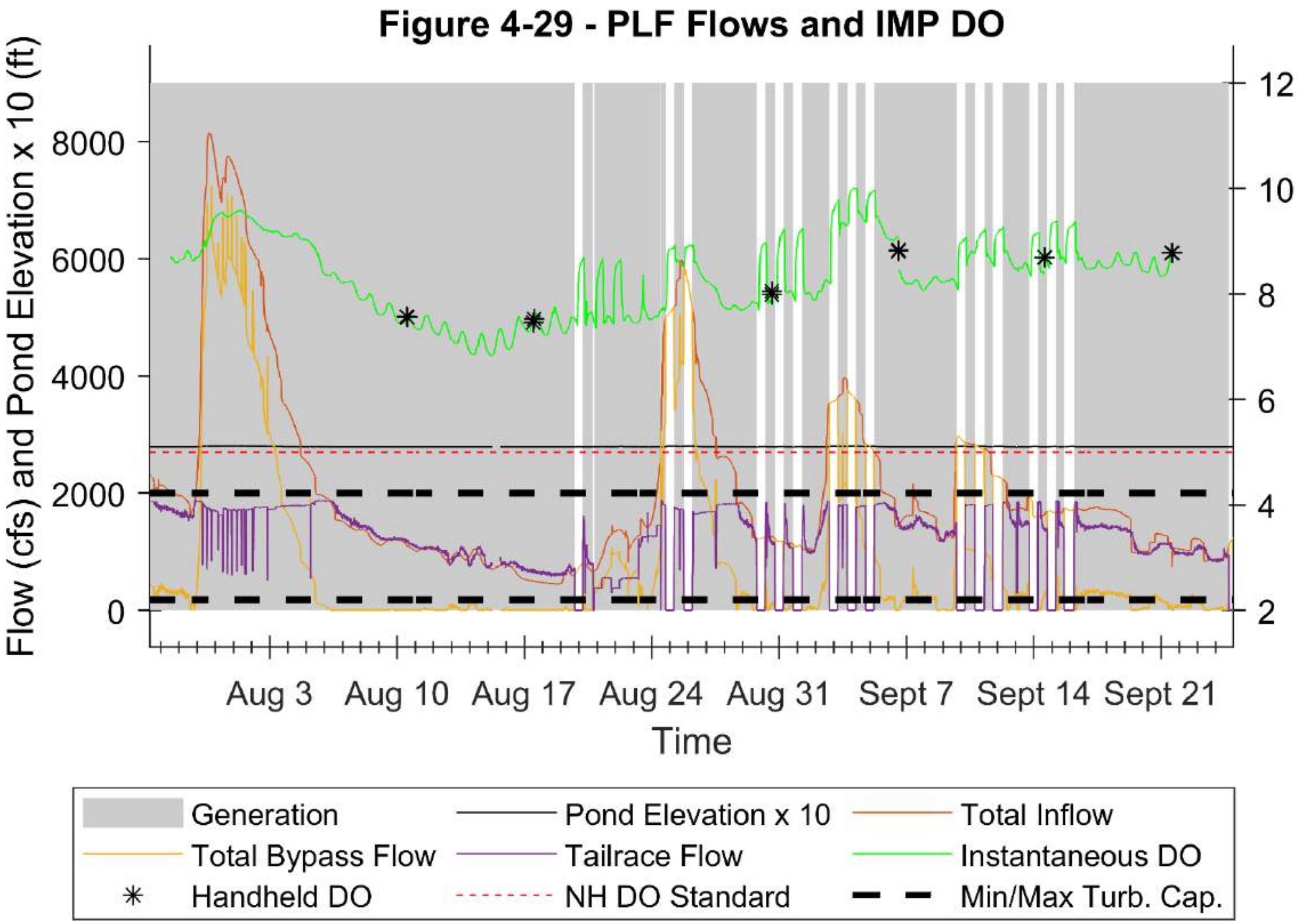


Figure 14–29. PLF-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

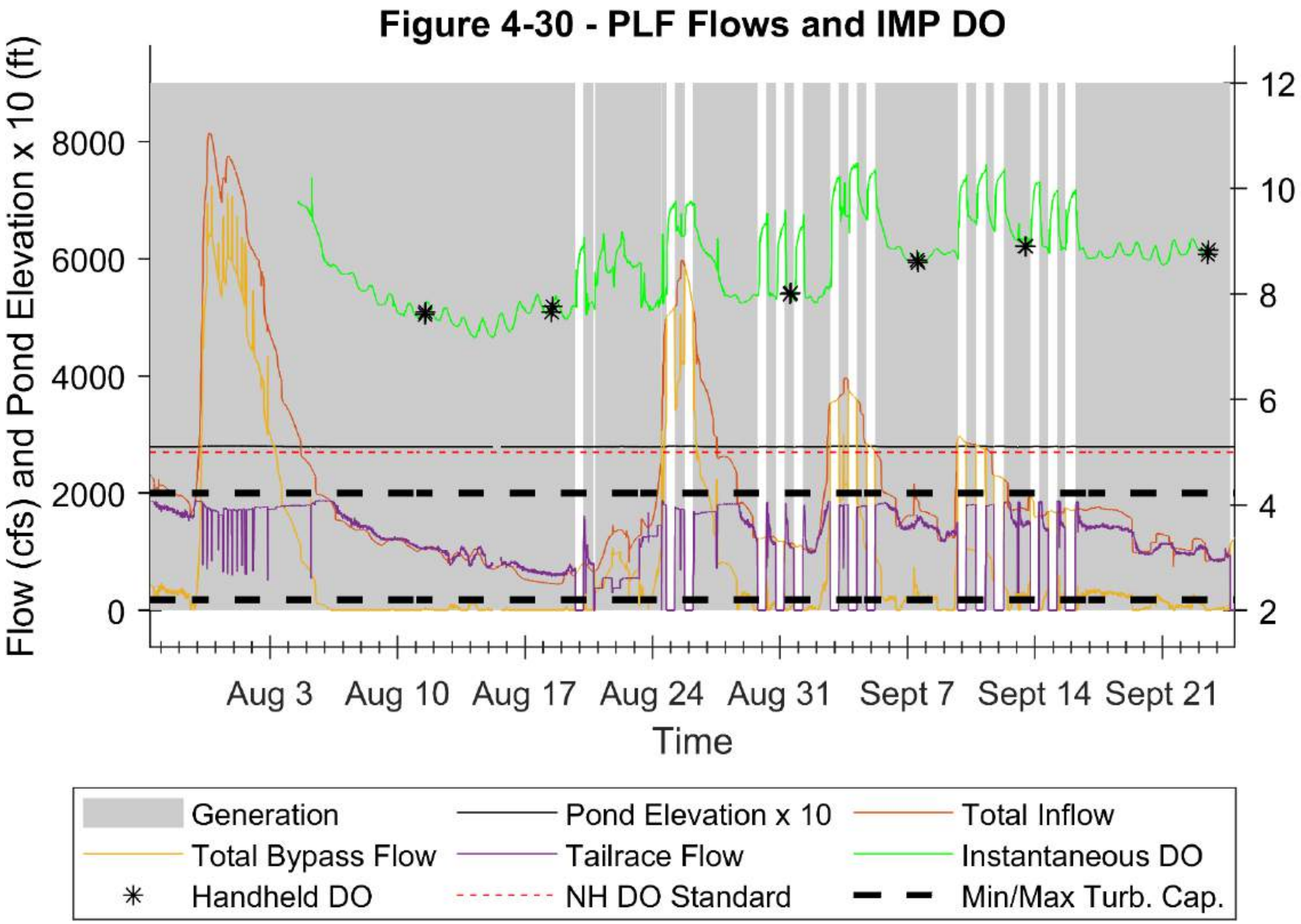


Figure 14–30. PLF-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

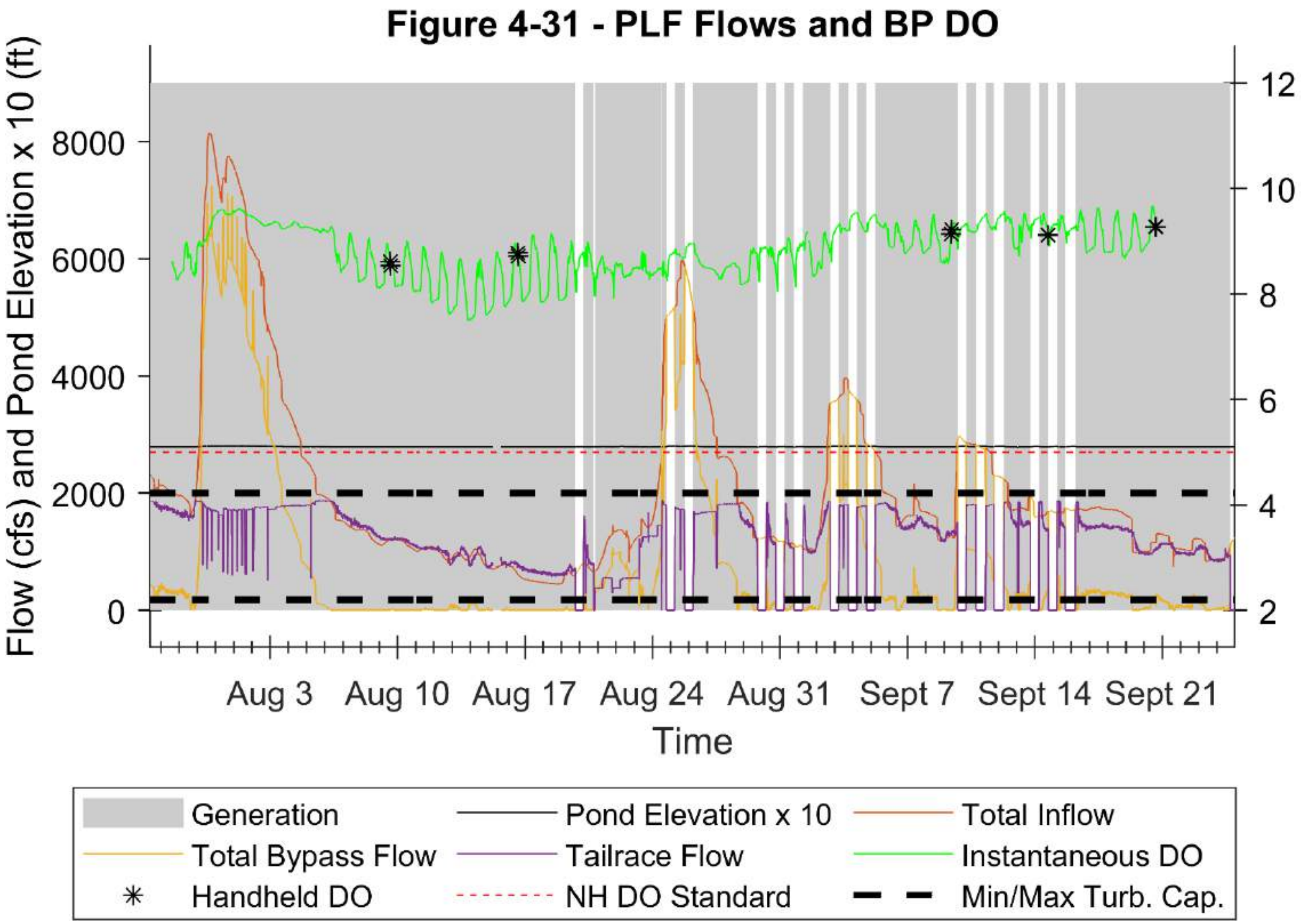


Figure 14–31. PLF-BP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs), datasonde DO (mg/L), and handheld meter DO observed during 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

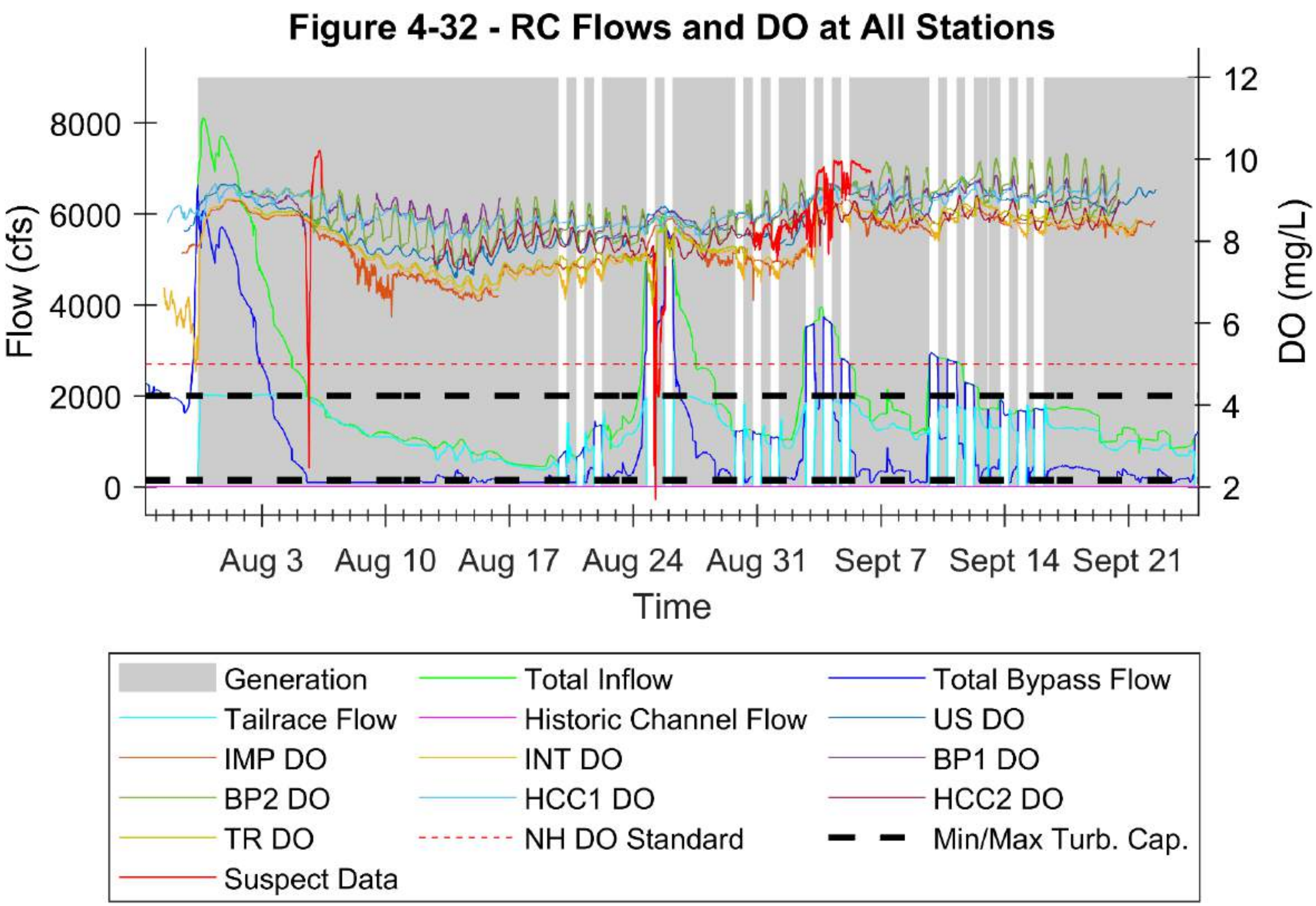


Figure 14–32. Rolfe Canal. Datasonde DO (mg/L) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. NH instantaneous DO water quality standard shown at 5 mg/L. Periods of power generation shaded.

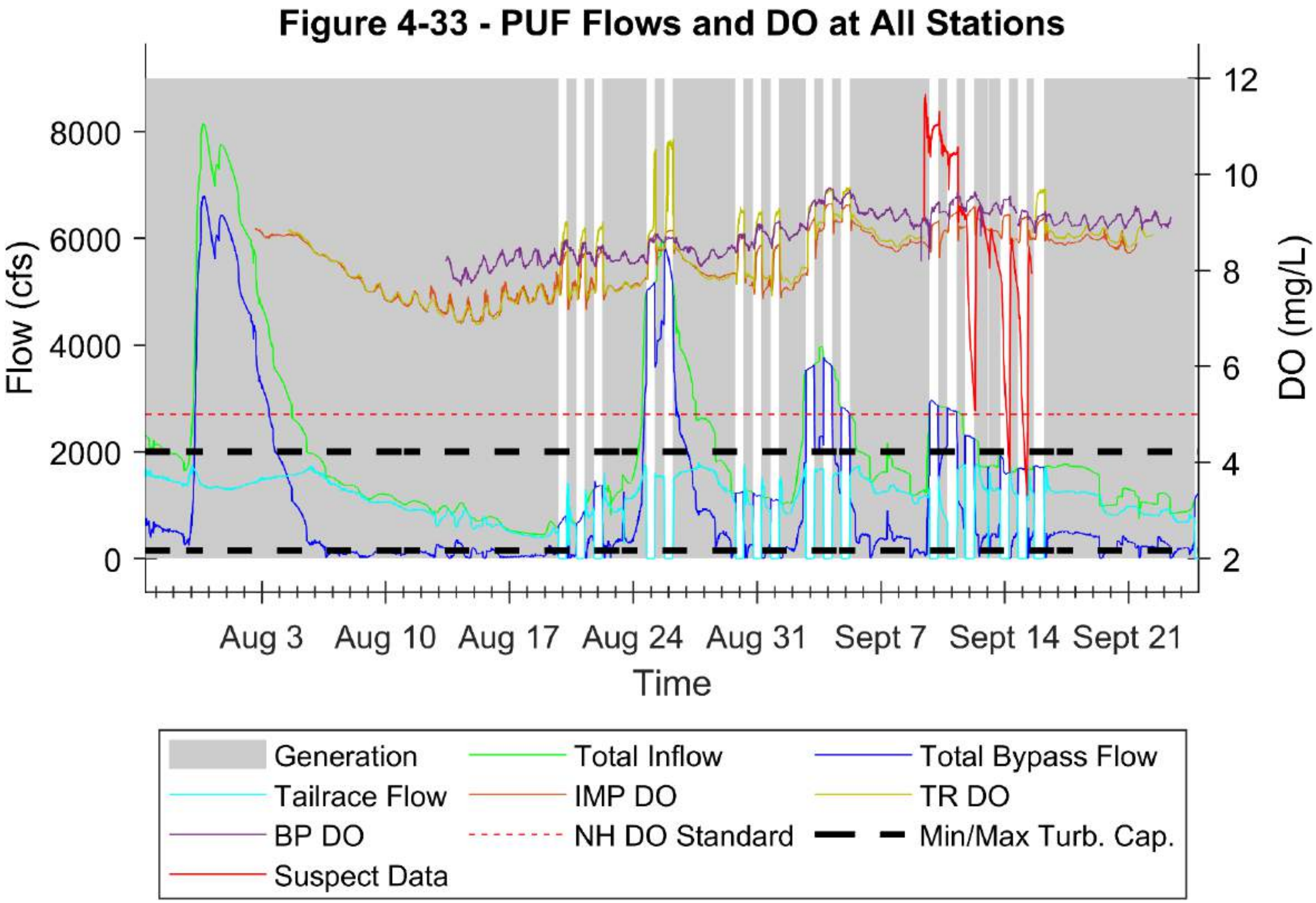


Figure 14–33. Penacook Upper Falls. Datasonde DO (mg/L) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. NH instantaneous DO water quality standard shown at 5 mg/L. Periods of power generation shaded.

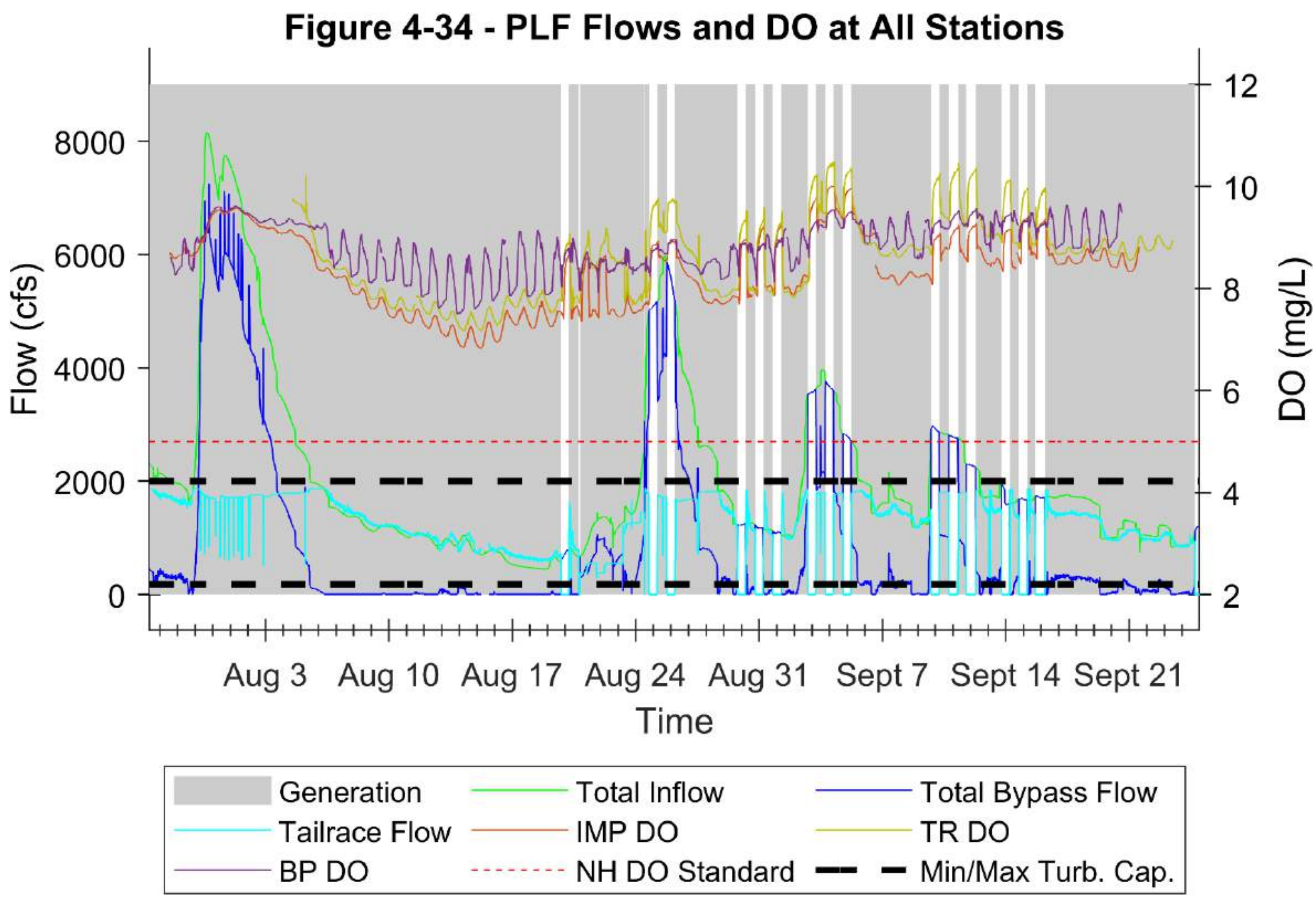


Figure 14–34. Penacook Lower Falls. Datasonde DO (mg/L) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. NH instantaneous DO water quality standard shown at 5 mg/L. Periods of power generation shaded.

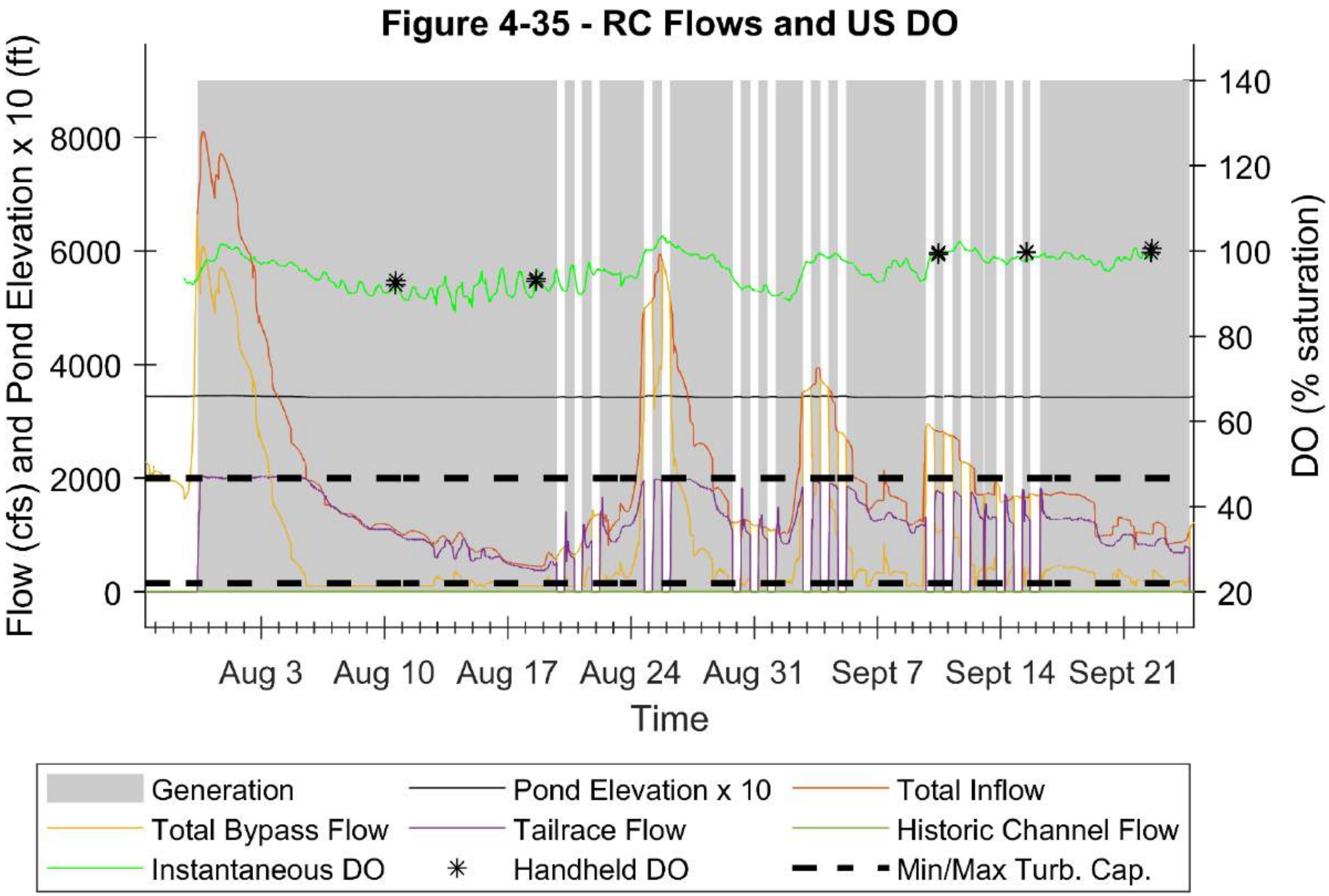


Figure 14–35. RC-US. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

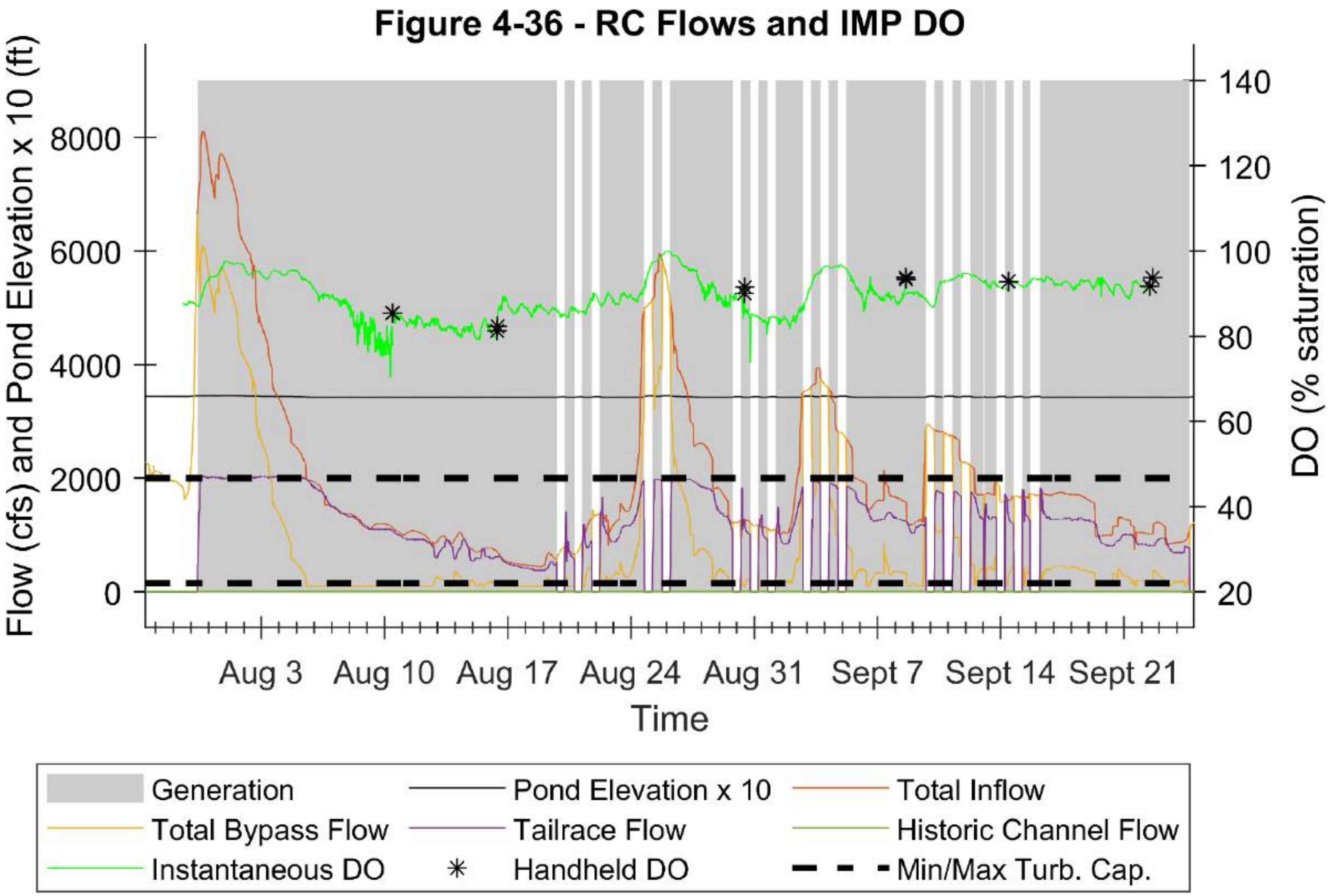


Figure 14–36. RC-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

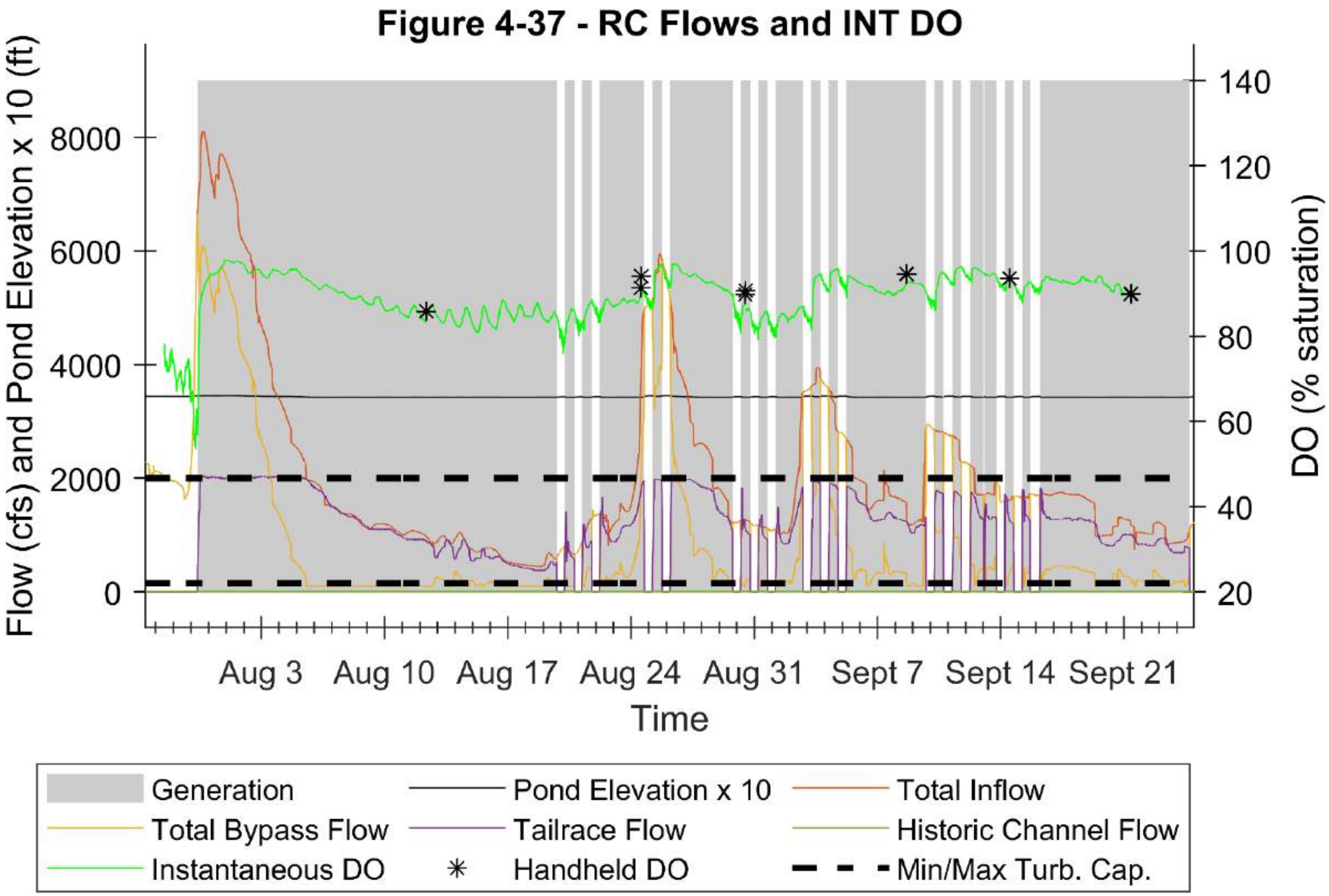


Figure 14–37. RC-INT. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

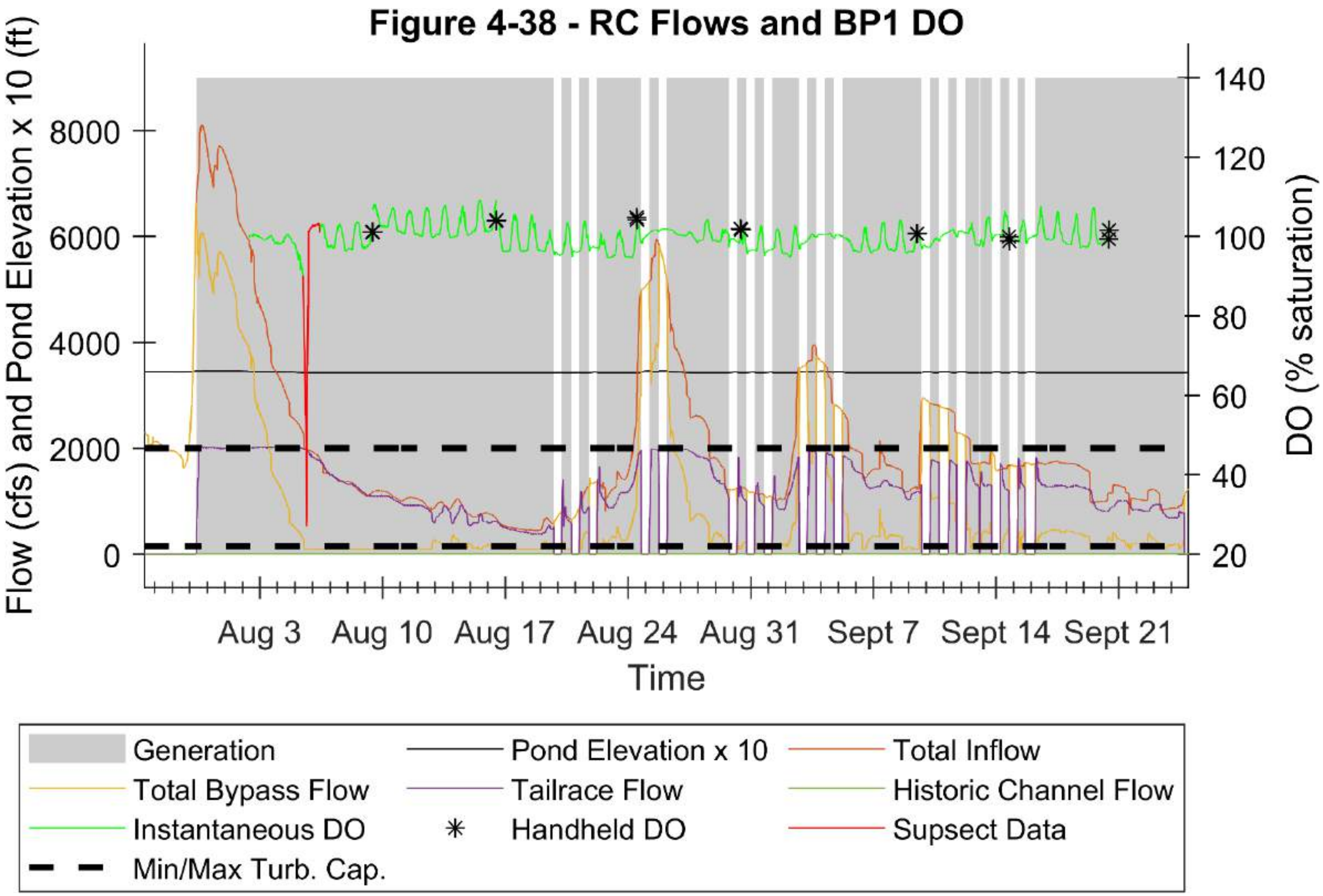


Figure 14–38. RC-BP1. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

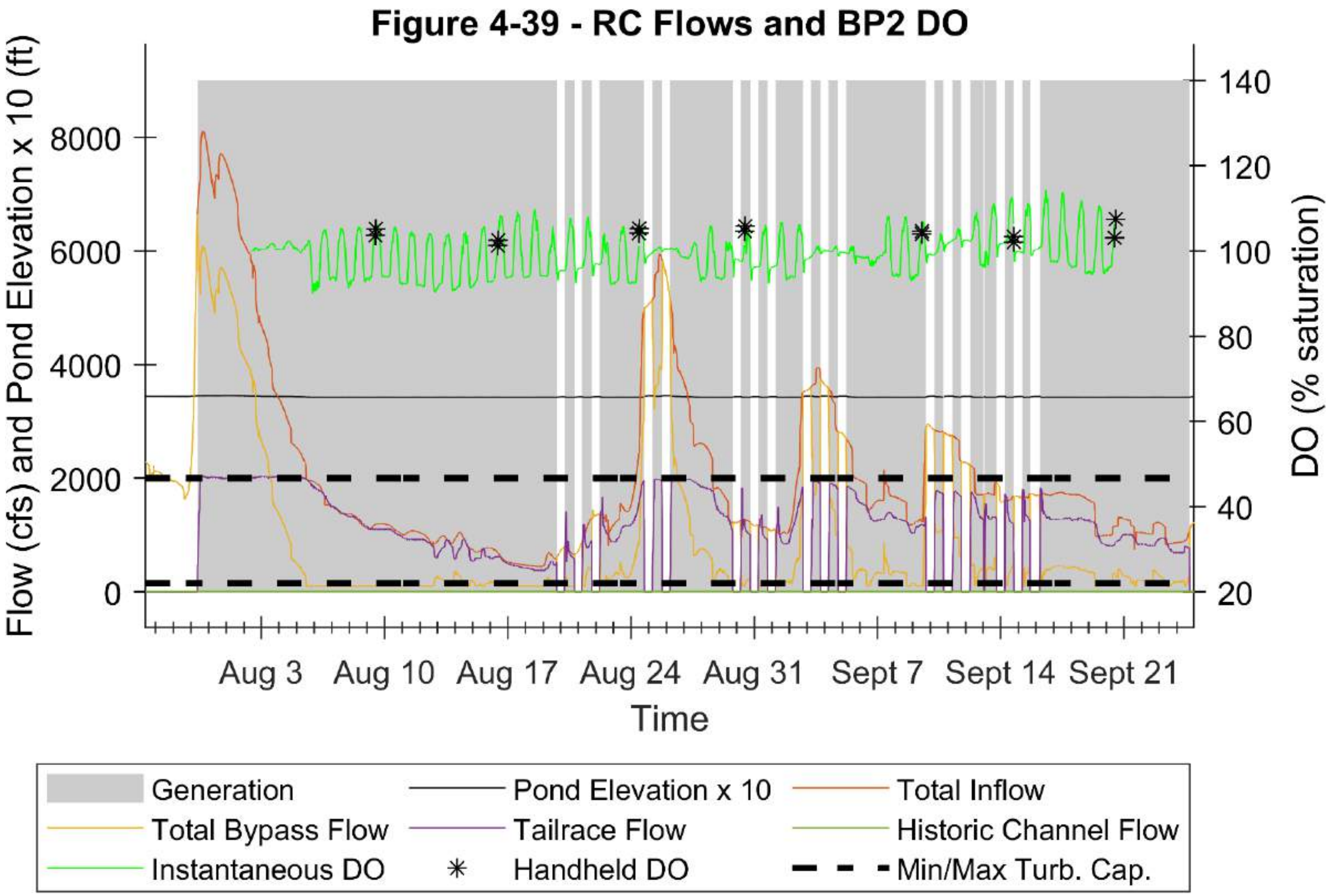


Figure 14–39. RC-BP2. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

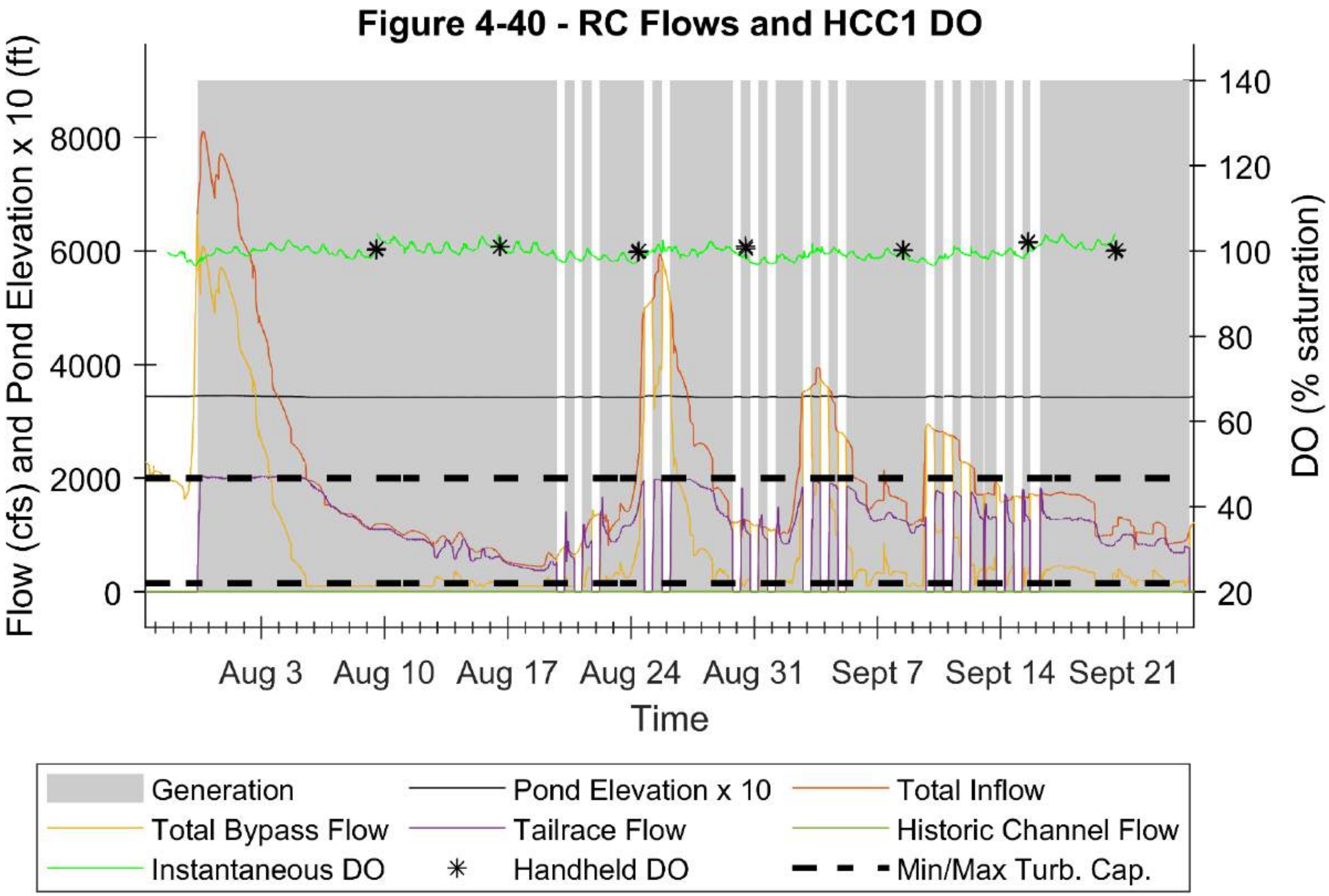


Figure 14–40. RC-HCC1. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

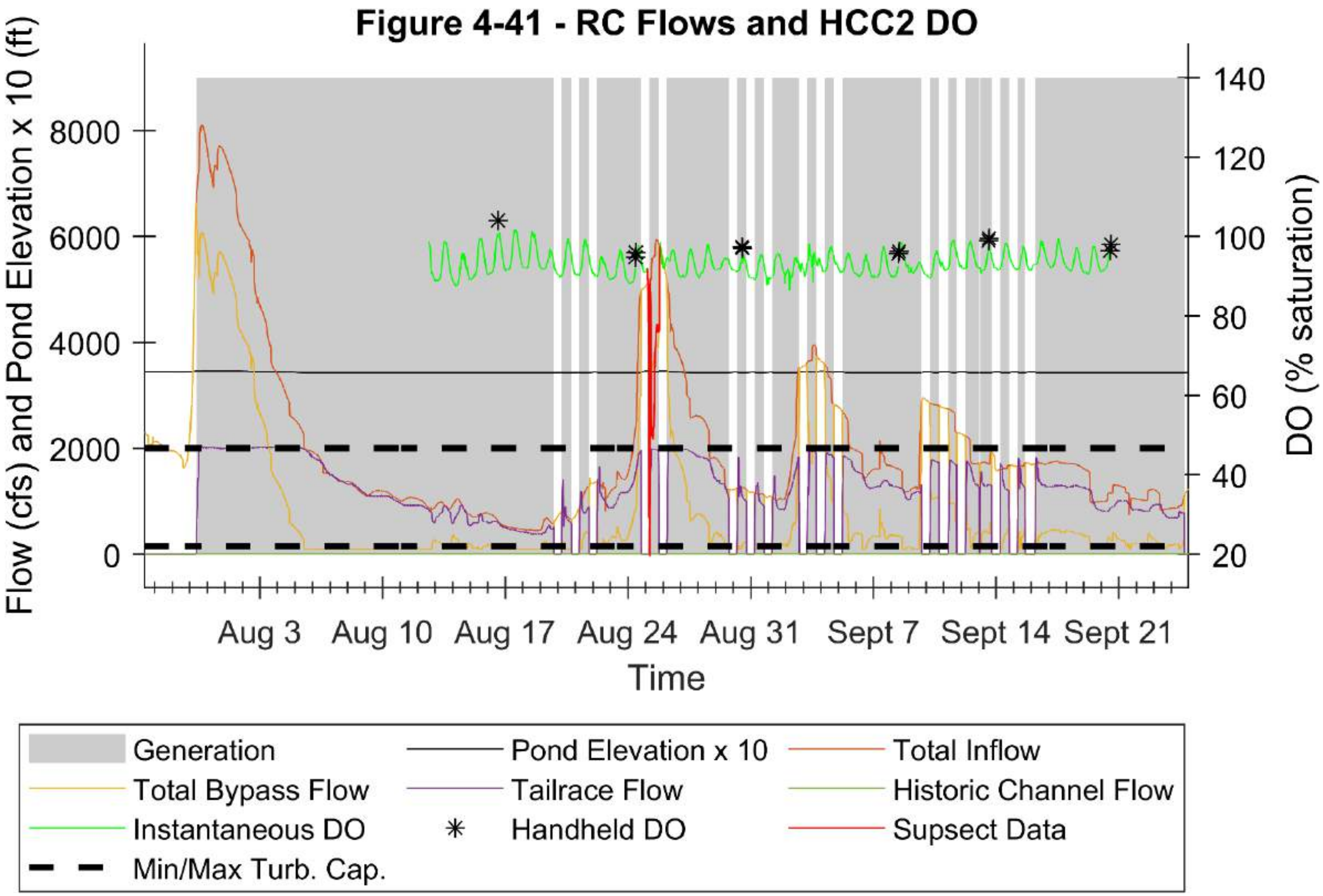


Figure 14–41. RC-HCC2. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

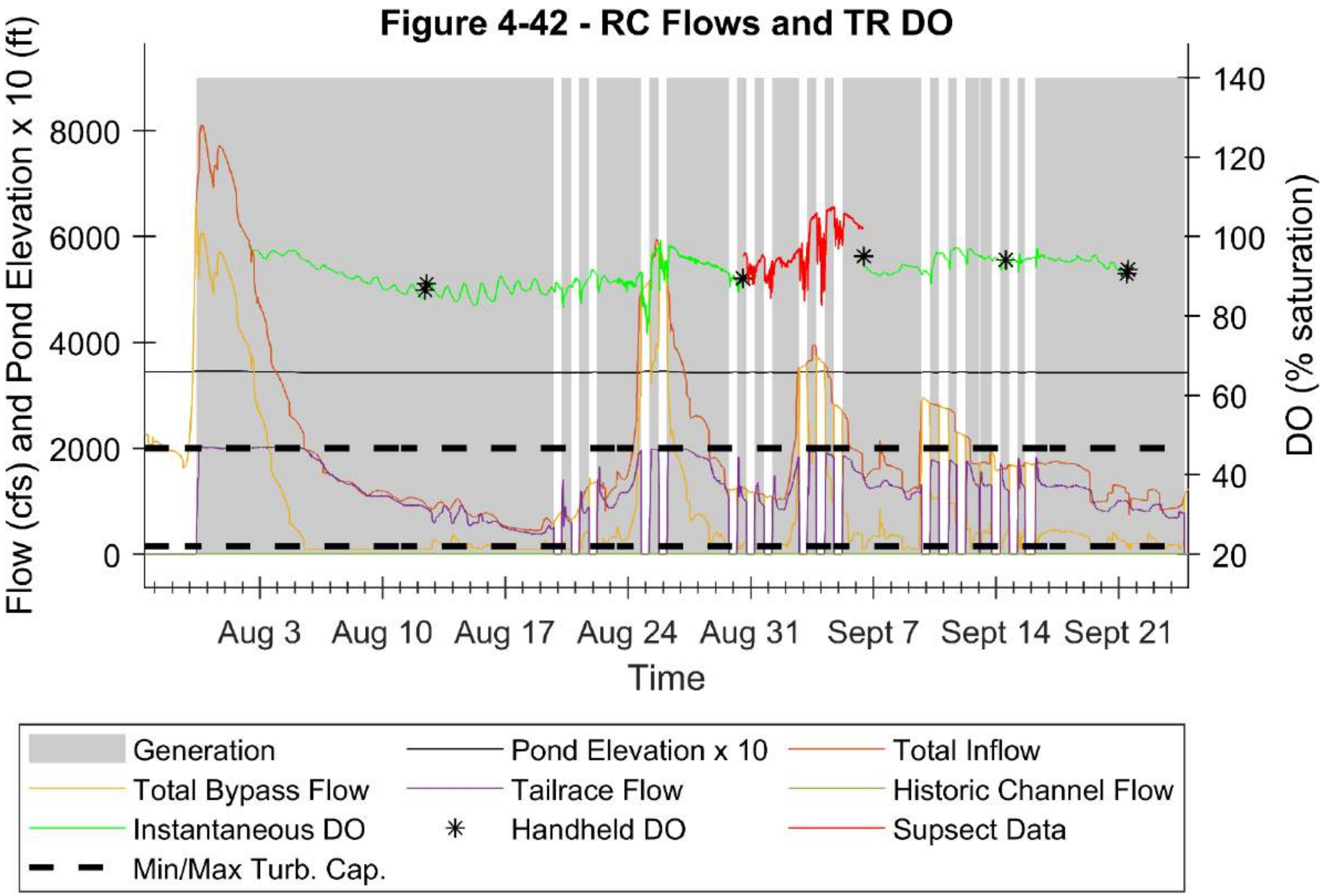


Figure 14–42. RC-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

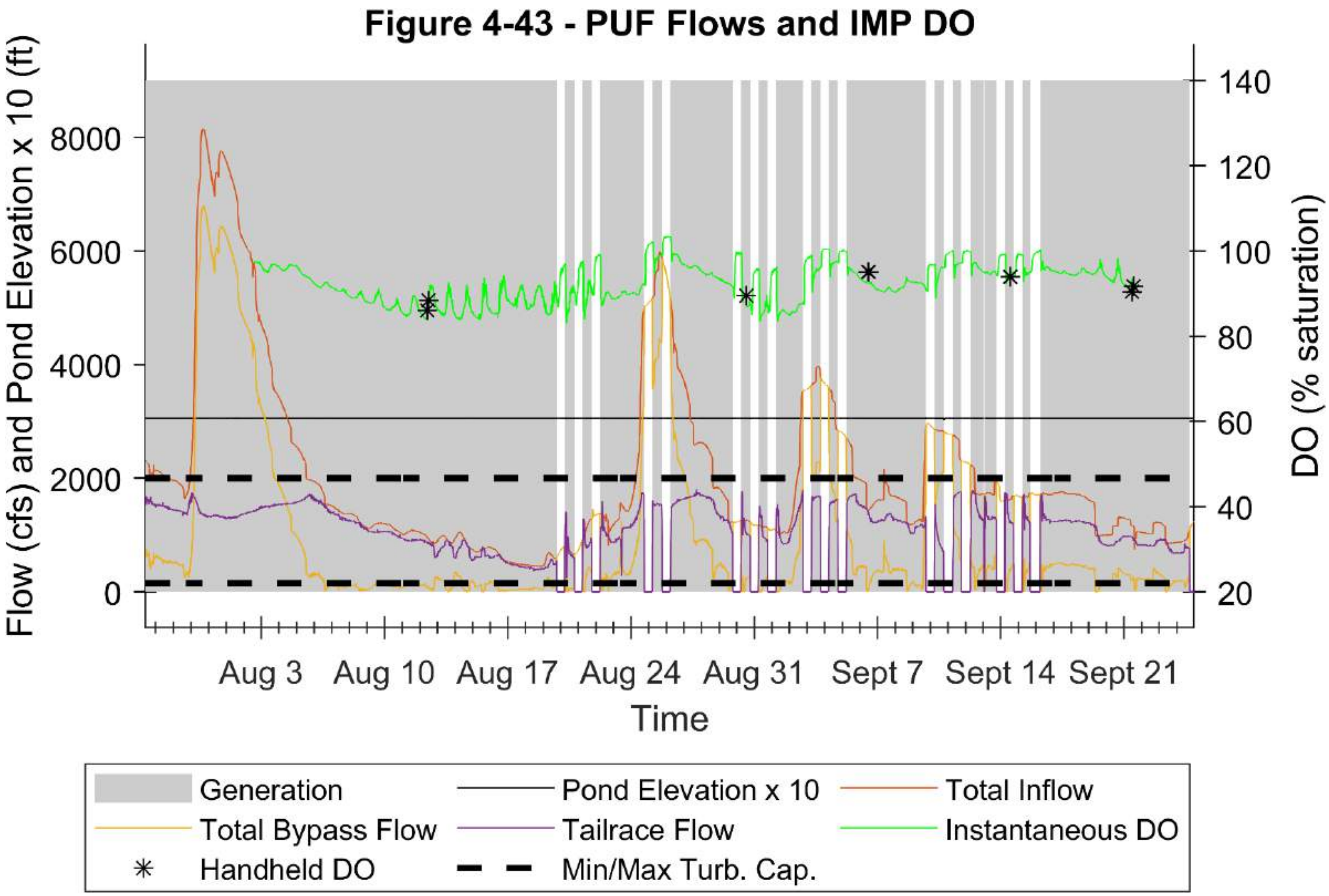


Figure 14–43. PUF-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

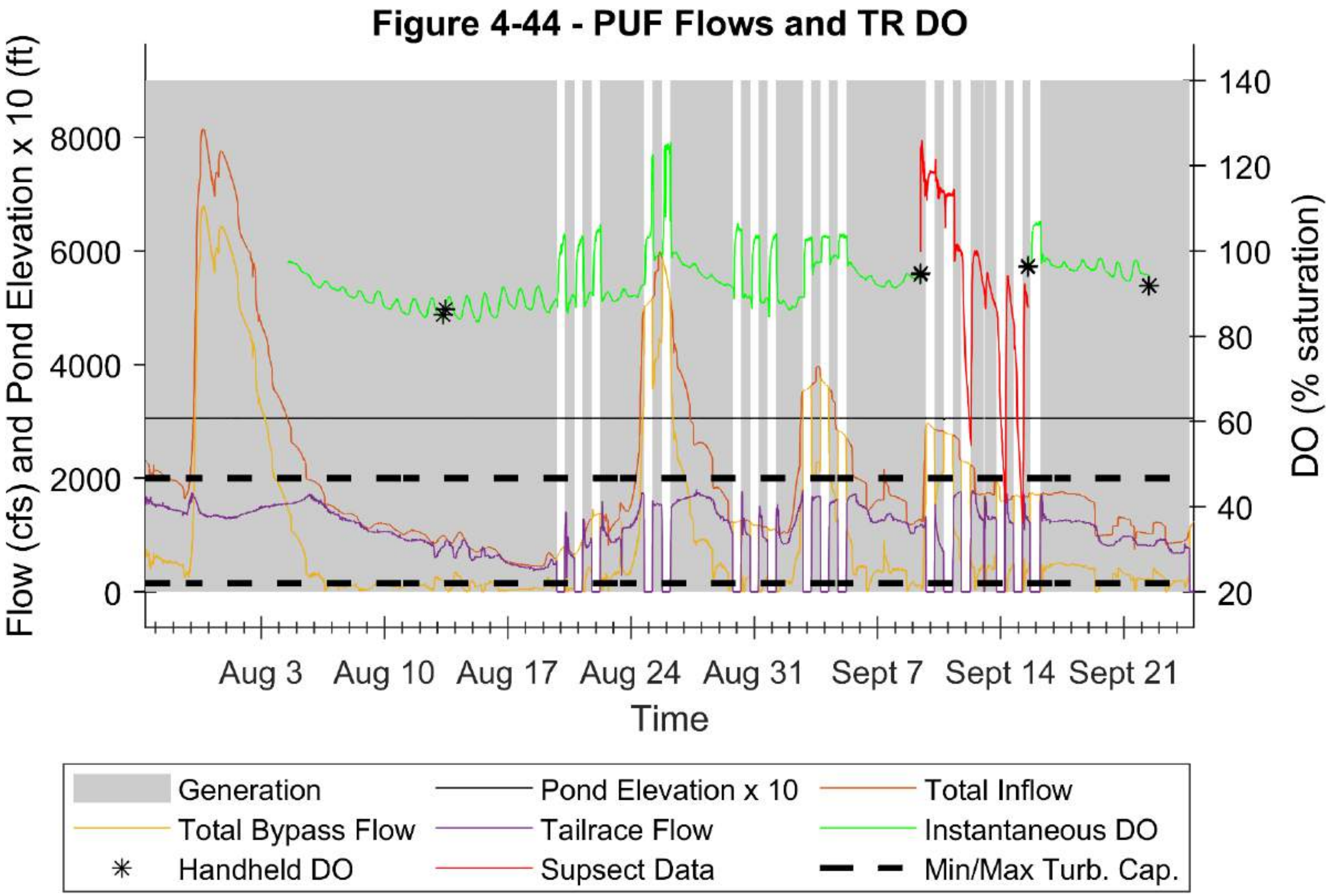


Figure 14–44. PUF-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

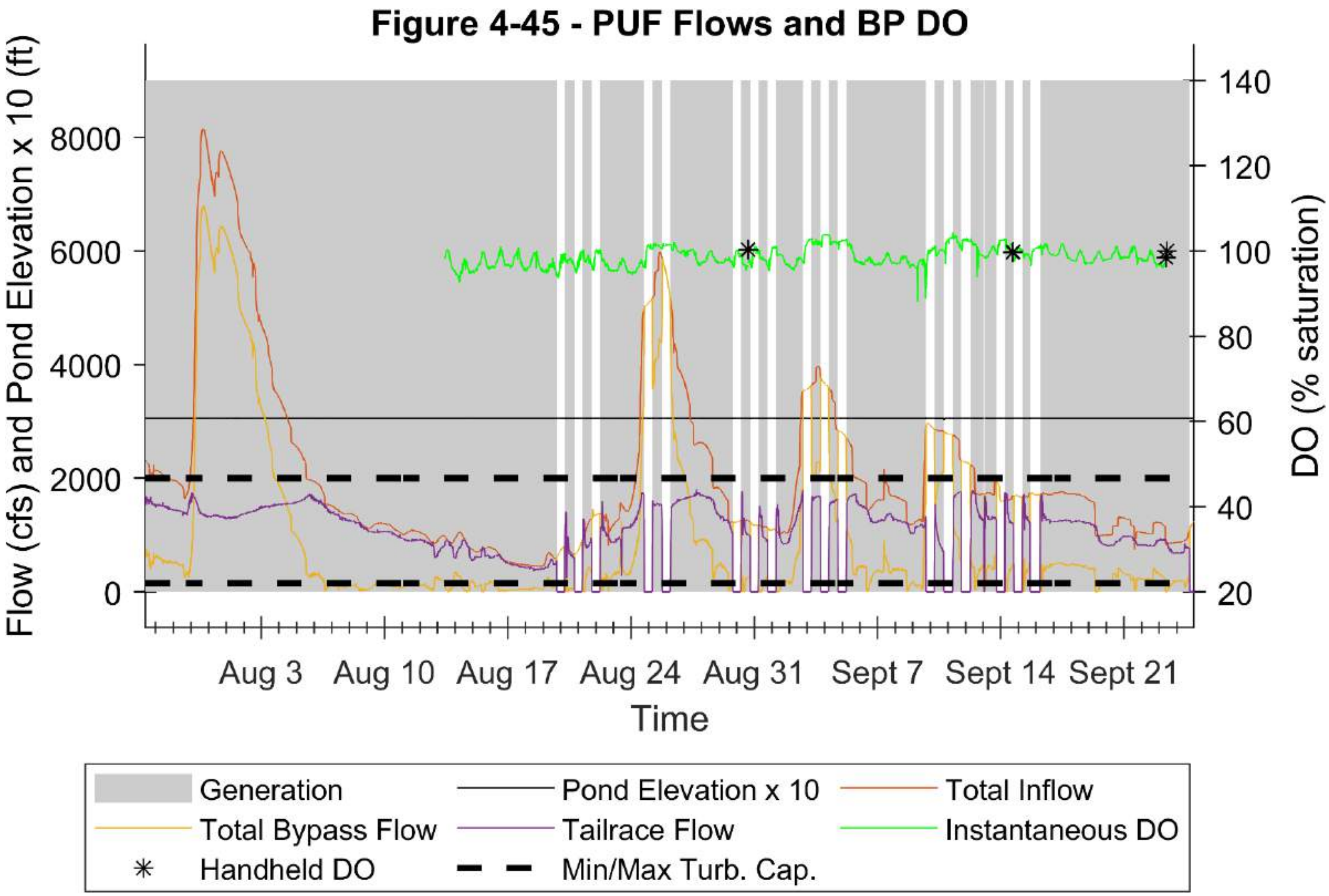


Figure 14–45. PUF-BP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

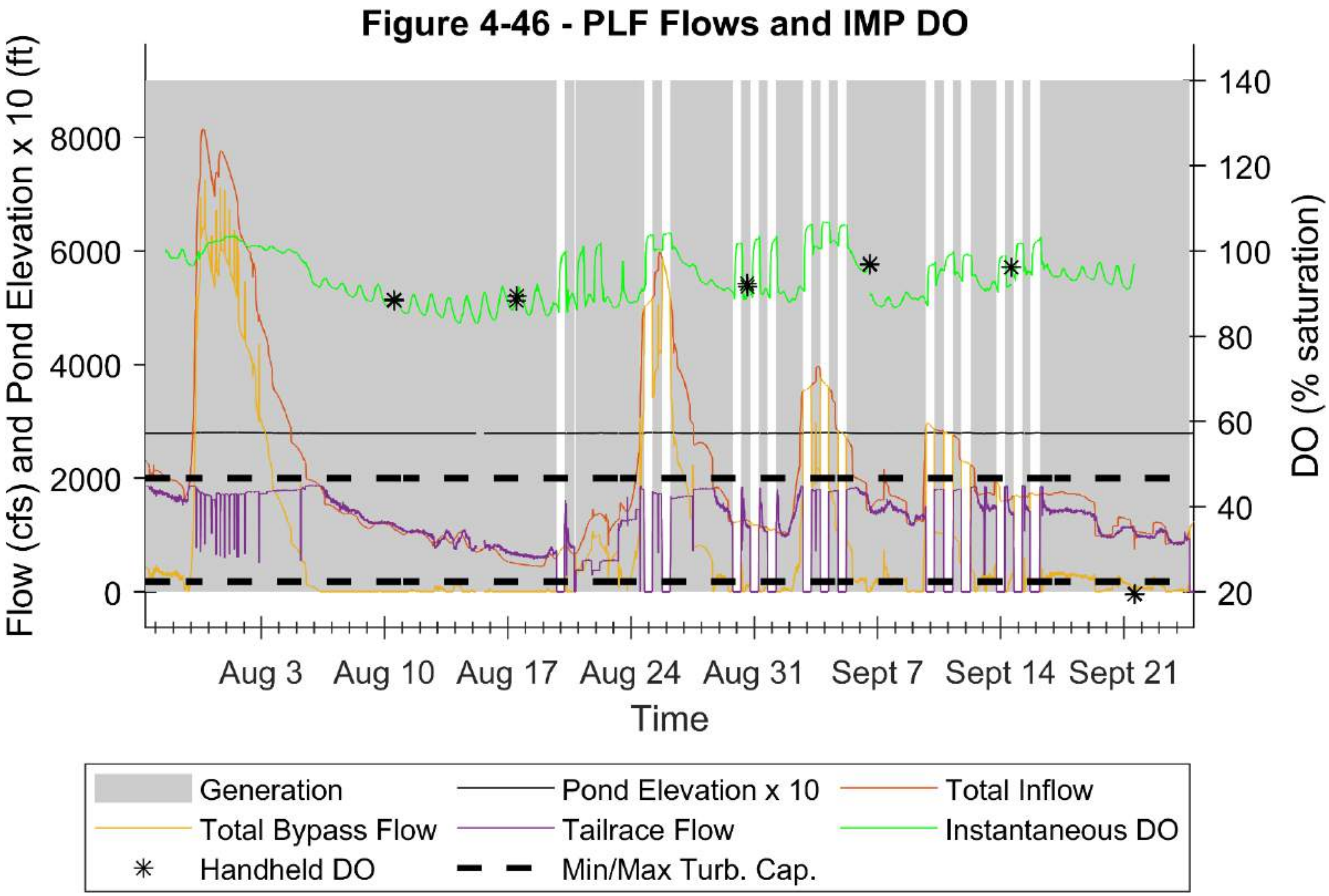


Figure 14–46. PLF-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

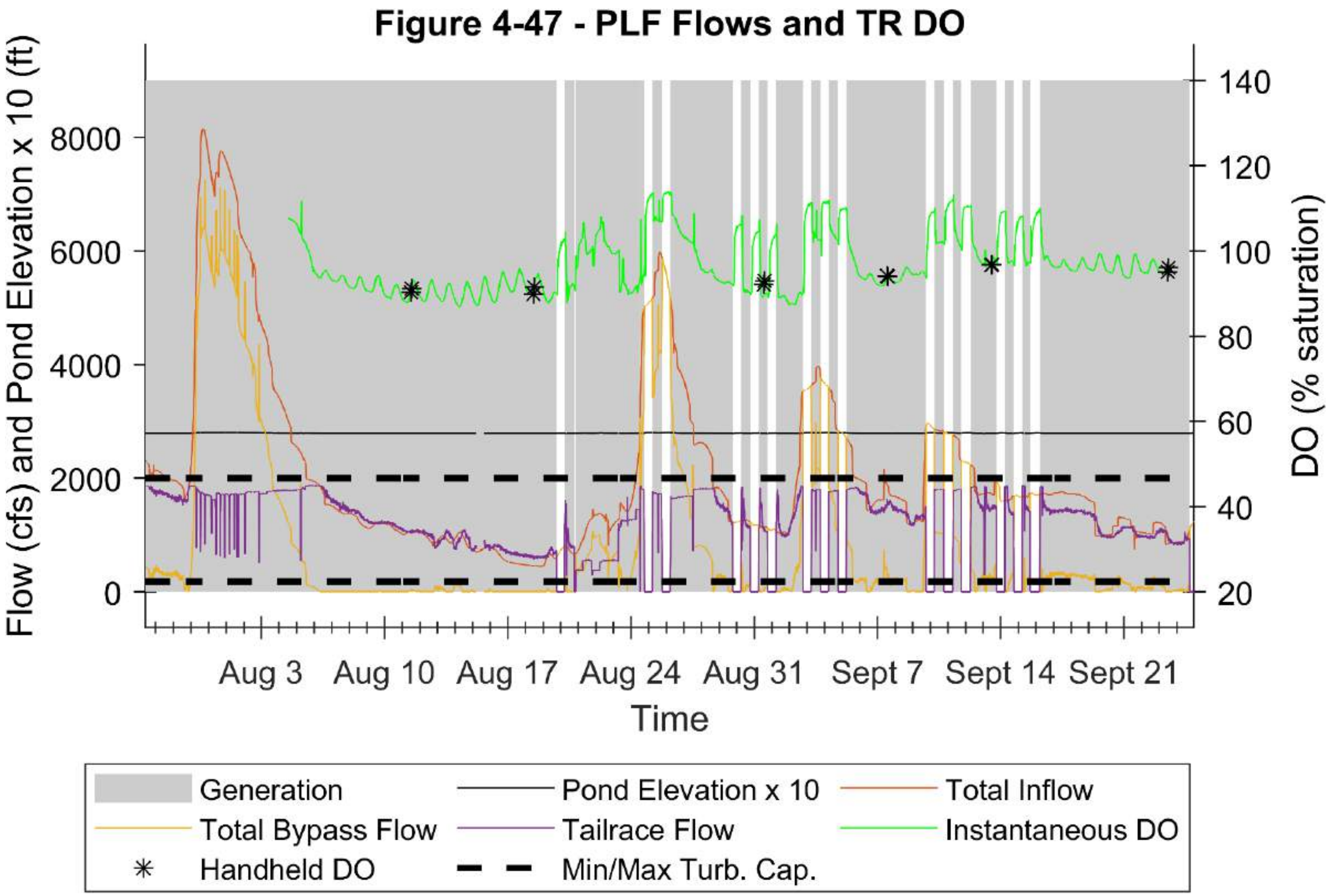


Figure 14–47. PLF-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

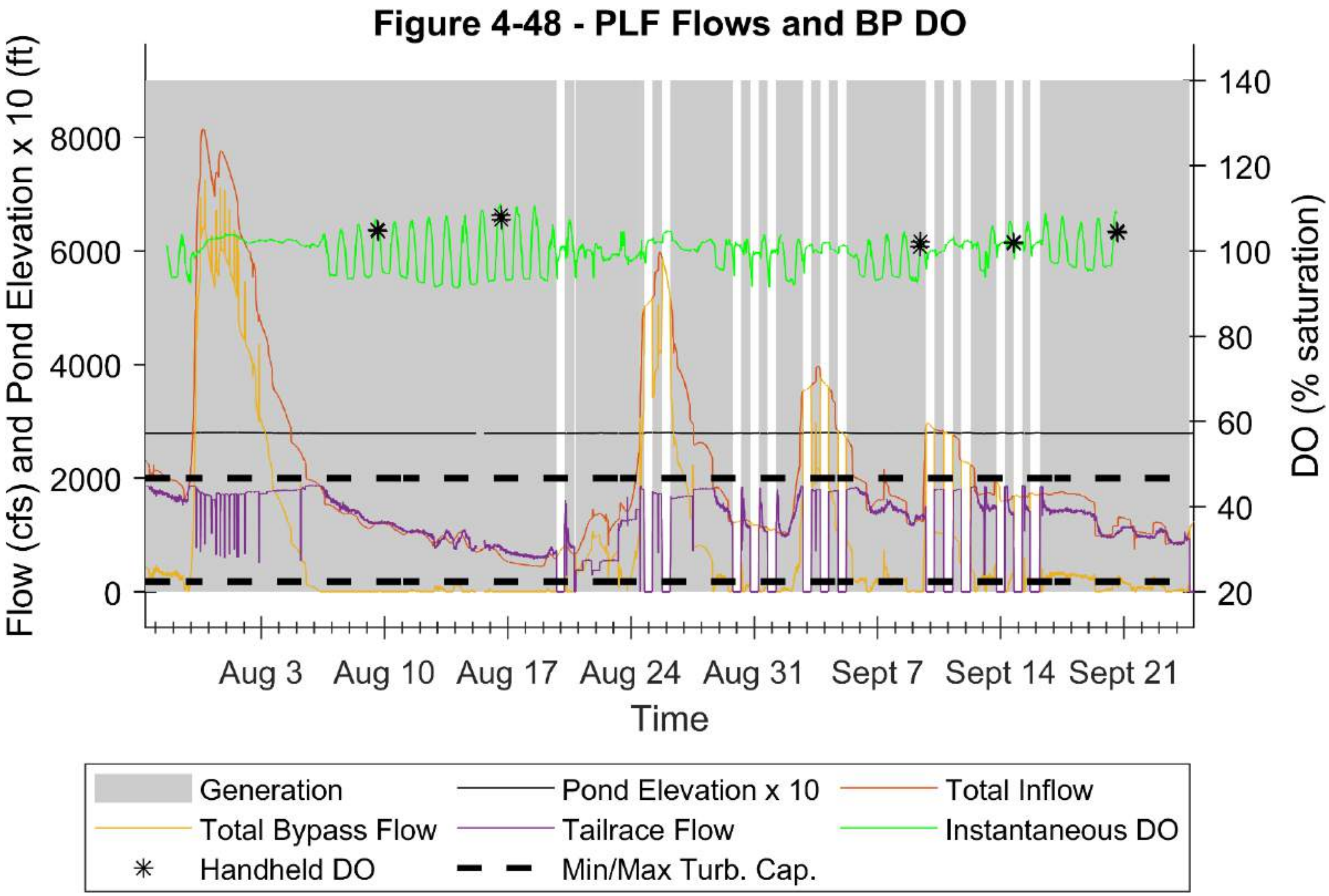


Figure 14–48. PLF-BP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde DO saturation (%) and handheld meter DO saturation observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

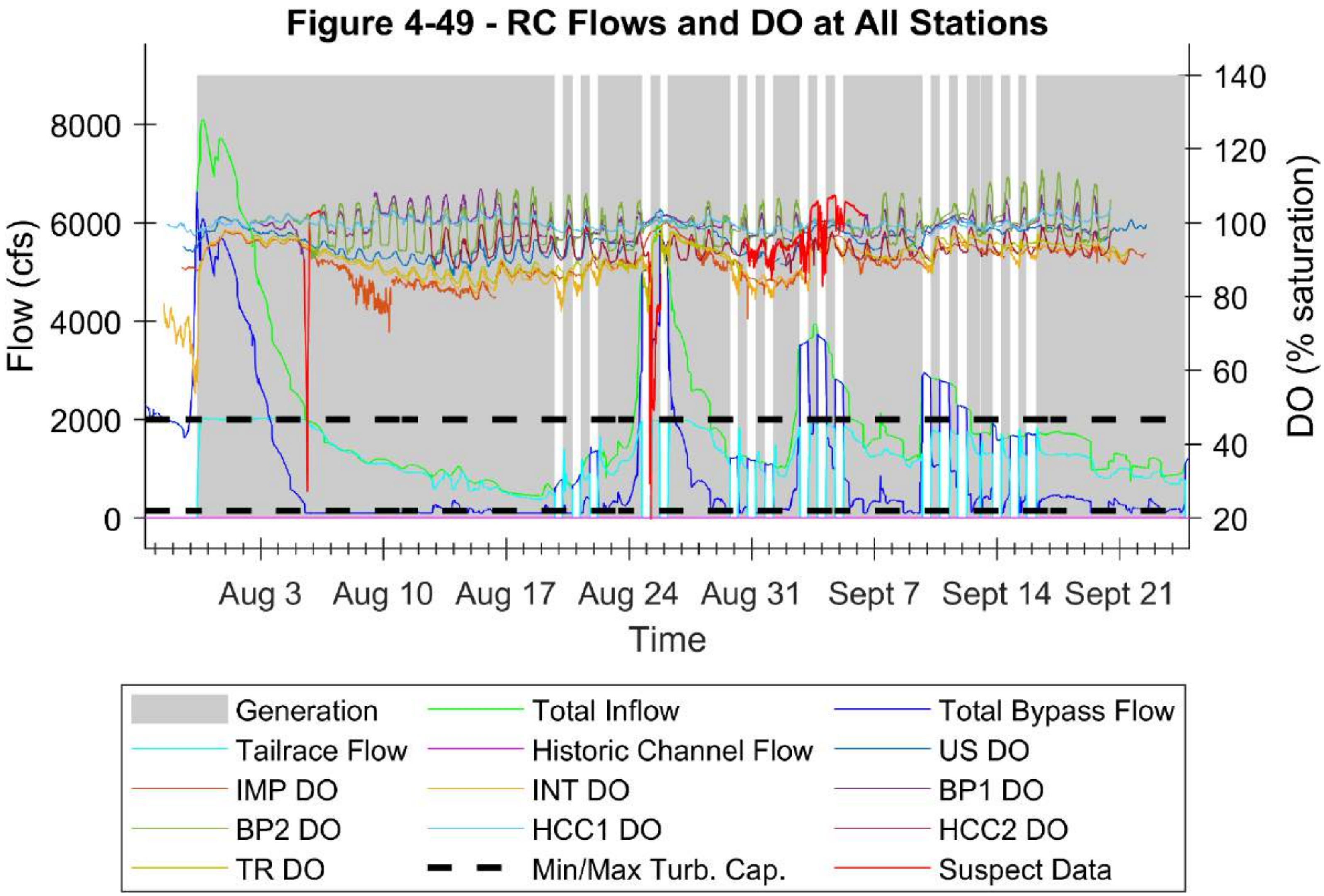


Figure 14–49. Rolfe Canal. Datasonde DO saturation (%) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

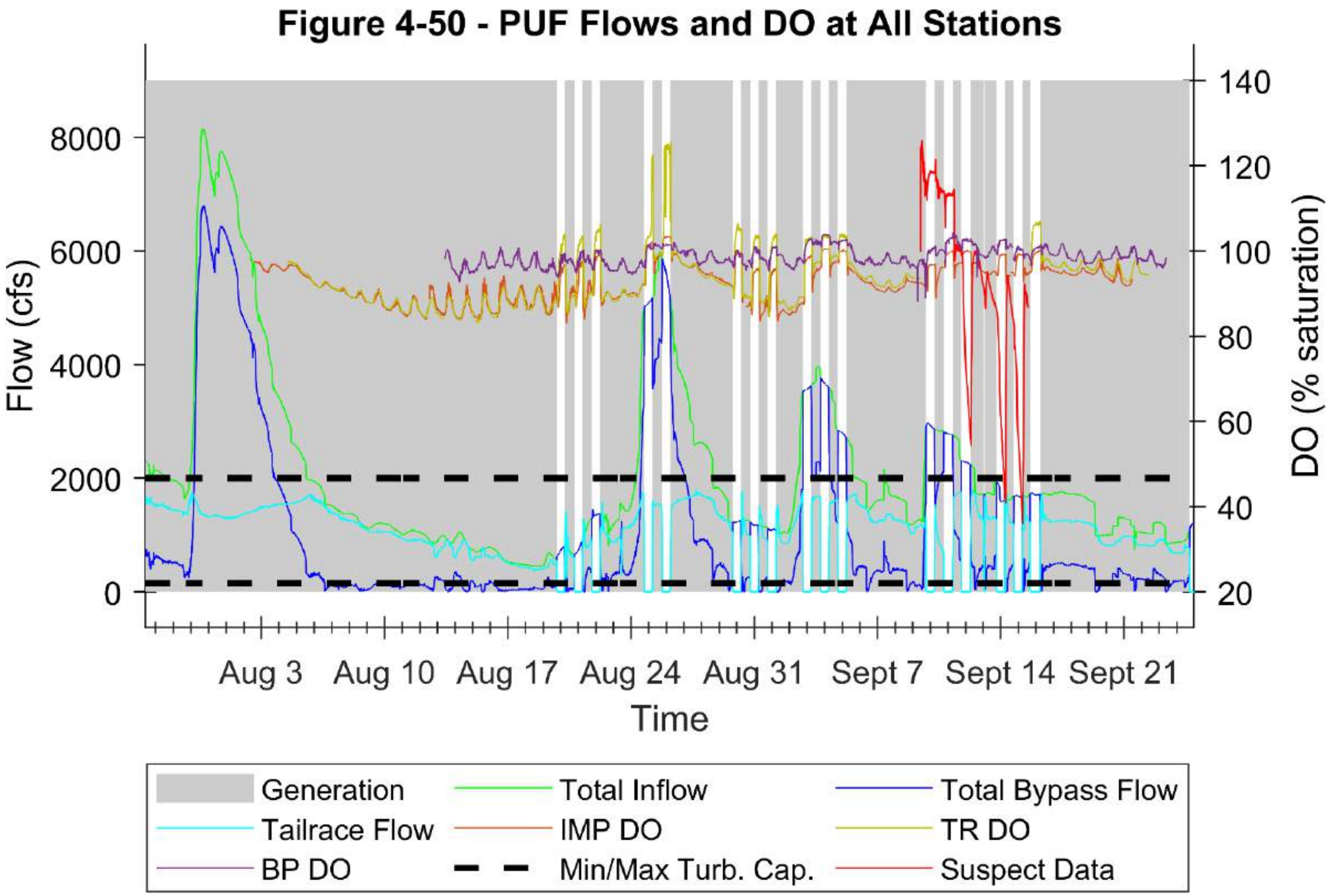


Figure 14–50. Penacook Upper Falls. Datasonde DO saturation (%) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

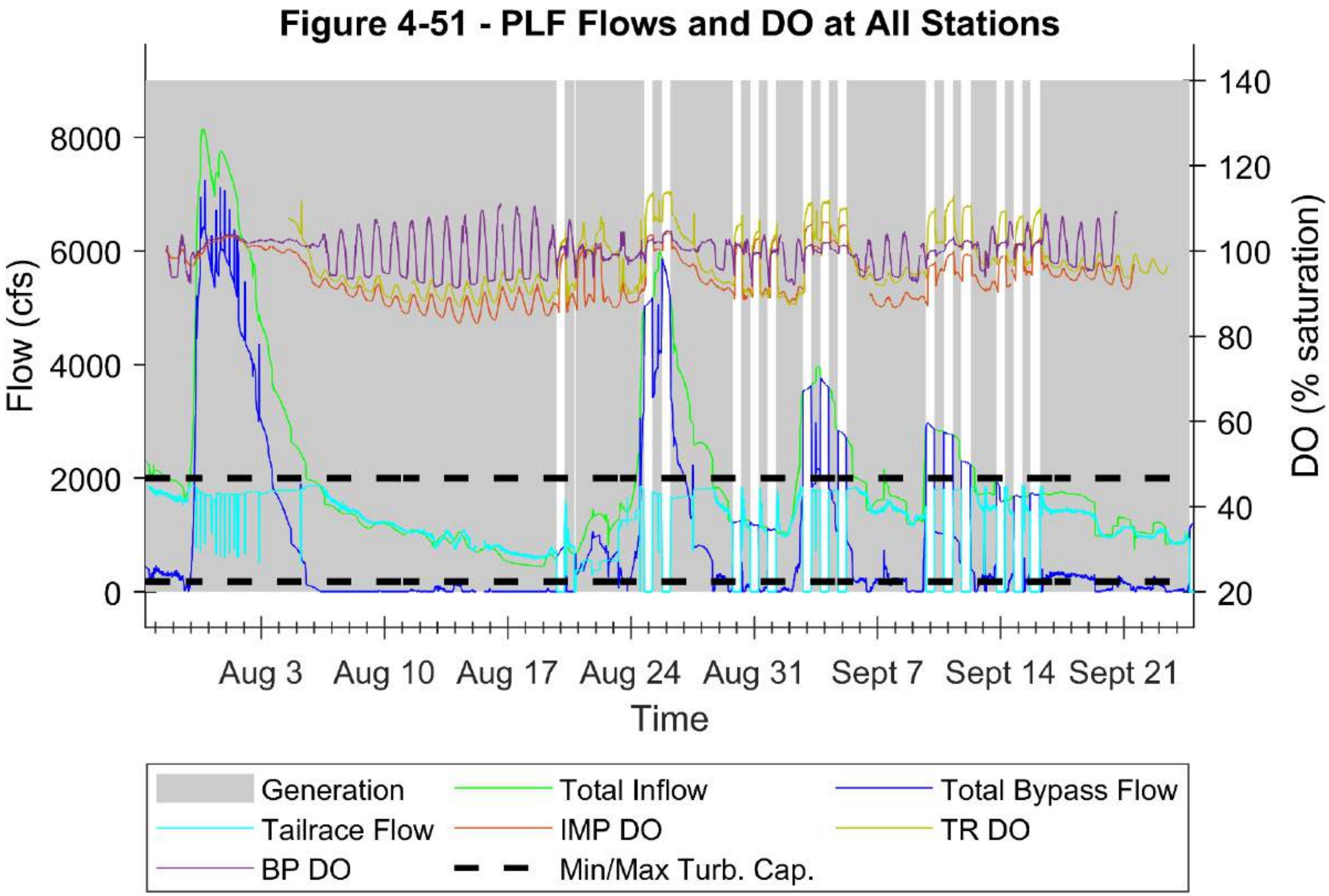


Figure 14–51. Penacook Lower Falls. Datasonde DO saturation (%) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

18 pH

PH was measured at 13 of the 14 continuous monitoring stations (no logger could be obtained from the manufacturer for the additional monitoring station RC-HCC2) for the eight week study period, concurrent with the temperature and DO monitoring, and included periods of variable flow, temperature, and operating conditions as presented in Figures 5-52 through 5-68 and Table 5-5. PH data at RC-BP2 was only completed for the period 8/2/21 through 8/12/21 as the logger was moved to the PUF-BP station after that date due to the lack of sufficient loggers to instrument all of the stations (there was a lack of available instruments from the manufacturer in 2021 due to supply chain shortages). There were six separate instances of instrument performance issues where pH data were flagged as suspect data and omitted from the final dataset. Suspect data are presented in the pH figures but are included as a separate time series for clarity (Suspect data are also presented in Appendix E). A summary of the suspect data removed from the final data set is highlighted in Table 5-6.

PH varied from 6.2 – 7.7 s.u. across all continuous monitoring stations during the study with median values ranging from 6.5 at multiple stations to 6.9 at PLF-BP. There were multiple exceedances of the lower pH standard for Class B waters of 6.5; at all stations except RC-BP2 (for which there is only a 10 day record) and RC-HCC1. It is worth noting the reference station (RC-US) also had multiple exceedances of the lower pH standard indicating that low pH may be due to natural causes and/or is a watershed-wide water quality issue. There were no documented exceedances of the higher pH standard for Class B waters of 8.0 (there were pH values in excess of 8.0 s.u. at Station PLF-BP; however, those data were determined to be invalid due to the failure of a QC reading by a large margin). Slightly higher average pH values (by 0.2-0.4 s.u.) were documented at the Project bypass reaches and the RC historic canal channel compared to other stations.

PH varied over the study period and exhibited daily patterns, longer term trends, and changes correlated with Project operations. At the upstream station (RC-US) and the RC Impoundment (RC-IMP) and intake (RC-INT) stations, pH patterns were similar and followed a natural regime with little direct effect from Project operations. At these stations, pH increased with decreasing flows on the recession leg of a large flow event in early August, rising from a low of ~6.2 s.u. to a peak of ~ 6.7 s.u., coinciding with the peak of a high flow event in late August, before decreasing again to a minimum of ~6.3 s.u. pH then gradually increased through the remainder of the study period in late September reaching high values of ~6.7. At these three stations, pH was inversely related to flow with high flows tending to correspond with lower pH and receding flows corresponding with increased pH. Stations downstream of the RC Project were affected by spill over the dam, generation flows, and, at the historic canal channel, diversion of flows at a relatively constant rate, which altered the pH patterns compared to the stations located on the upstream side of the three Projects. At the bypass stations, there were typically daily pH cycles with a rise of 0.1-0.3 s.u. from a morning minimum to a mid-day maximum followed by a corresponding comparable decrease overnight. The daily pH variations were greatest during minimum flow periods and were greatly reduced during spill periods. The RC-HCC1 station also exhibited similar daily pH cycles with daily increases/decreases of ~0.1 s.u. throughout most of the study period. At the tailrace and impoundment station below the RC Project (i.e. RC-TR, PUF-IMP, PUF-TR, PLF-IMP, and PLF-TR) there was some evidence of the daily pH cycles; however, the magnitude was smaller, typically 0.1 s.u. or less and other pH patterns related to operations effects were more apparent.

At the PUF and PLF impoundment and tailrace stations there was evidence of changes in pH corresponding with Project operations that was similar to the effects on DO previously described. When generation was interrupted, pH exhibited a step change increase of 0.2-0.5 s.u. increase at these four stations followed by a similar step change decrease when power generation resumed. In the PUF and PLF bypass reaches, a decrease in pH of ~0.2 s.u. was documented when generation was interrupted and spill to the bypass initiated, although the pattern was complex and more variable than the pH response seen in the impoundment and tailrace reaches. The pattern of step increases/decreases with interrupted and resumed generation indicates an effect on downstream waters and likely represents a shift from a tailwater source to a bypass source and back to a tailwater source as generation stops and resumes.

Table 14–5. Summary of continuous monitoring pH data

	RC-US	RC-IMP	RC-INT	RC-BP1	RC-BP2	RC-HCC1	RC-HCC2	RC-TR	PUF-IMP	PUF-TR	PUF-BP	PLF-IMP	PLF-TR	PLF-BP
	pH (s.u.)													
Min	6.2	6.2	6.2	6.4	6.5	6.6	-	6.4	6.2	6.3	6.5	6.3	6.4	6.4
Max	6.8	6.7	6.8	7.3	7.3	7.1	-	6.8	6.8	7	7.2	7	7.2	7.7
Mean	6.5	6.5	6.5	6.8	6.8	6.9	-	6.5	6.5	6.6	6.9	6.6	6.7	6.8
Median	6.6	6.5	6.6	6.9	6.8	6.9	-	6.5	6.5	6.6	6.9	6.6	6.7	6.9

Table 14–6. Summary of suspect pH data removed from dataset

Continuous Monitoring Station	Suspect Data Period	Comment
RC-US	9/13/21 18:00 – 9/15/21 11:00	Equipment malfunction
RC-BP1	8/5/21 11:15 – 8/6/21 09:30	Logger was likely out of water
RC-TR	9/14/21 14:00 – 9/21/21 10:45	Equipment malfunction
PUF-TR	9/1/21 12:43 – 9/22/21 09:13	Equipment malfunction
PLF-IMP	8/5/21 17:15 – 8/10/21 12:15	Equipment malfunction
PLF-BP	8/9/21 15:30 – 8/16/21 14:15	Failed QC check likely caused by instrument fouling

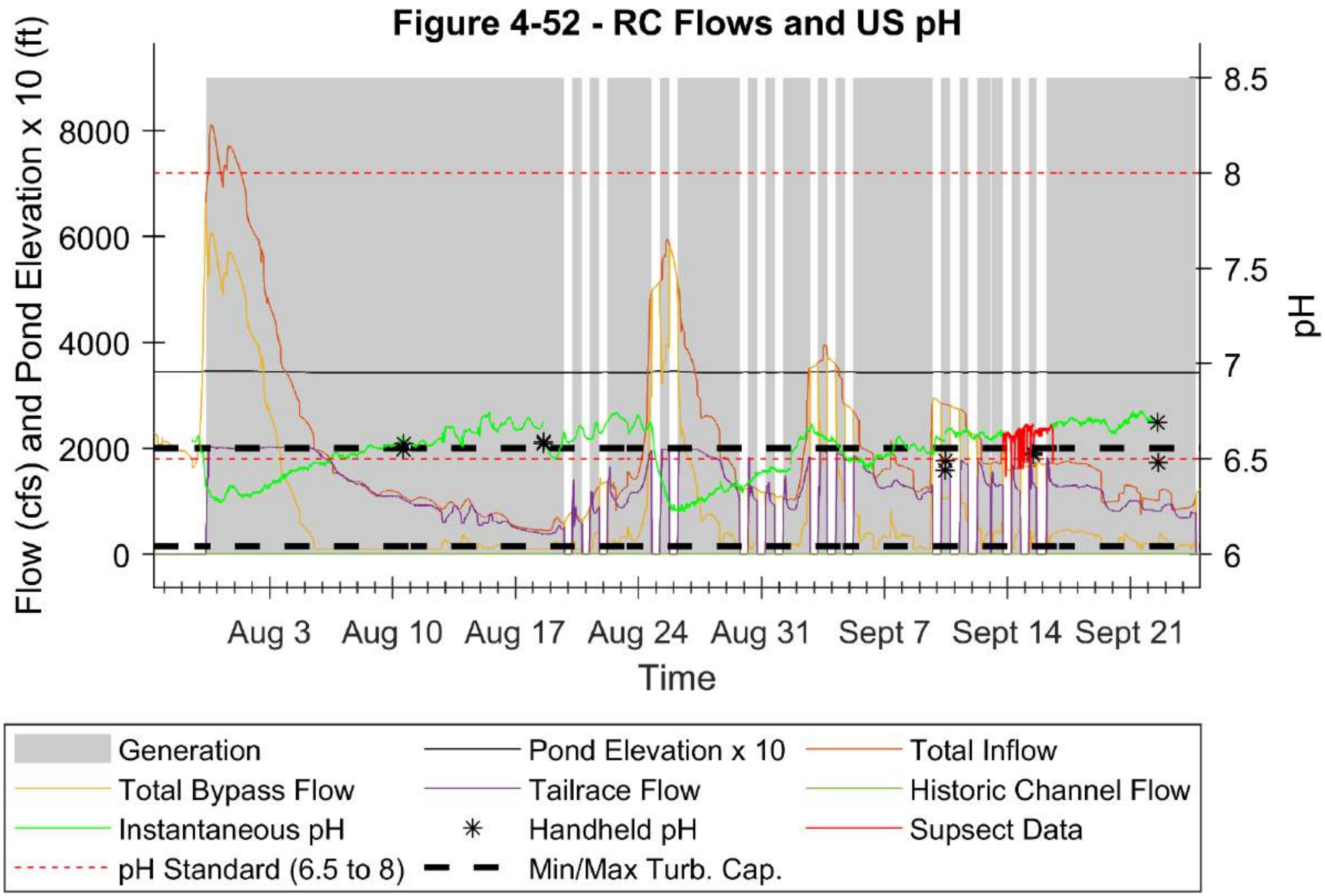


Figure 14–52. RC-US. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

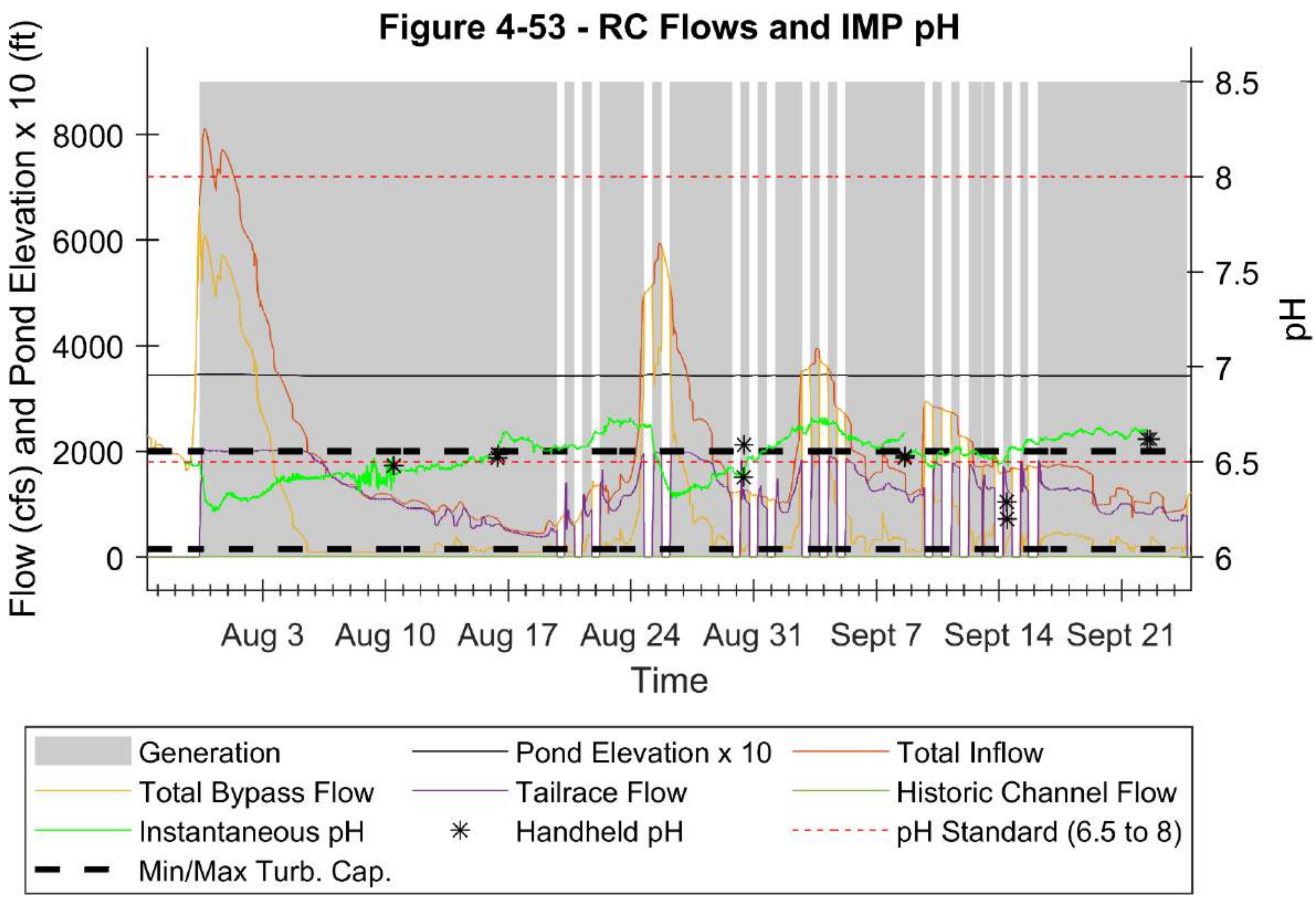


Figure 14–53. RC-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

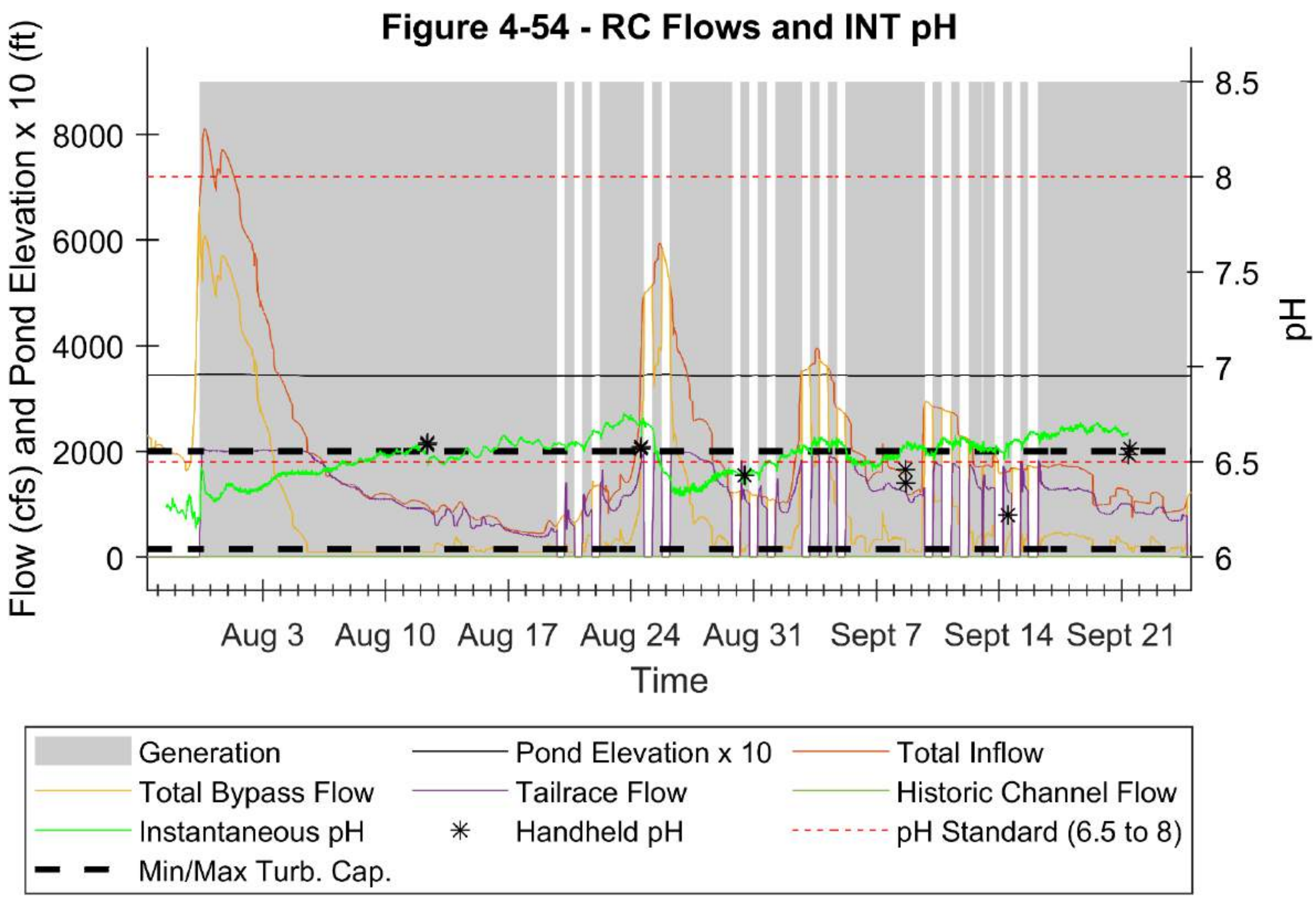


Figure 14–54. RC-INT. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

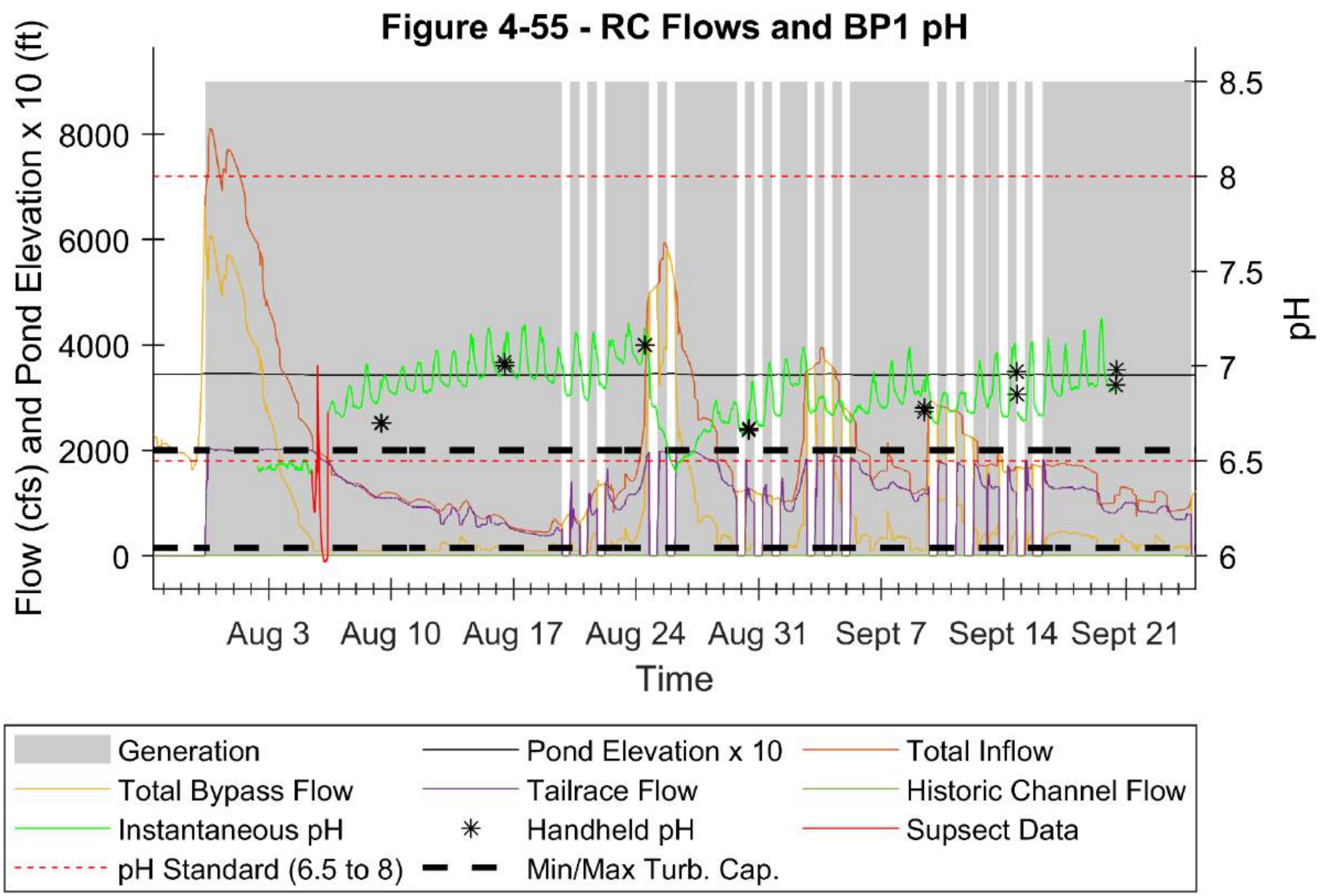


Figure 14–55. RC-BP1. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

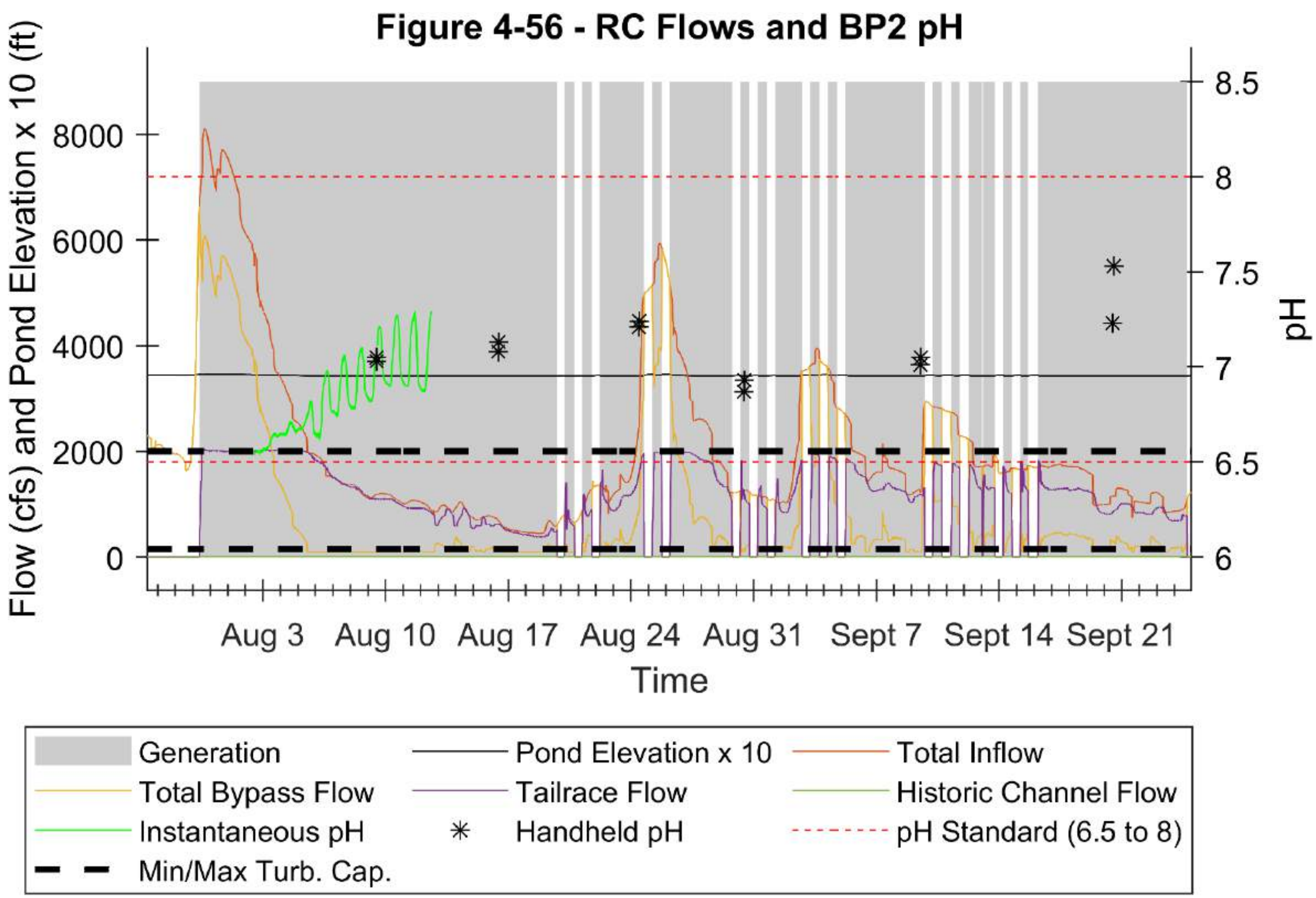


Figure 14–56. RC-BP2. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

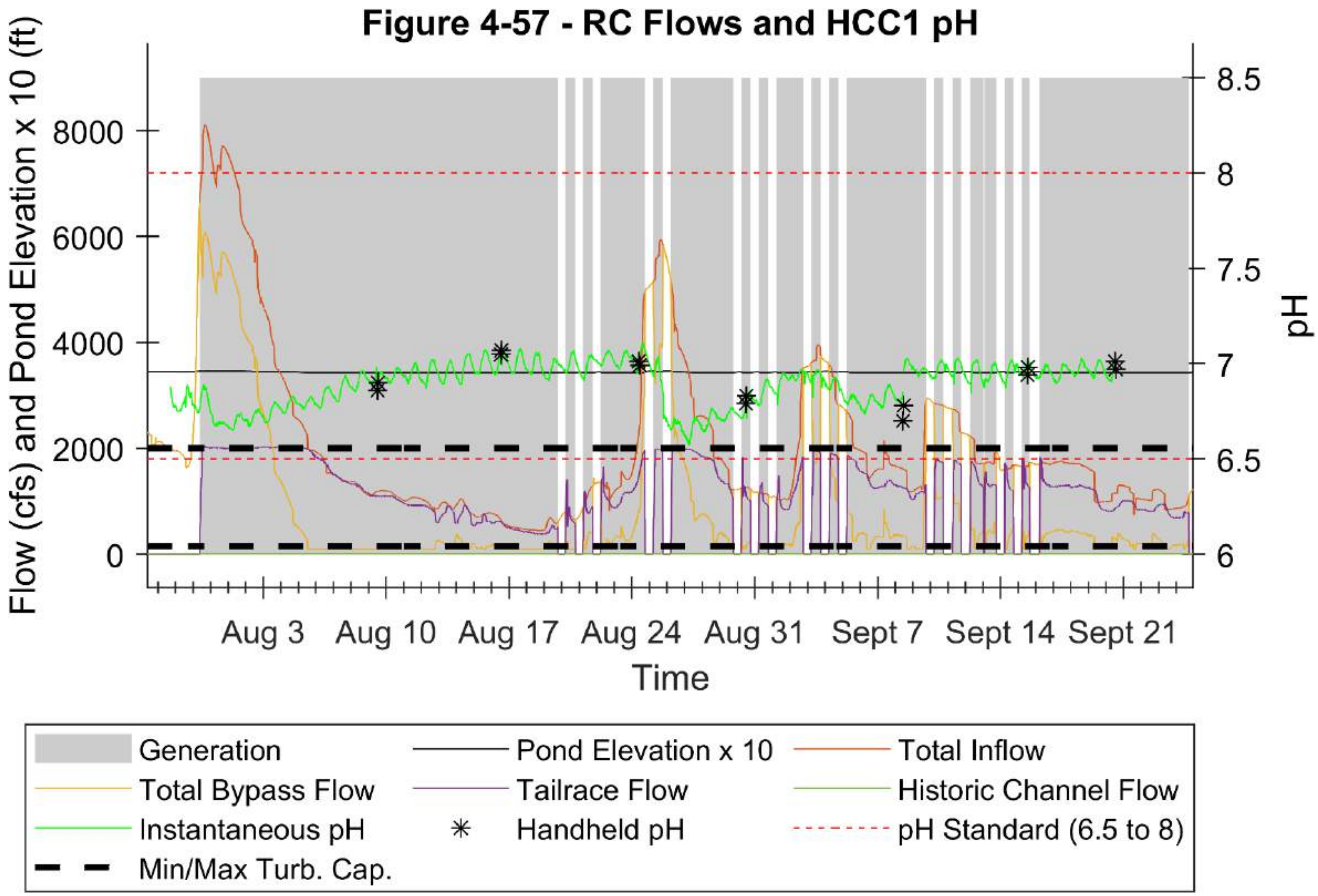


Figure 14–57. RC-HCC1. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

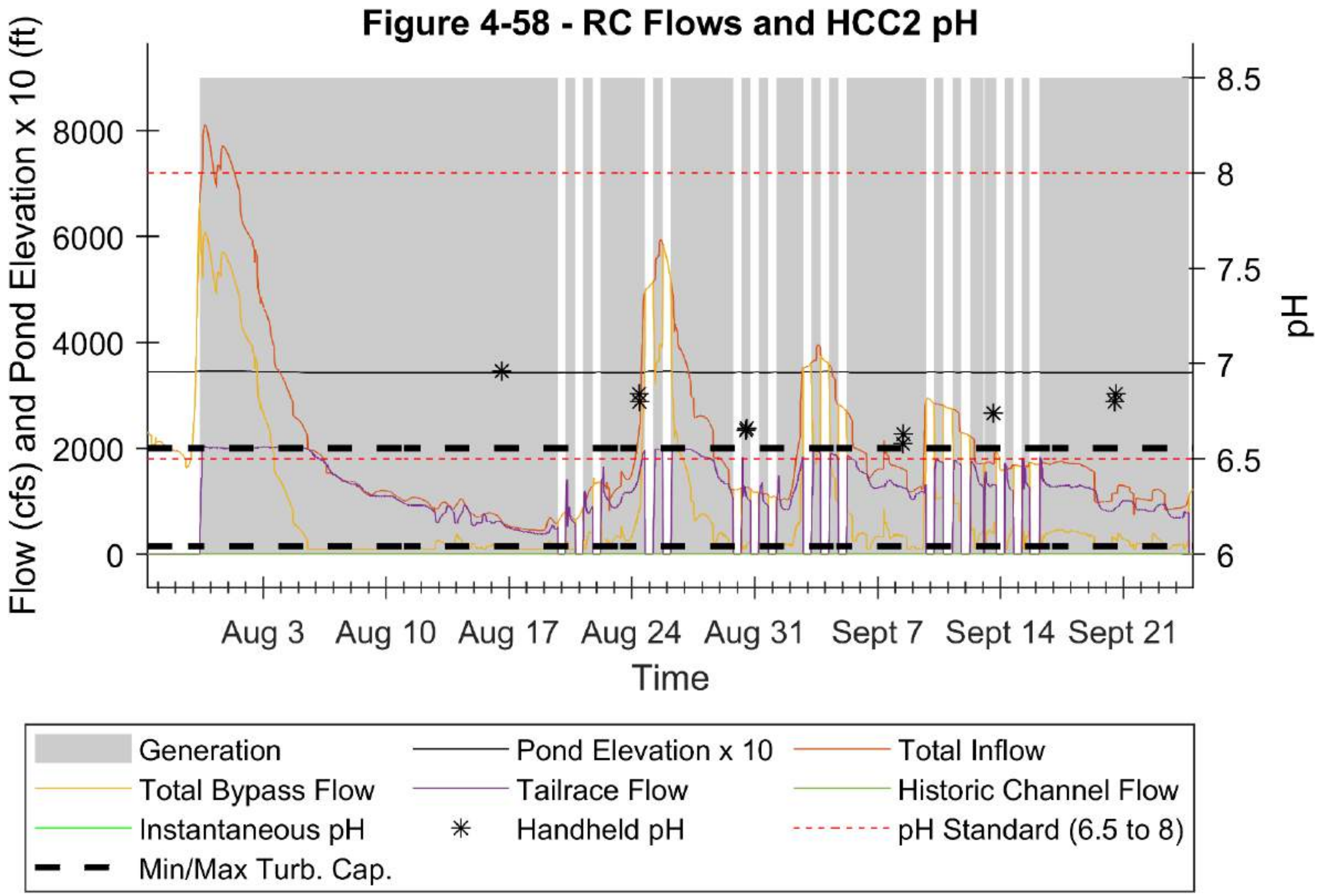


Figure 14–58. RC-HCC2. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

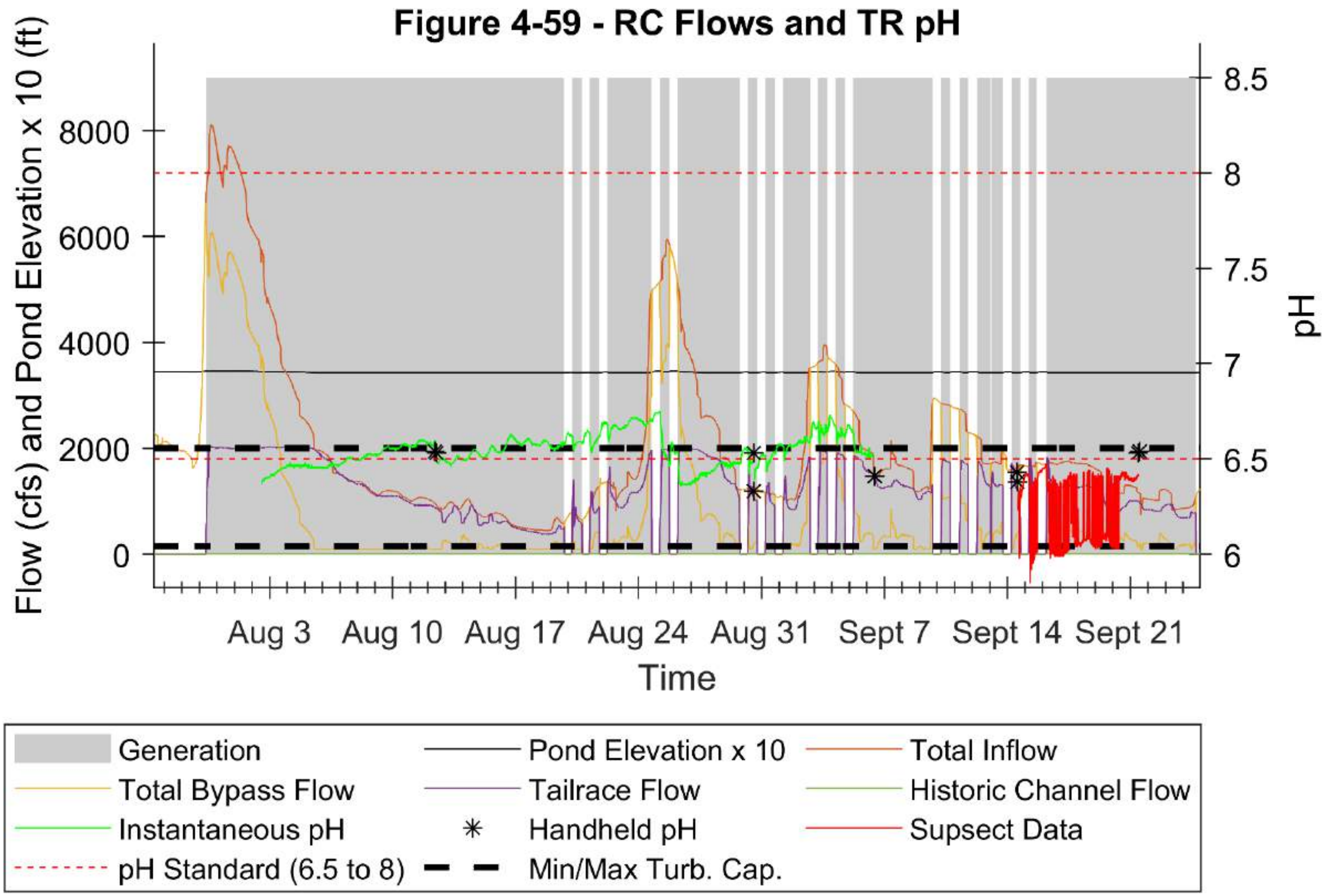


Figure 14–59. RC-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

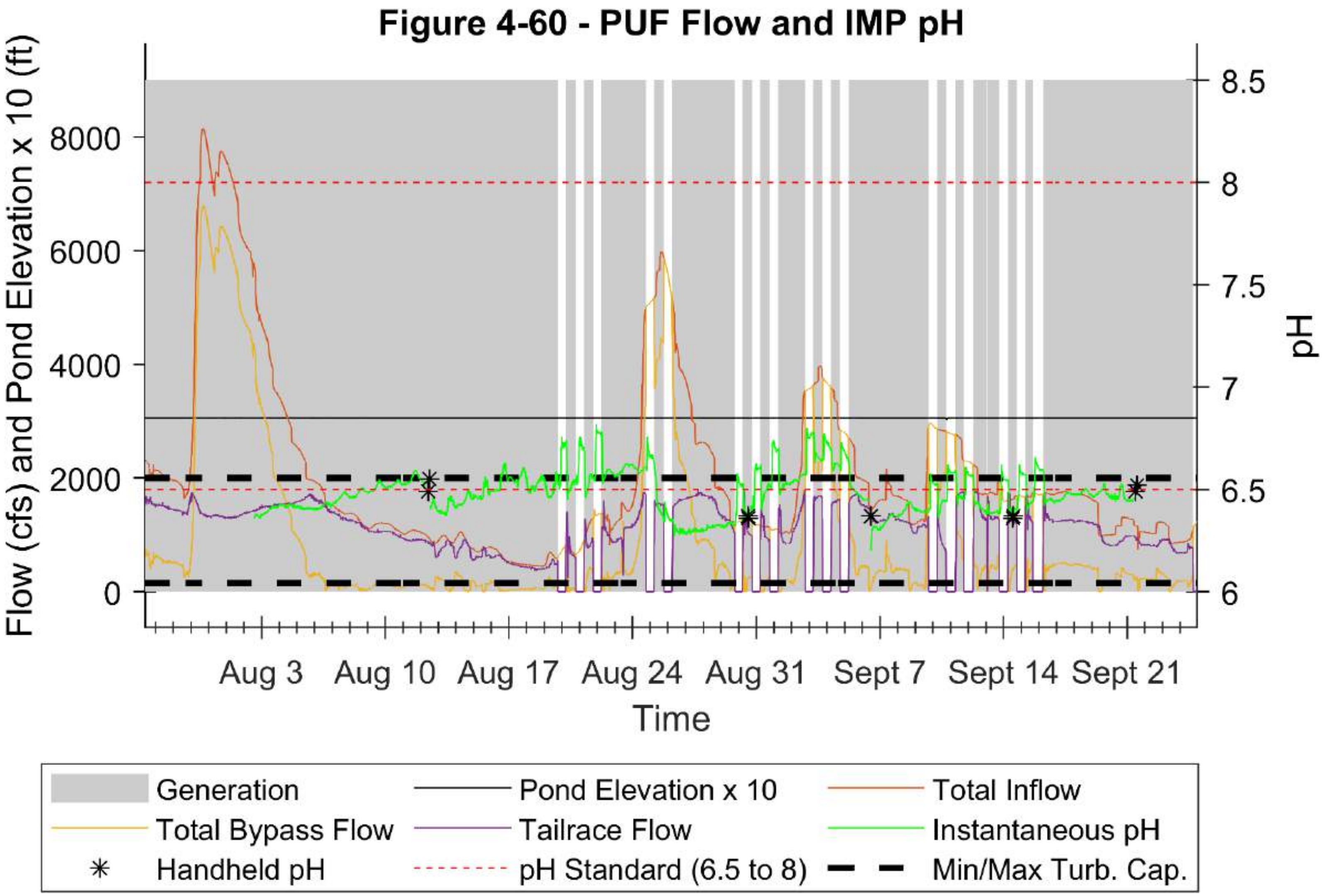


Figure 14–60. PUF-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

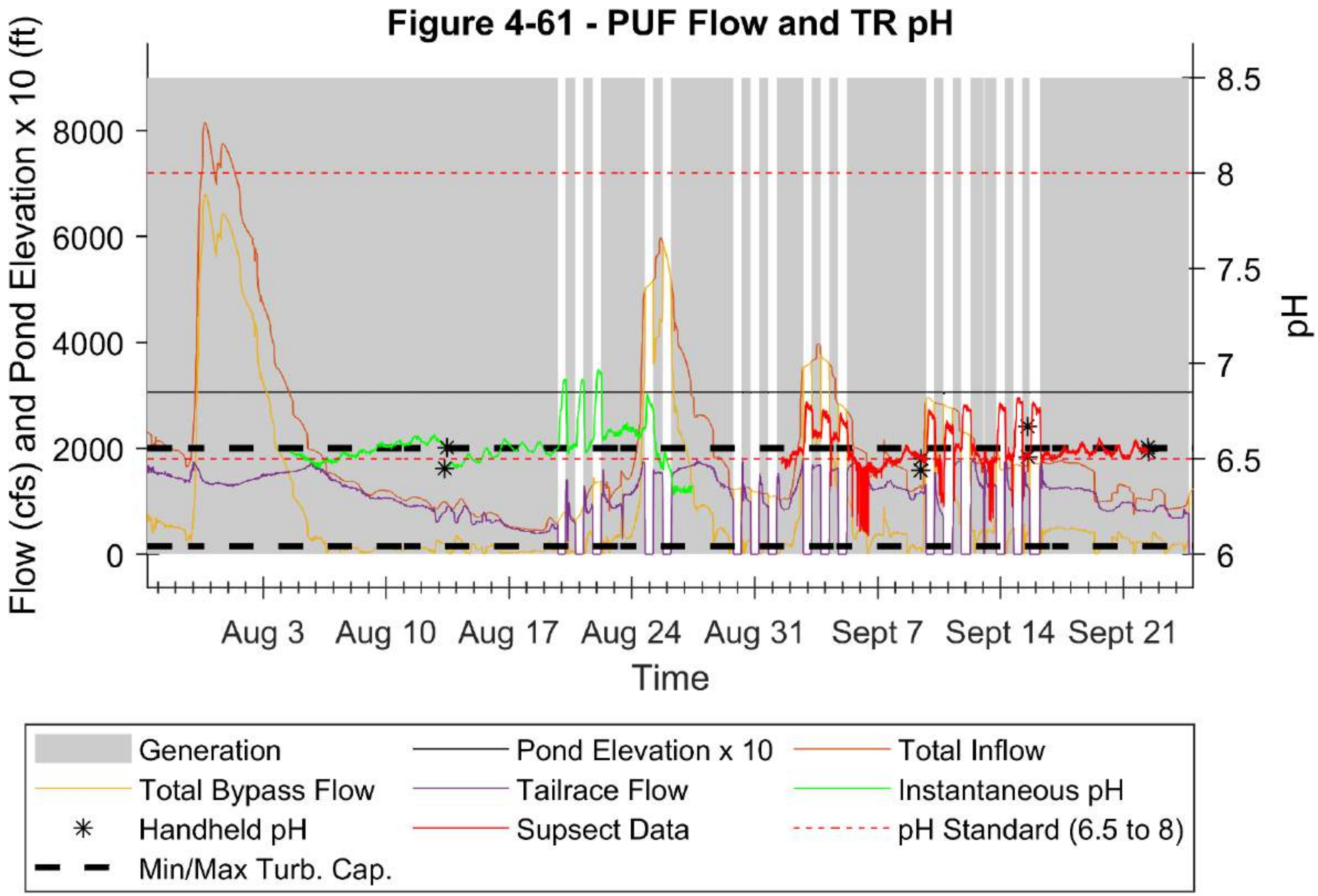


Figure 14–61. PUF-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

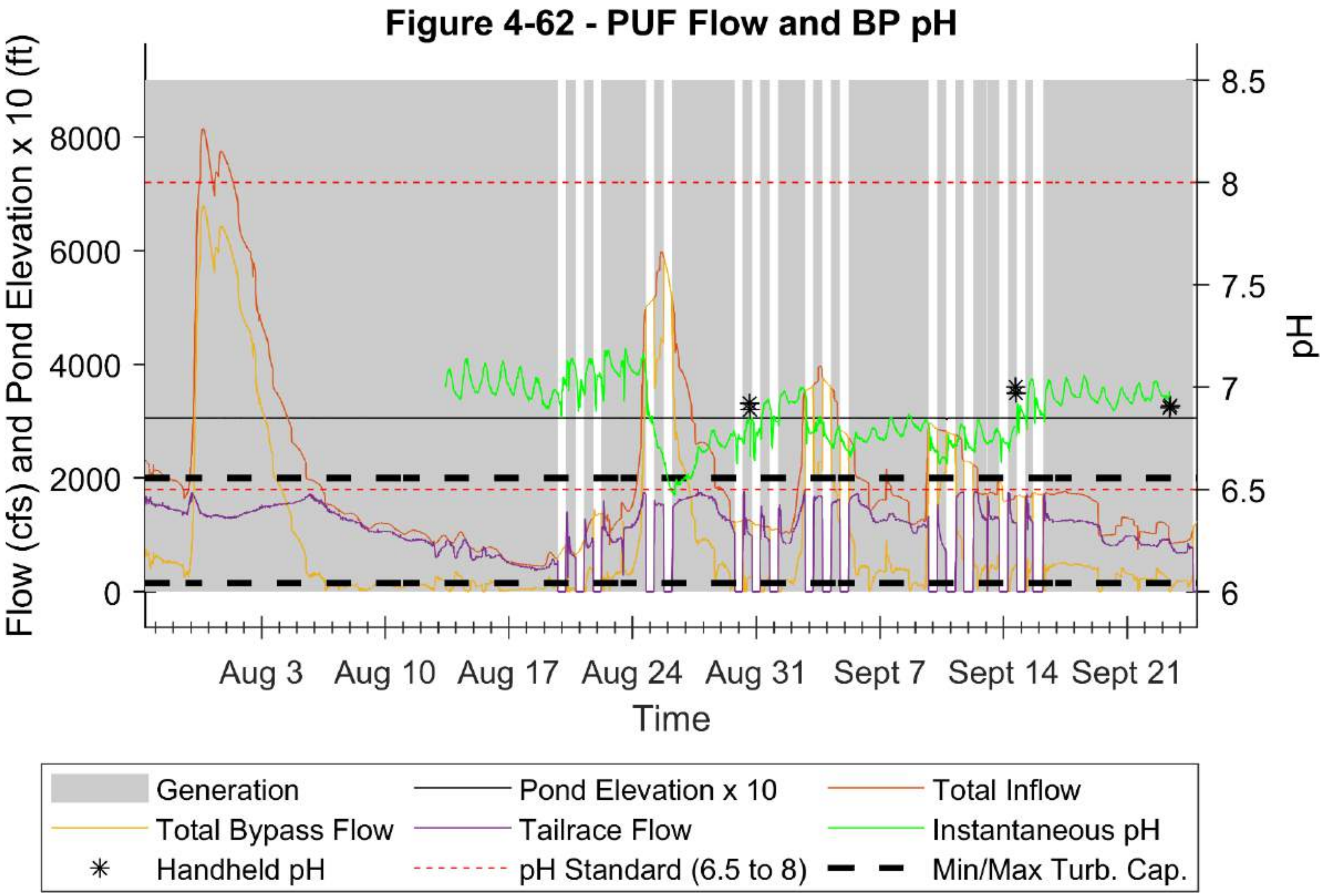


Figure 14–62. PUF-BP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

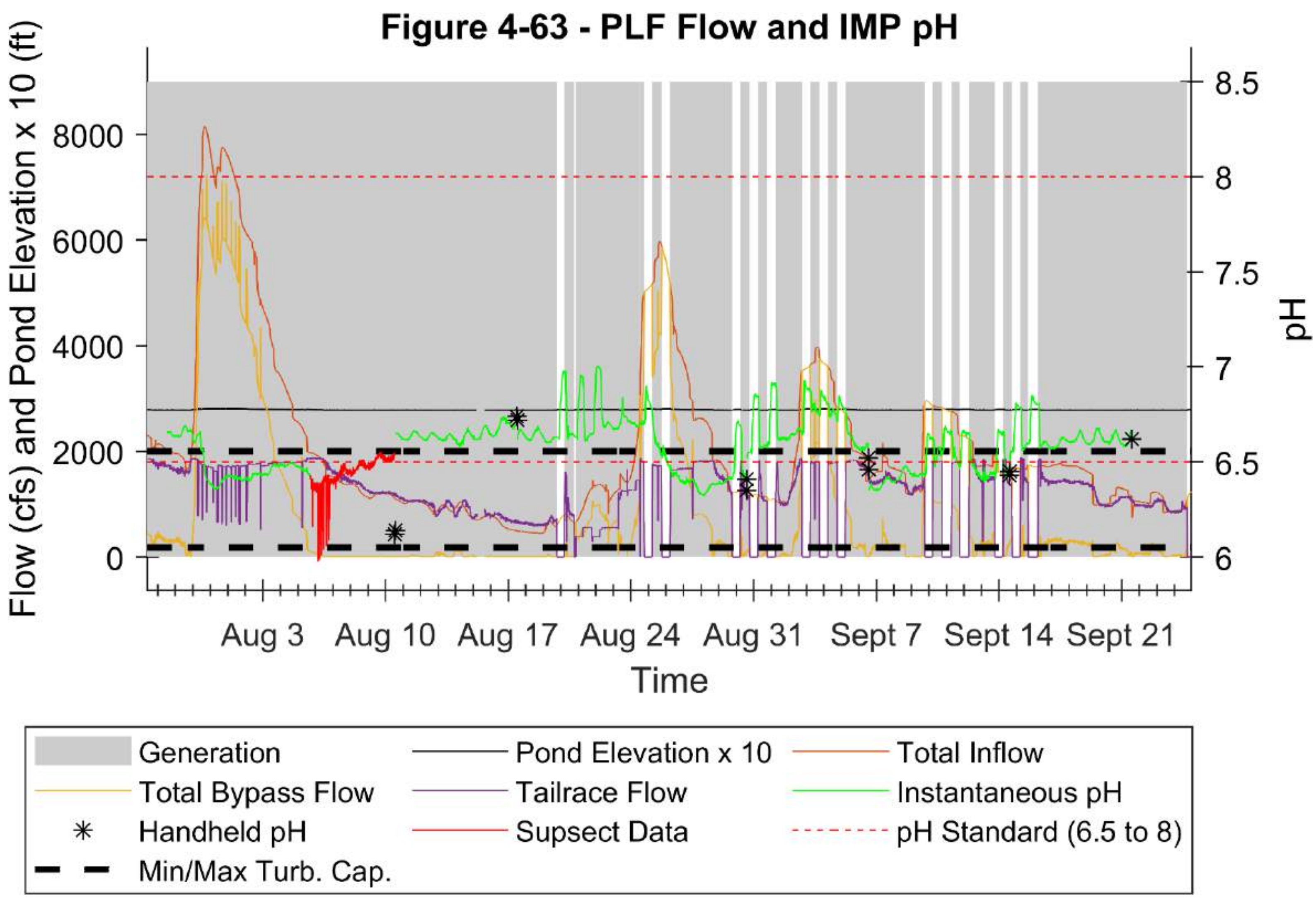


Figure 14–63. PLF-IMP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

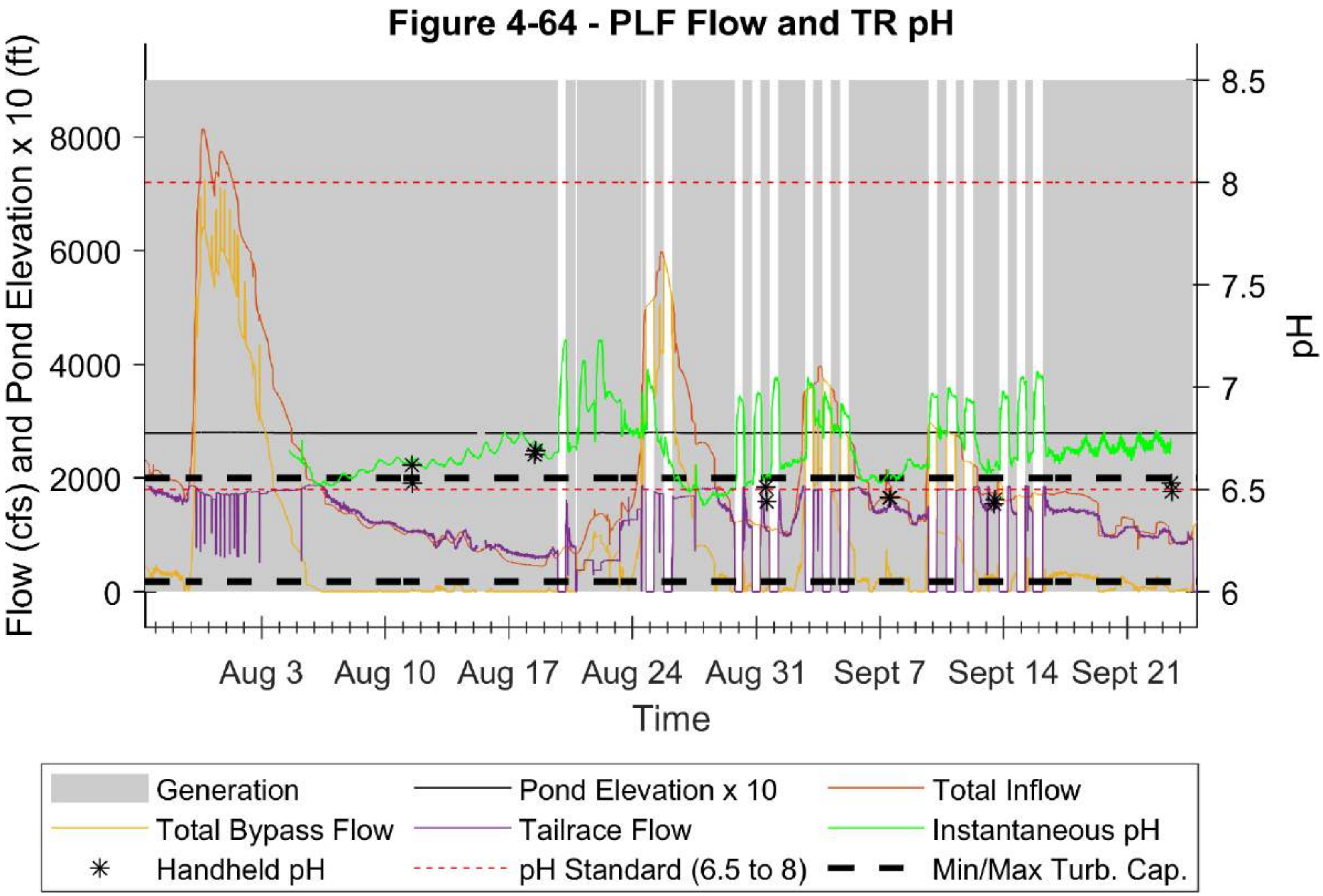


Figure 14–64. PLF-TR. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

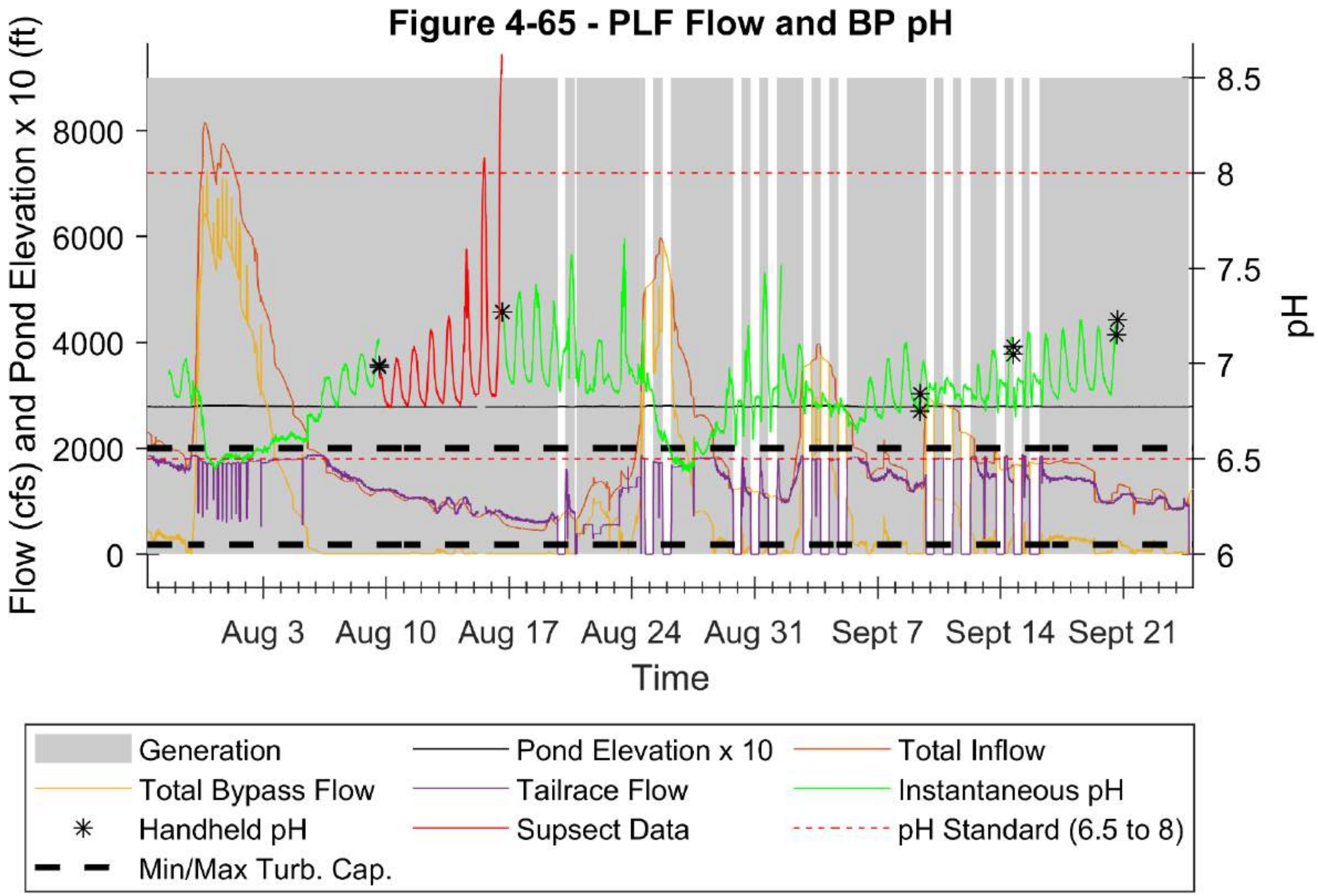


Figure 14–65. PLF-BP. Pond elevation (ft x 10, for clarity), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs); datasonde pH (s.u.), and handheld meter pH observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

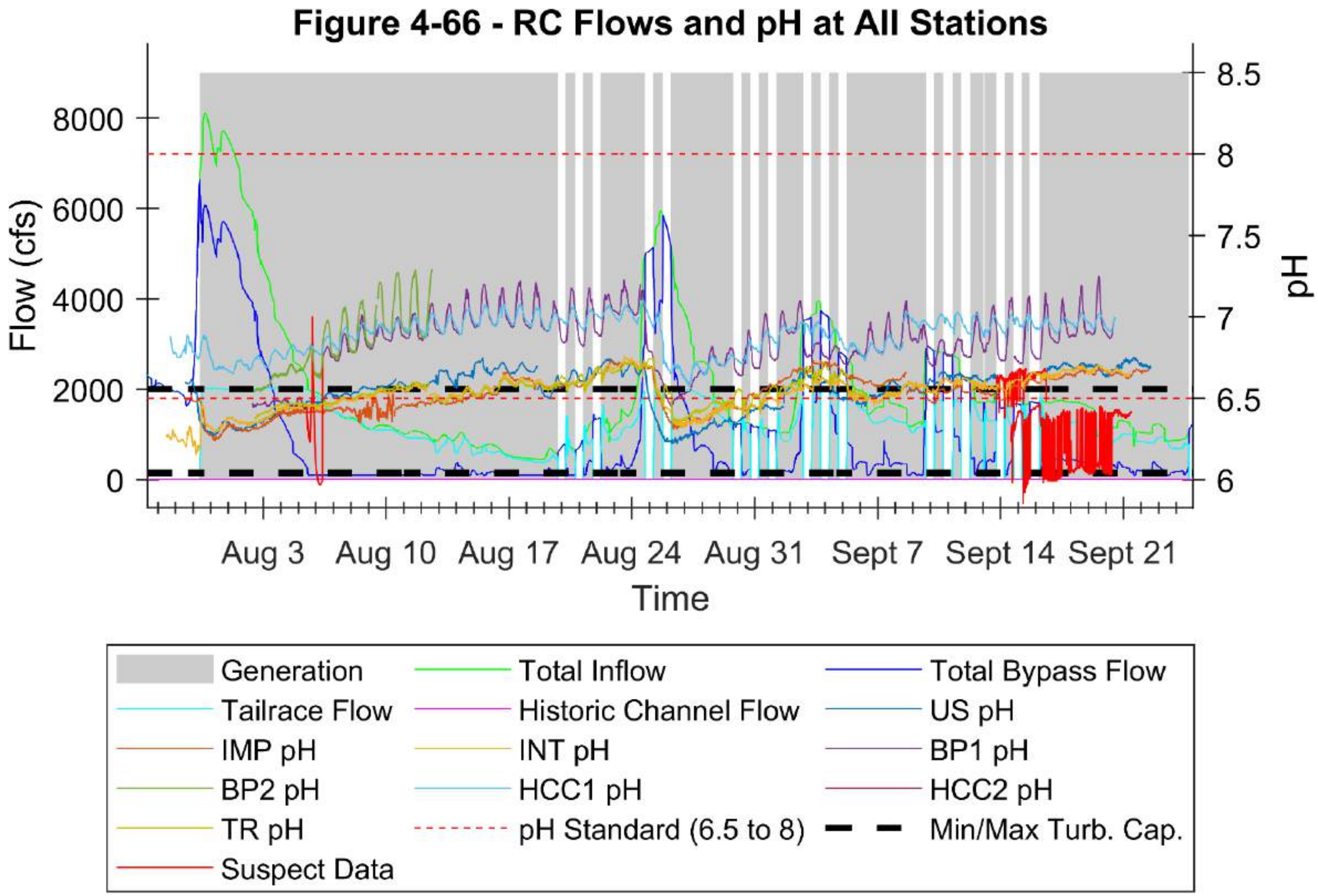


Figure 14–66. Rolfe Canal. Datasonde pH (s.u.) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

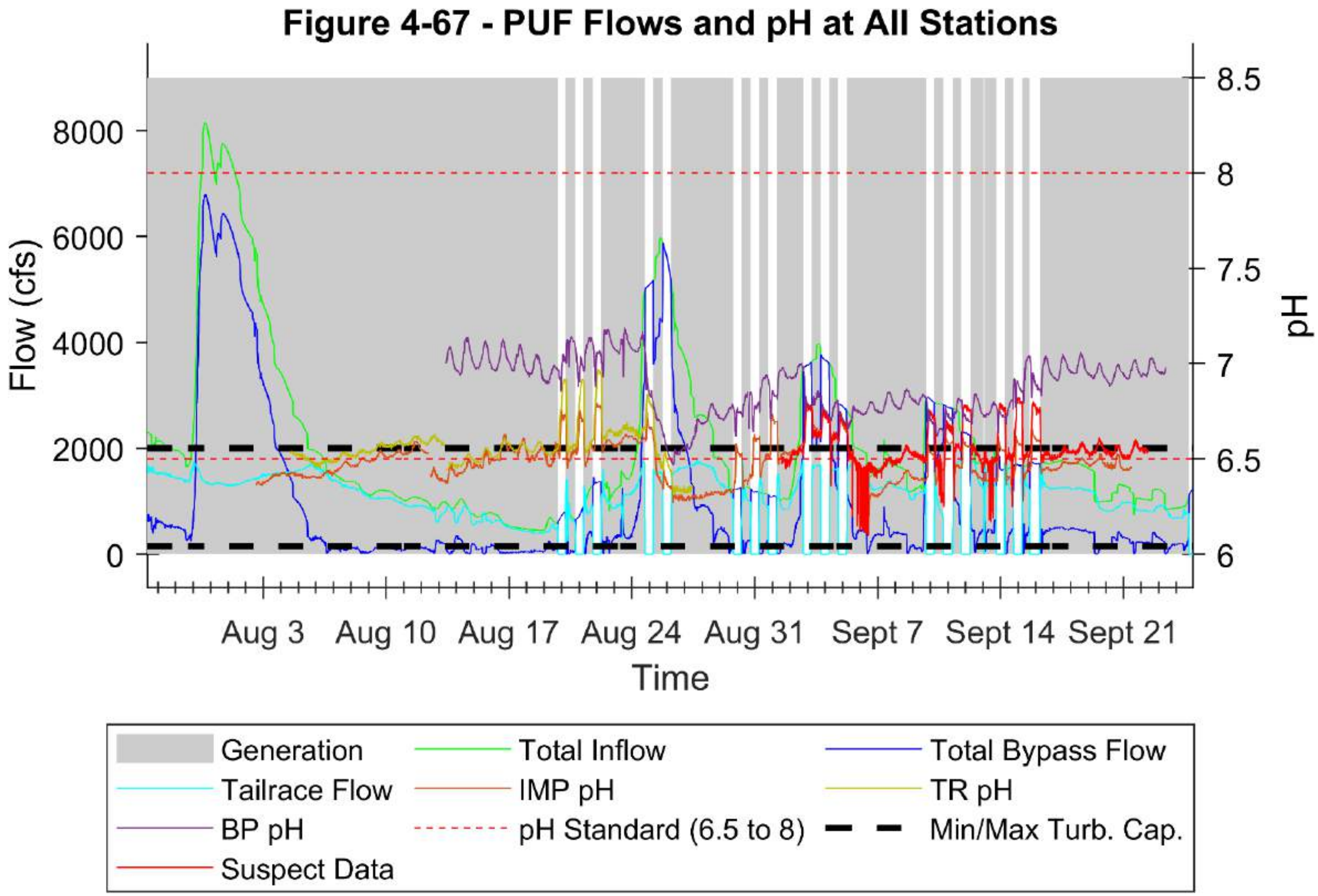


Figure 14–67. Penacook Upper Falls. Datasonde pH (s.u.) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

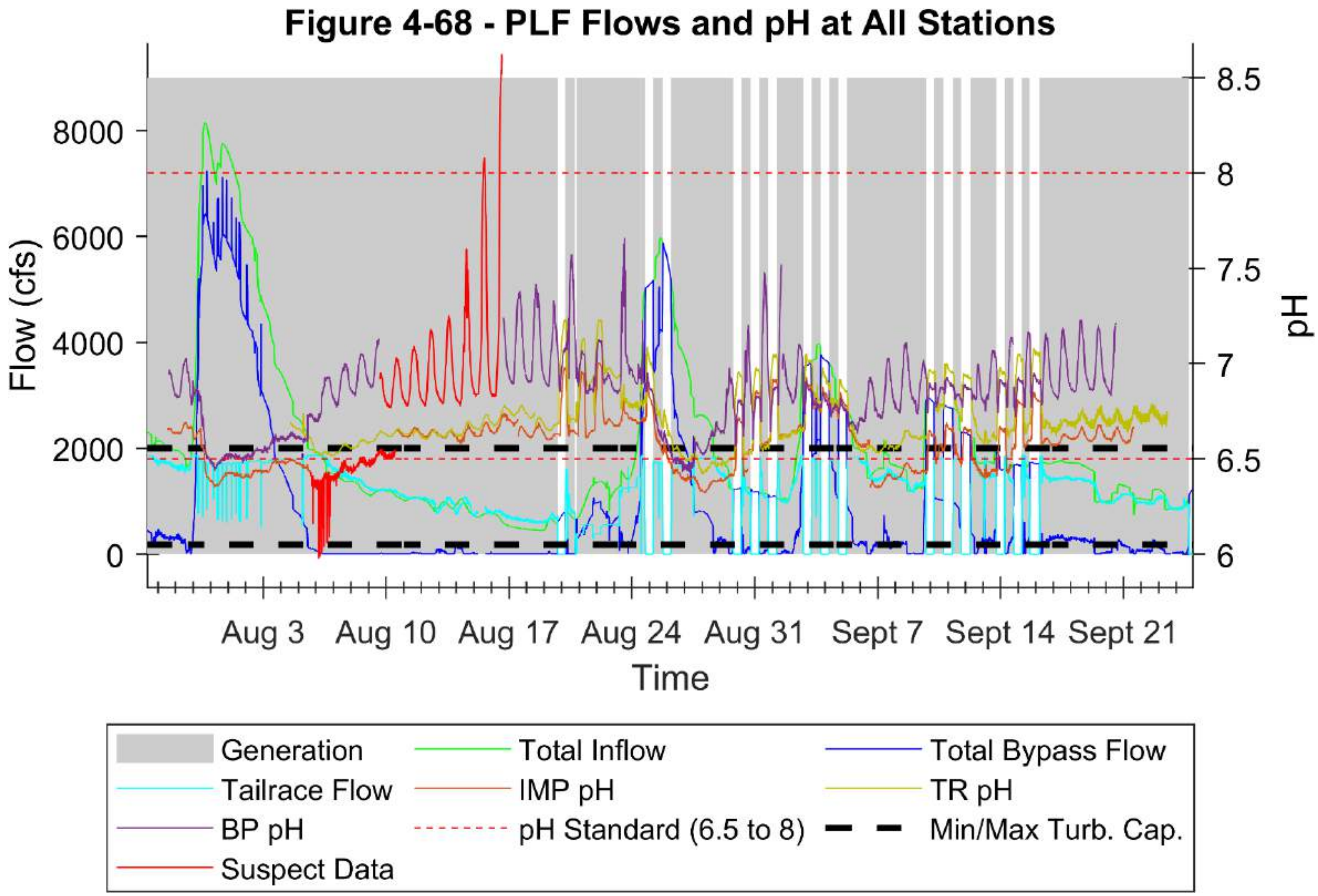


Figure 14–68. Penacook Lower Falls. Datasonde pH (s.u.) for all stations, total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. NH pH standards shown at 6.5 & 8. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

19 Vertical Profiles (Dissolved Oxygen and Temperature)

Vertical profiles of temperature and DO were measured at each of the three Project impoundment stations (RC-IMP, PUF-IMP, and PLF-IMP) as well as the RC-INT station as presented in Figures 5-69 through 5-76. The profile data were collected to characterize water quality at the intakes of each of the Projects and determine whether there was thermal/chemical stratification and therefore the potential for entrainment and discharge of low-DO bottom water. For laboratory sample collection purposes, a threshold of 5 °C surface to bottom temperature difference (consistent with NHDES, 2020) was used to identify whether stratification was great enough to require discrete sampling of hypolimnetic and epilimnetic waters. Thermal stratification was documented to some degree at the RC-IMP station during low flow periods in August and September, with the thermal stratification criteria met on two occasions: 8/12/21 and 8/17/21. There were also exceedances of the 5 mg/L DO standard in the bottom water on those two dates at RC-IMP. DO concentration varied from 3.51 mg/L to 7.30 mg/L in the water column on 8/12/21 and from 1.34 mg/L to 7.07 mg/L in the water column on 8/17/21. Under unstratified conditions, DO concentrations were greater than 7 mg/L at RC-IMP. There were no other exceedances of the 5 mg/L standard at RC-IMP or any other station during this study in the vertical profile measurements or in the continuous monitoring data.

Temperature and DO profiles at the RC-INT, PUF-IMP, and PLF-IMP stations were relatively homogeneous (i.e., little variation with depth) under various flow and temperature conditions and DO concentrations were above 7 mg/L for all profiles collected at those stations. Thermal/chemical stratification was not documented at those three stations and was likely due to the Project configurations. At the RC Project, water is diverted to the canal for generation well upstream of the York Dam and therefore inflows to the impoundment are limited to minimum flows under non-spill conditions. At the PUF and PLF impoundments the full inflow is conveyed to the impoundment (and the WQ stations) as there are no diversions upstream of either dam. Therefore, thermal stratification is more likely at the Rolfe Canal impoundment (due to limited inflow below the canal diversion) compared to the two lower Projects, as was demonstrated in the vertical profile data.

As a note, the vertical profile figures show the measurement elevations, the channel bottom elevations, and the invert elevations for the Project intake structures. It is apparent that the Project intake structures are lower in elevation than the channel bottom (by approximately 15-30 ft). It is worth noting that the intake structures are excavated into the channels at lower elevations than the natural channel bottom in the forebay areas leading to the intake structures. The vertical profile locations were located at the deepest location accessible (i.e., above the buoy line for each Project) and the difference between the identified channel deep spot and the Project invert elevations should not be interpreted as misrepresenting the full depth of the Project impoundments.

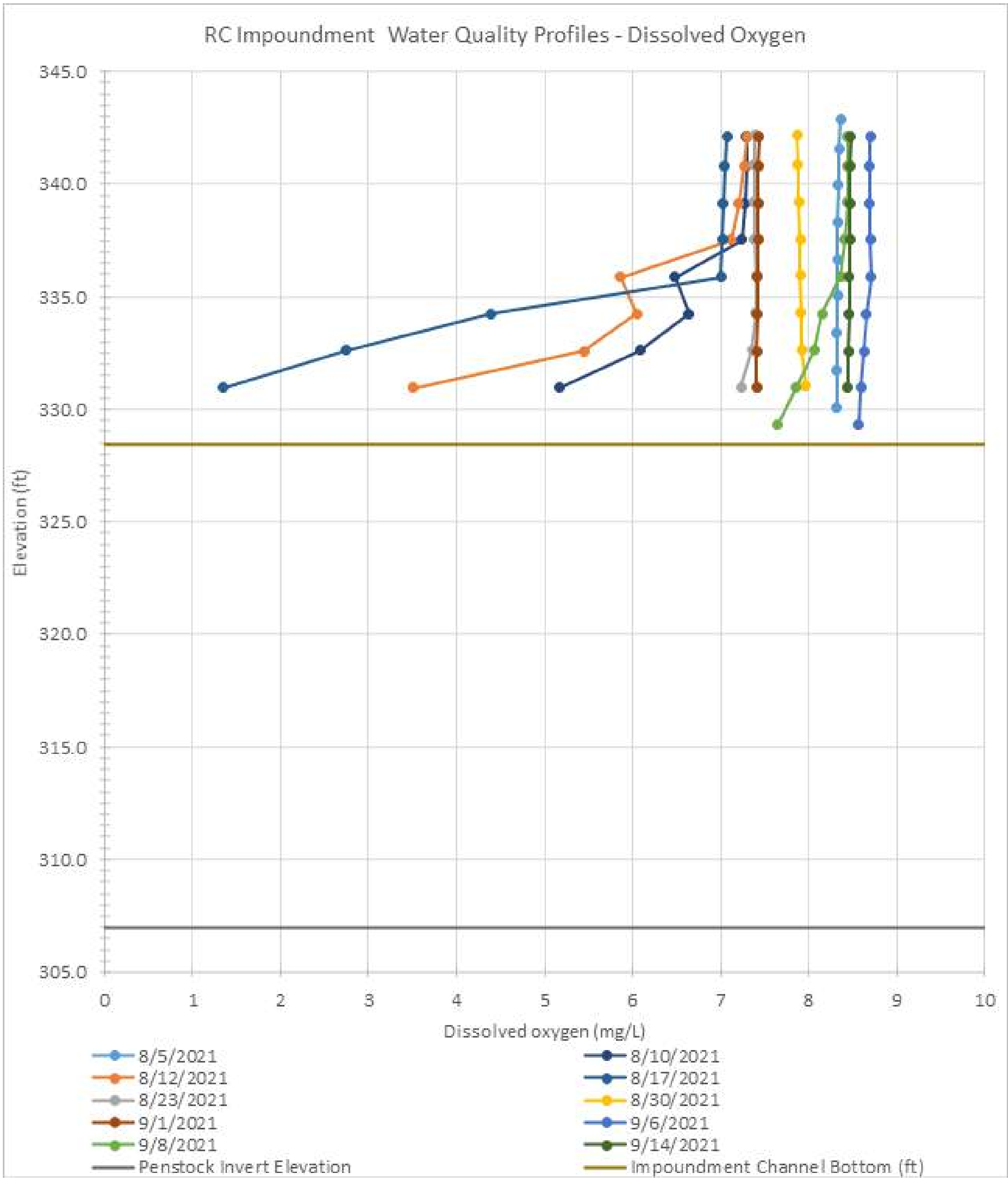


Figure 14–69. RC-IMP. Vertical profiles of DO (mg/L) across depth during 2021 study. Bottom invert penstock elevation and impoundment channel bottom shown across horizontal x-axis as solid line.

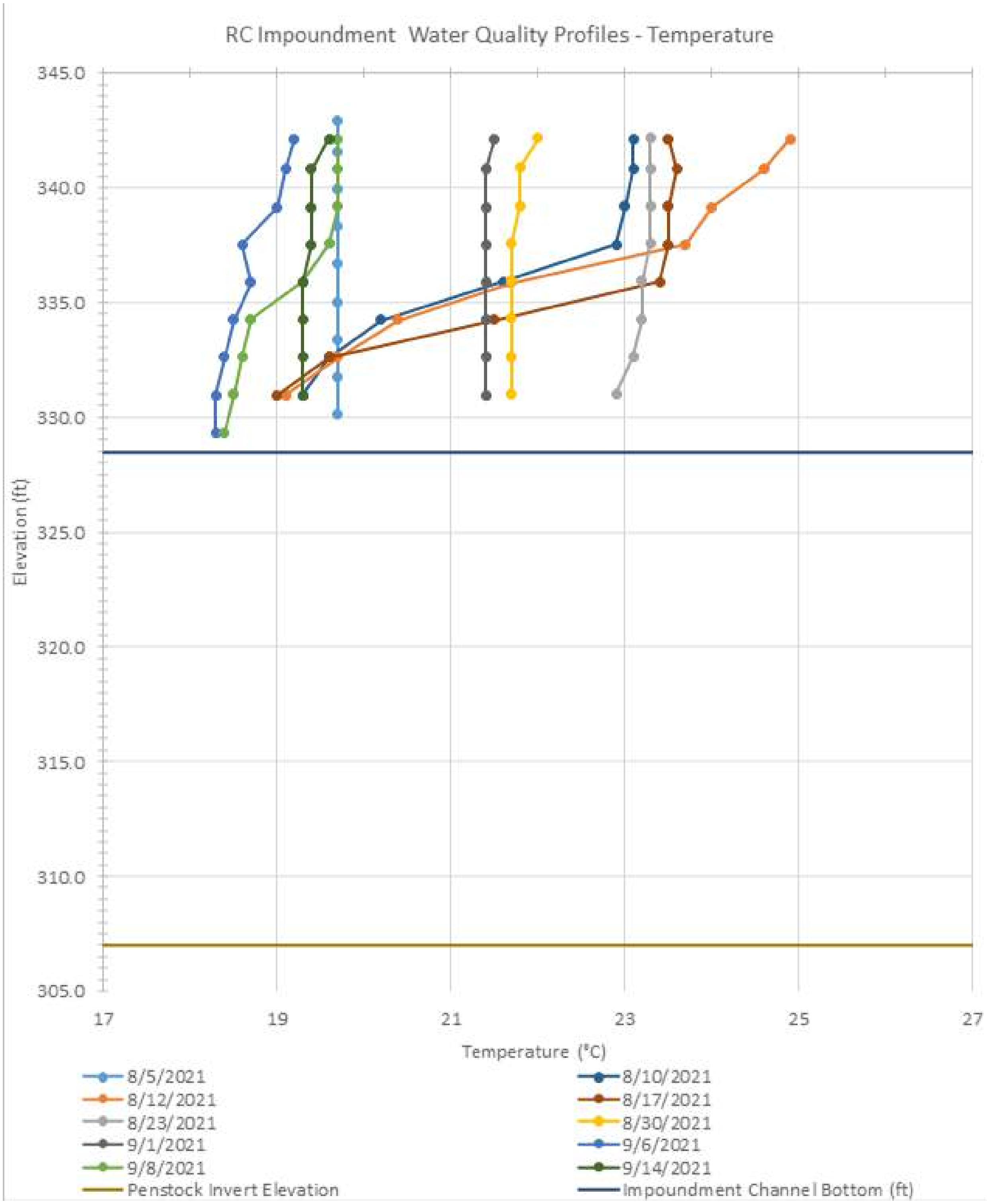


Figure 14–70. RC-IMP. Vertical profiles of temperature (°C) across depth during 2021 study. Bottom invert penstock elevation and impoundment channel bottom shown across horizontal x-axis as solid line.

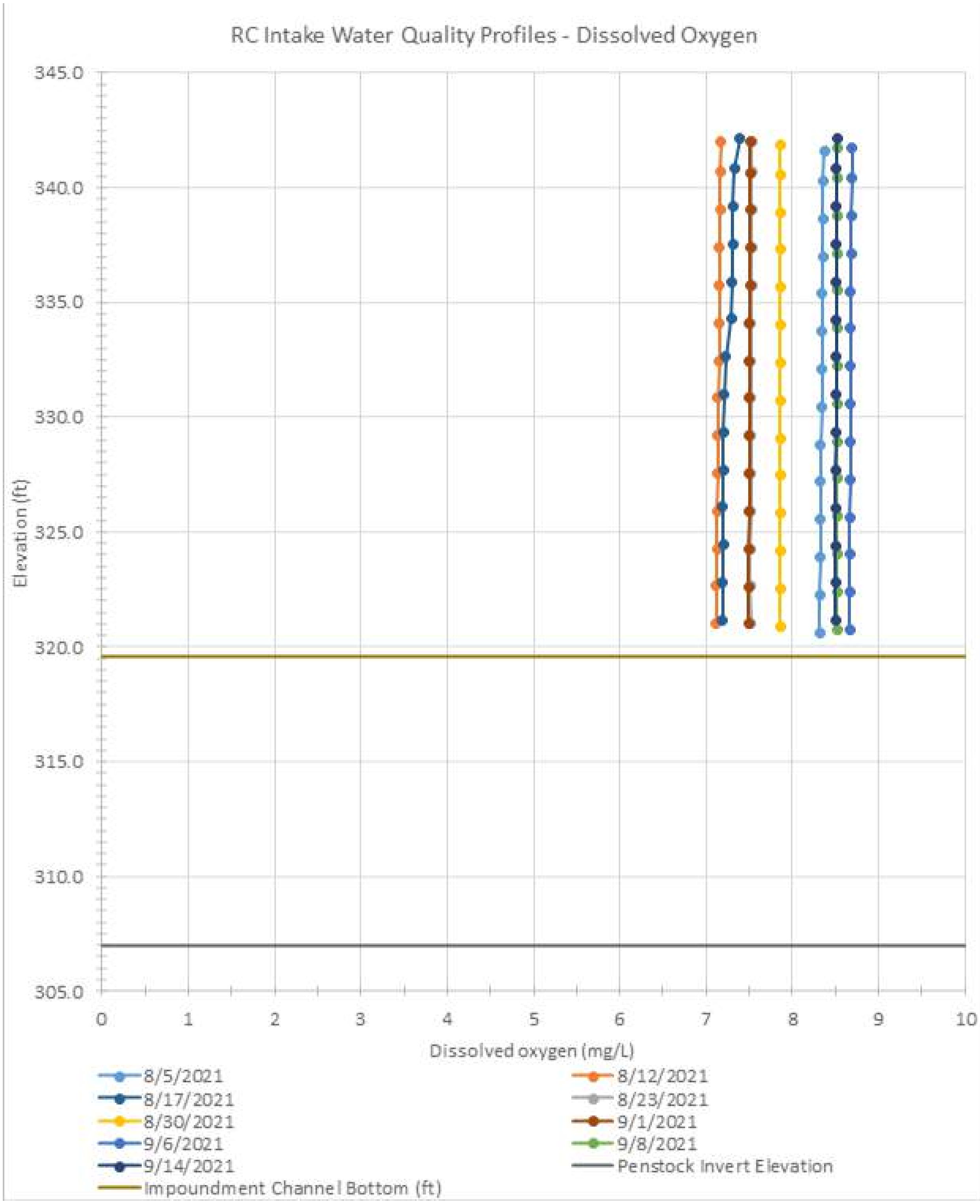


Figure 14–71. RC-INT. Vertical profiles of DO (mg/L) across depth during 2021 study. Bottom invert penstock elevation and impoundment channel bottom shown across horizontal x-axis as solid line.

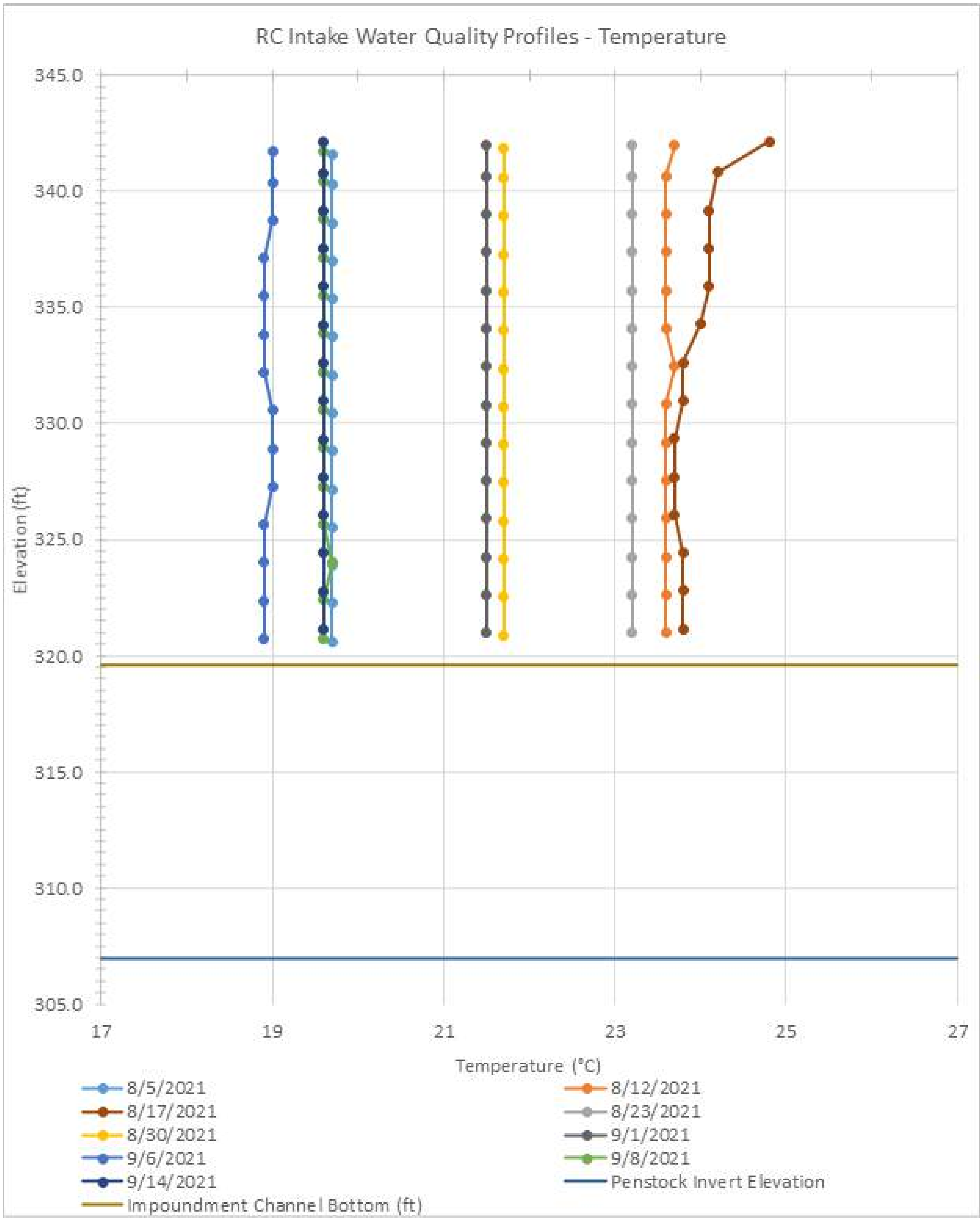


Figure 14–72. RC-INT. Vertical profiles of DO (mg/L) across depth during 2021 study. Bottom invert penstock elevation and impoundment channel bottom shown across horizontal x-axis as solid line.

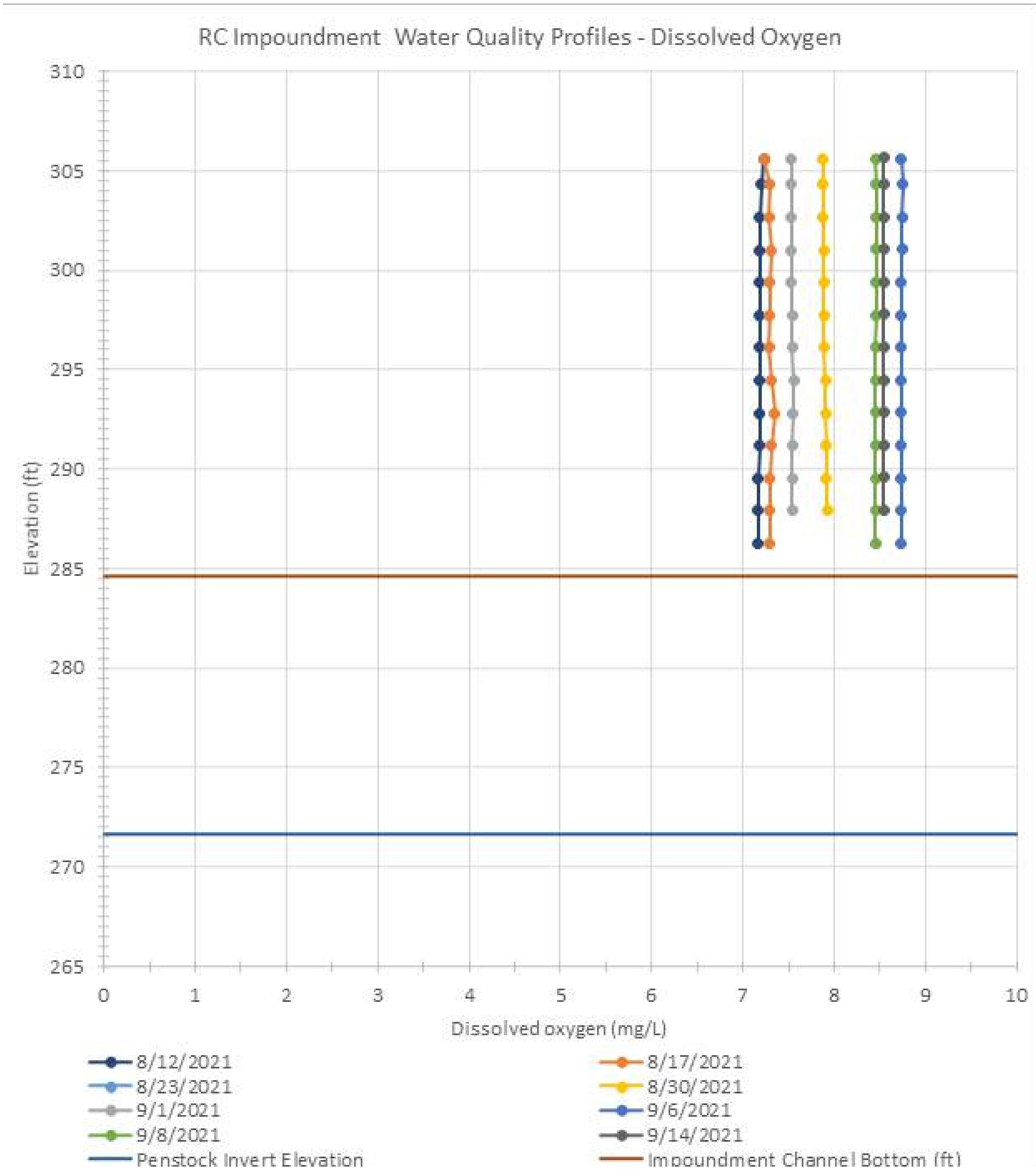


Figure 14–73. PUF-IMP. Vertical profiles of DO (mg/L) across depth during 2021 study. Bottom invert penstock elevation and impoundment channel bottom shown across horizontal x-axis as solid line.

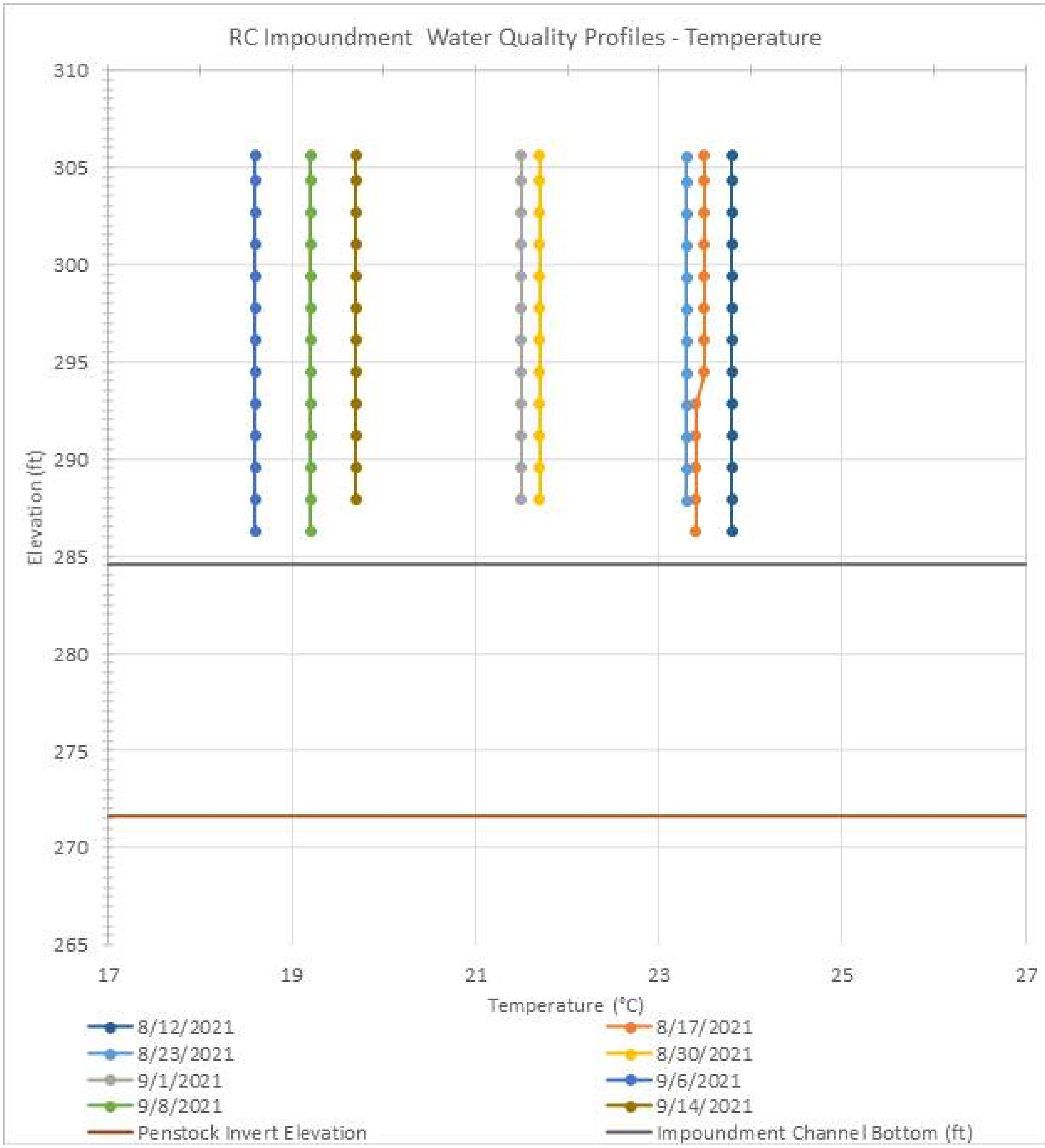


Figure 14–74. PUF-IMP. Vertical profiles of temperature (°C) across depth during 2021 study. Bottom invert penstock elevation and impoundment channel bottom shown across horizontal x-axis as solid line.

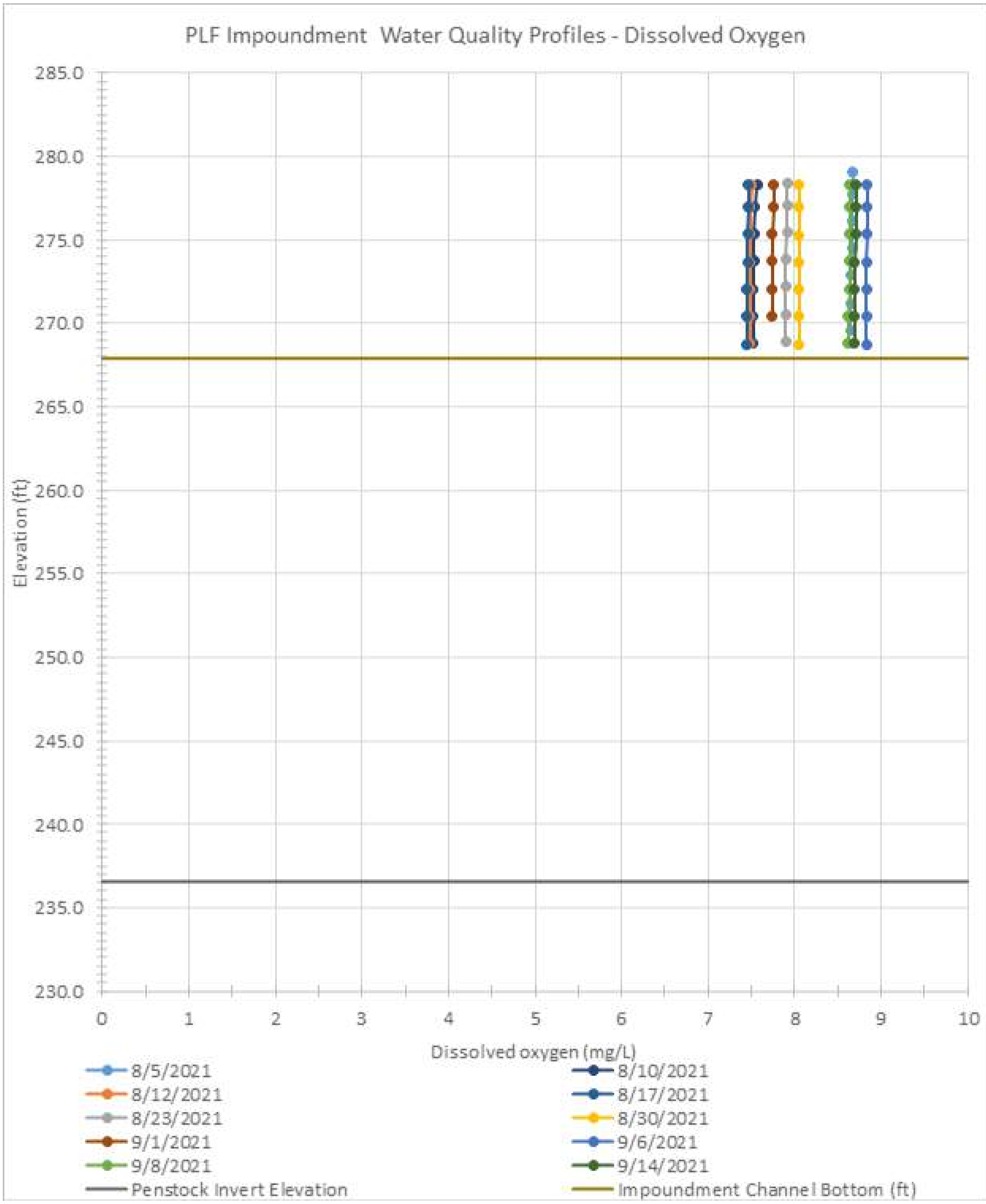


Figure 14–75. PLF-IMP. Vertical profiles of DO (mg/L) across depth during 2021 study. Bottom invert penstock elevation and impoundment channel bottom shown across horizontal x-axis as solid line.

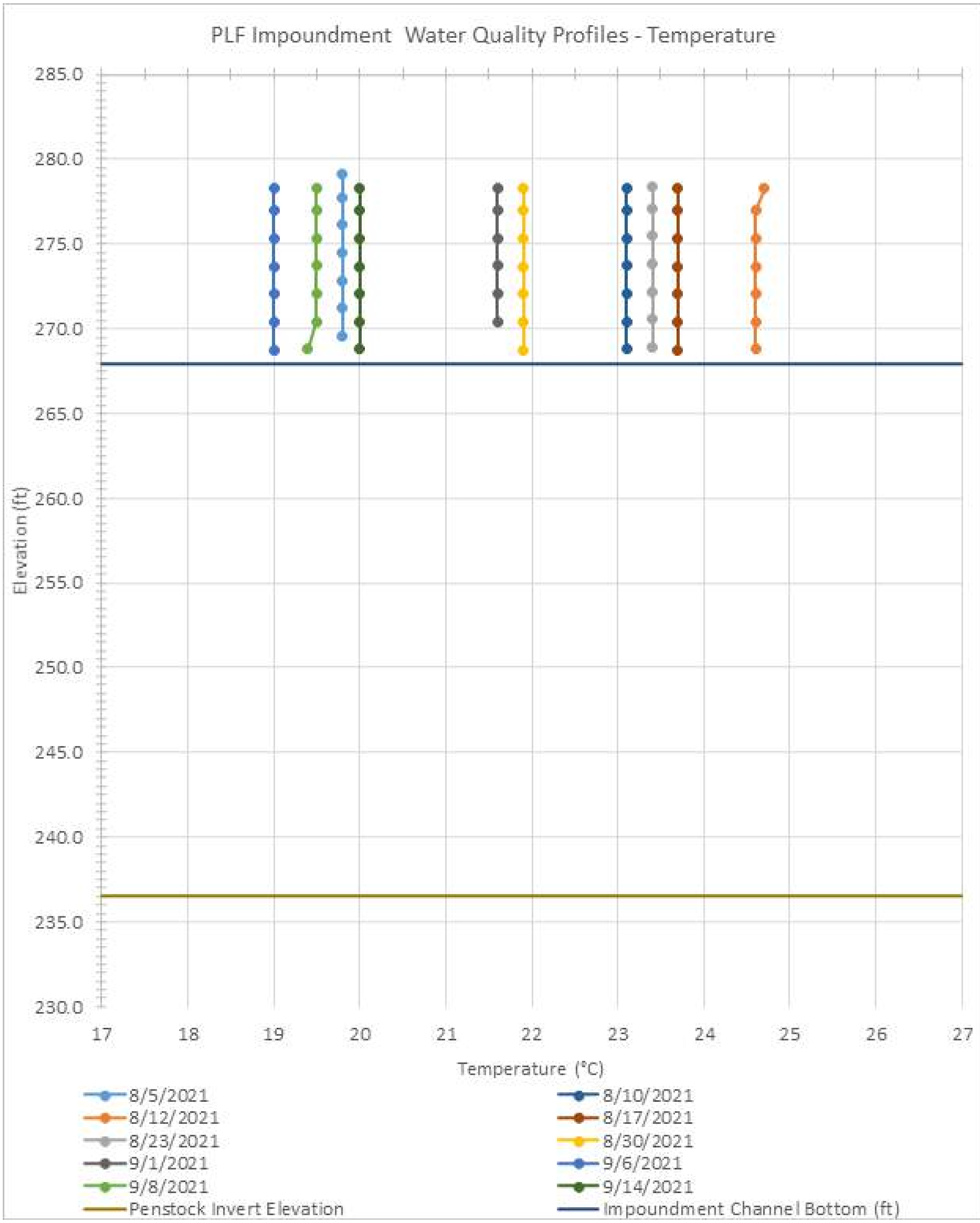


Figure 14–76. PLF-IMP. Vertical profiles of temperature (°C) across depth during 2021 study. Bottom invert penstock elevation and impoundment channel bottom shown across horizontal x-axis as solid line.

20 Laboratory Analysis (Nutrients and Chlorophyll-*a*)

Water samples were collected once or twice per week in August and September 2021 from the three impoundment stations (RC-IMP, PUF-IMP, PLF-IMP) and the Rolfe Canal Project Intake (RC-INT) and submitted for laboratory analysis as discussed in Section 4.3 and in accordance with the SAP. The full schedule of 10 samples and a field replicate were collected from RC-IMP and PLF-IMP, as per the SAP. At RC-INT, a total of six samples and a field replicate were collected (the SAP specified 5 samples) and at PUF-IMP only 8 samples plus a field replicate were collected due to high flow conditions preventing access for two of the planned sampling rounds (10 samples were to be collected per the SAP). Secchi depth was measured concurrent with collection of laboratory samples. The results of the sample analysis and Secchi depth are presented in Tables 5-7 through 5-10. Nitrite was not detectable above the reporting limit of 0.05 mg/L in any sample collected. Nitrate was measured at levels ranging from <0.050 mg/L – 0.14 mg/L and was measured at similar concentrations between stations and over the course of the study. Median nitrate values by station ranged from 0.089 mg/L at RC-INT to 0.097 mg/L at RC-IMP. Total Kjeldahl nitrogen (TKN) was detected in all samples collected at concentrations ranging from 0.23 to 0.97 mg/L, both measured at Station PUF-IMP, with median values by station ranging from 0.405 mg/L at PUF-IMP to 0.455 at RC-INT. There are no numerical standards for nitrogen in freshwater surface waters in NH; however, EPA guidance for the region lists a reference condition of 0.71 mg/L for total nitrogen which can be used for evaluation of water quality. During this study total nitrogen (estimated as nitrate + TKN) ranged from <0.29 – 1.06 mg/L with median station values ranging from 0.48 mg/L at PUF-IMP to 0.54 mg/L at RC-INT which were below the EPA reference condition of 0.71 mg/L. Total phosphorus was measured in both the epilimnion and hypolimnion samples as in the SAP and varied from 0.011 – 0.100 mg/L (Station RC-IMP) with median station values ranging from 0.022 mg/L at RC-INT to 0.077 at PUF-IMP. The detected phosphorus concentrations were generally within or in excess of the CALM (indicator 7b) category for Eutrophic waters of 0.012-0.028 mg/L. Chlorophyll a was measured at levels ranging from 0.8 – 2.1 ug/L, with median station values ranging from 1.475 ug/L at RC-INT to 1.60 ug/L at RC-IMP and PLF-IMP, all below the NH numeric threshold (CALM indicator 7b) for an oligotrophic lake of <3.3 ug/L.

Table 14–7. Summary of laboratory results at RC-IMP

Date	NO3-N	NO2-N	TKN	TP	TKN	TP	Chlorophyll a	Notes
			Epilimnion		Hypolimnion			
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	
8/5/2021 9:30	0.067	<0.05	0.48	0.023	-	-	1.6	Secchi depth 8 ft
8/10/2021 11:20	0.11	<0.05	0.46	0.026	-	-	1.7	Secchi depth 10 ft
8/12/2021 13:15	0.093	<0.05	0.39	0.062	-	0.066	1.6	Secchi depth 11 ft
8/17/2021 9:35	0.11	<0.05	0.94	0.098	-	0.099	2.1	Secchi depth 11 ft
8/23/2021 9:05	0.12	<0.05	0.37	0.1	-	-	0.8	Secchi depth 10.5 ft
8/30/2021 10:05	0.099	<0.05	0.49	0.083	-	-	1.3	Secchi depth 8 ft
8/30/2021 10:05	0.077	<0.05	0.58	0.017	-	-	1.6	Field replicate
9/1/2021 10:39	0.1	<0.05	0.33	0.094	-	-	1.7	Secchi depth 9 ft
9/6/2021 14:30	0.06	<0.05	0.36	0.02	-	-	1.2	Secchi depth 9.5 ft
9/8/2021 14:59	0.085	<0.05	0.31	0.011	-	-	1.1	Secchi depth 11 ft
9/14/2021 11:00	0.14	<0.05	0.73	0.02	-	-	1.7	Secchi depth 9.5 ft
10 sample median	0.0965	<0.05	0.425	0.038	-	0.0825	1.6	

Table 14–8. Summary of laboratory results at RC-INT

Date	NO3-N	NO2-N	TKN	TP	Chlorophyll a	Notes
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	
8/5/2021 10:30	0.056	<0.05	0.46	0.023	1.6	Secchi depth 8 ft
8/10/2021 10:00	-	-	-	-	-	Secchi depth 10 ft
8/12/2021 8:40	0.1	<0.05	0.51	0.021	1.2	Secchi depth 11 ft
8/17/2021 9:30	-	-	-	-	-	Secchi depth 11 ft
8/23/2021 10:12	0.12	<0.05	0.45	0.031	1.1	Secchi depth 10.5 ft
8/30/2021 11:38	0.088	<0.05	0.54	0.024	1.3	Secchi depth 8 ft
8/30/2021 11:38	0.08	<0.05	0.53	0.093	1.8	Field replicate
9/1/2021 10:39	-	-	-	-	-	Secchi depth 9 ft
9/6/2021 15:35	0.052	<0.05	0.35	0.019	1.6	Secchi depth 9.5 ft
9/8/2021 14:59	-	-	-	-	-	Secchi depth 11 ft
9/14/2021 13:05	0.093	<0.05	0.35	0.019	1.4	Secchi depth 9.5 ft
10 sample median	0.0885	<0.05	0.455	0.022	1.475	

Table 14–9. Summary of laboratory results at PUF-IMP

Date	NO3-N (mg/L)	NO2-N (mg/L)	TKN (mg/L)	TP (mg/L)	Chlorophyll a (µg/L)	Notes
8/5/2021 9:30	-	-	-	-	-	Secchi depth 8 ft
8/10/2021 11:20	-	-	-	-	-	Secchi depth 10 ft
8/12/2021 10:35	0.091	<0.05	0.41	0.077	1.3	Secchi depth 11 ft
8/17/2021 10:40	0.11	<0.05	0.58	0.077	1.8	Secchi depth 11 ft
8/23/2021 11:15	0.12	<0.05	0.33	0.094	1.3	Secchi depth 10.5 ft
8/30/2021 12:45	0.082	<0.05	0.56	0.075	1.5	Secchi depth 8 ft
8/30/2021 12:45	0.087	<0.05	0.5	0.09	1.6	Field replicate
9/1/2021 12:47	0.11	<0.05	0.33	0.079	1.5	Secchi depth 9 ft
9/6/2021 12:05	0.066	<0.05	0.4	0.018	1.6	Secchi depth 9.5 ft
9/8/2021 12:10	0.1	<0.05	0.23	0.022	1.4	Secchi depth 11 ft
9/14/2021 12:00	0.089	<0.05	0.97	0.021	2	Secchi depth 9.5 ft
10 sample median	0.0955	<0.05	0.405	0.077	1.525	

Table 14–10. Summary of laboratory results at PLF-IMP

Date	NO3-N (mg/L)	NO2-N (mg/L)	TKN (mg/L)	TP (mg/L)	Chlorophyll a (µg/L)	Notes
8/5/2021 11:40	0.057	<0.05	0.45	0.022	1.8	Secchi depth 8 ft
8/10/2021 12:55	0.11	<0.05	0.44	0.097	1.6	Secchi depth 10 ft
8/12/2021 14:00	0.099	<0.05	0.37	0.062	1.6	Secchi depth 11 ft
8/17/2021 11:35	0.11	<0.05	0.61	0.076	1.4	Secchi depth 11 ft
8/23/2021 12:05	0.13	<0.05	0.47	0.085	1.2	Secchi depth 10.5 ft
8/30/2021 14:15	0.086	<0.05	0.53	0.094	1.6	Secchi depth 8 ft
8/30/2021 14:15	0.086	<0.05	0.47	0.069	1.3	Field replicate
9/1/2021 14:16	0.11	<0.05	0.35	0.028	2	Secchi depth 9 ft
9/6/2021 13:35	0.062	<0.05	0.34	0.017	1.1	Secchi depth 9.5 ft
9/8/2021 13:38	<0.050	<0.05	0.24	0.014	1.6	Secchi depth 11 ft
9/14/2021 14:36	0.091	<0.05	0.52	0.019	1.6	Secchi depth 9.5 ft
10 sample median	0.099	<0.05	0.445	0.045	1.6	

21 Flow Gaging

Flows were estimated for the study utilizing the nearest USGS gage data (prorated based on watershed area as presented in Section 4.5) in combination with station operations data to estimate inflow to each Project and outflows through the tailraces, bypasses, and the Rolfe Canal historic canal channel. To verify the inflow and outflow estimates a water level logger was installed at the PLF-TR station to represent the full outflow from the Projects. The water level logger recorded stage data from 8/11/21 through 9/23/21, which represented all but the first two weeks of the study. Five gaging trips were completed to measure streamflow at various stage levels at PLF-TR and from those data a stage/flow regression was developed (flow (cfs) = $8*10^{-39}e^{0.9495*stage(feet)}$). In addition, five flow gaging measurements were completed at RC-HCC2 to verify the minimum flow requirement through the historic canal channel and five flow gaging measurements were completed at RC-BP1 to verify outflow estimates to the RC bypass reach. Flow gaging measurements and estimated inflows are presented in Table 5-11. A time series of measured stage and estimated flows (both from prorated USGS flow data and from measured stage) is presented in Figure 5-77.

Flow gaging measurements at the RC-BP1 station were collected in August and September at flows ranging from 65-119 cfs, as measured using conventional flow gaging techniques and a flow meter. Estimated flows to the bypass ranged from 100 – 580 cfs, as determined by the difference in estimated inflow (prorated USGS gage data), flows to the historic canal channel, and flows to the tailrace (or 100 cfs, whichever is greater). As shown in Table 5-11, the estimated and measured flows were variable and at times were quite different. The measured flows were generally below the LIHI minimum flow requirement to the bypass reach of 100 cfs, but in all cases were above the FERC license requirement of 50 cfs. Some of the differences in estimated and measured bypass flow were likely due to lag times between the USGS gages and the Project as well as reservoir storage effects (i.e., filling or drawing down of the water surface as hydraulic control settings are changed). Minimum flow requirements to the RC bypass are maintained through the downstream eel passage gate and are not likely to be affected in minor changes in water surface elevation.

Flows to the RC historic canal channel are maintained through a fixed diameter orifice in the RC intake structure and are required to maintain at least 5 cfs. Estimated flows based on canal surface level and standard hydraulic equations were less than 5 cfs and ranged from 4.39 – 4.49 cfs. Measured flows at

Station RC-HCC2 ranged from 3.97 – 5.66 cfs, as determined using conventional flow gaging techniques and a flow meter.

At Station PLF-TR, flows were measured with an ADCP, which typically provides greater accuracy in measurements versus conventional stream gaging techniques with a flow meter. Measured flows at PLF-TR were compared to estimated inflow to the Project (based on prorated USGS gage data as discussed previously). The estimated and measured flows were similar and were within 3-16% RPD and adds confidence in the flow record developed from the water level logger data at PLF-TR. The flow record estimated from PLF-TR water level data is presented in Figure 5-77 and compares those flow data with estimated flows based on prorated USGS gage data. Flow estimates above the maximum (1,635 cfs) and below the minimum (498 cfs) measured values have a high level of uncertainty and are presented with that caveat. Within the measured flow range (498-1,635 cfs), there is generally good agreement between the two methods of estimating flow. However, there are short term variations caused by Project operations that are represented in the flows estimated from water level that are not represented in the USGS flow estimates (due to the USGS gages being located upstream of the Projects).

Table 14–11. Summary of estimated and measured flows at RC-BP1, RC-HCC2, and PLF-TR

RC-BP1		
Date	Estimated bypass flow (cfs)	Measured flow (cfs)
8/11/2021 14:20	149	67
8/18/2021 9:20	100	65
8/31/2021 9:45	100	119
9/7/2021 10:30	580	69
9/13/2021 15:00	378	72
RC-HCC2		
Date	Estimated flow (cfs)	Measured flow (cfs)
8/11/2021 15:15	4.46	3.97
8/18/2021 10:10	4.49	5.04
8/31/2021 11:30	4.44	5.26
9/7/2021 11:22	4.39	5.66
9/13/2021 14:30	4.41	5.49
PLF-TR		
Date	Estimated flow (cfs)	Measured flow (cfs)
8/11/2021 11:30	1,073	1,021
8/18/2021 10:45	459	498
8/31/2021 14:30	1,143	1,109
9/7/2021 14:15	1,860	1,635
9/13/2021 12:45	1,715	1,455

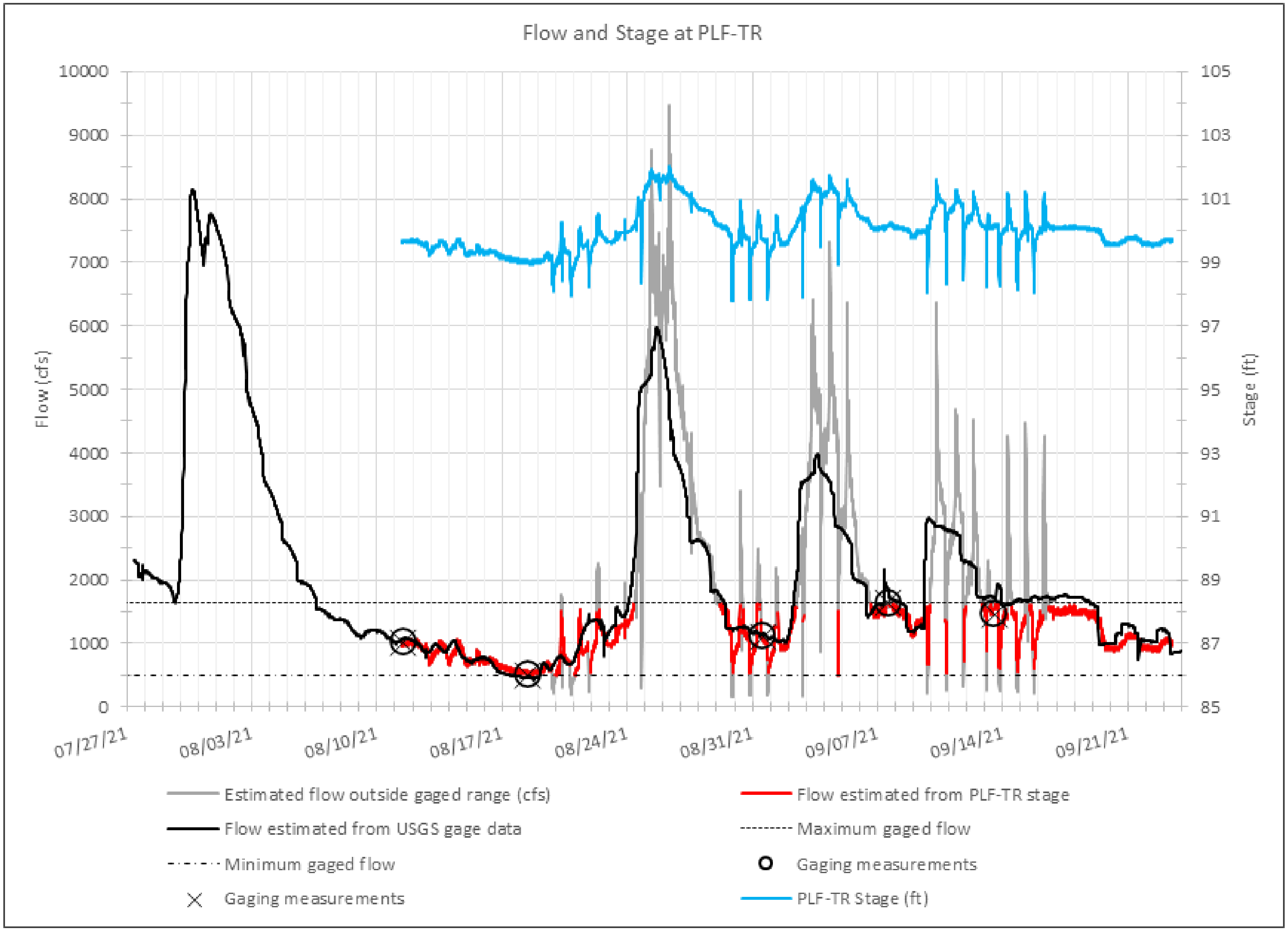


Figure 14–77. Measured and estimated flows and stage at PLF-TR.

22 Summary

The water quality study was completed in accordance with the SAP to maximum extent practicable. Water quality was monitored at 14 stations from July 27, 2021 though September 23, 2021 and included a wide range of flow, temperature, and operating conditions. Water quality was generally excellent throughout the Project study area, with a few exceptions as summarized below.

There were several documented exceedances of the DO standards for Class B waters during this study. At Station RC-INT, DO concentrations dropped below the 5 mg/L standard on July 30, 2021. The daily average DO % saturation also fell below the 75% saturation standard at RC-INT on July 28, 2021 and July 29, 2021. These exceedances of the DO standards occurred during a low flow period when there was no power generation at the RC Project and therefore inflow to the canal was limited to the 5 cfs diversion to the historic canal channel, which likely explains the DO exceedances under those conditions. When power generation resumed on July 30, 2021 the DO levels returned to more typical levels above 7 mg/L. There were also exceedances of the DO standard at RC-IMP on August 12, 2021 and August 17, 2021 as determined during vertical profiles. On August 12, 2021 a DO value of 3.51 mg/L was recorded and on August 17, 2021 a DO value of 1.34 mg/L was recorded. Those dates correspond to periods with minimum flows to the RC bypass and high water temperatures, which likely explains the development of thermal stratification and low DO bottom water in the impoundment. During the same timeframe there was no documented thermal stratification and/or low DO at the RC-INT station and DO levels in the bypass and tailrace were well above the DO standards. Therefore, the low DO area in the impoundment appears to be limited to the middle and lower depths in the area below the diversion and did not appear to affect downstream waters.

There were multiple documented exceedances of the lower pH standard for Class B waters (6.5 s.u.) and no exceedances of the higher pH standard (8.0 s.u.). Exceedances of the lower pH standard were recorded at all stations except RC-BP2 (for which there was only a 10 day record) and RC-HCC2 (where no pH logger was deployed). Low pH is likely a watershed issue in the study area, rather than a Project effect, as low pH (including exceedances of the pH standard) was documented at the RC-US station, above the influence of the Project.

Project operations had measurable effects on water quality in the Project area, particularly in the stations below the Rolfe Canal/ York Dam. As mentioned above, the presence of the RC dam and the diversion of flows to the RC intake did lead to reduced flows in the lower RC impoundment below the diversion, with documented thermal stratification and low DO bottom water. Below the RC dam there were measurable effects in the RC bypass where spill versus minimum flow conditions affected DO concentrations - with greater daily variations under minimum flow conditions and more stable and slightly higher DO concentrations under spill conditions. The bypass reaches in the PUF and PLF projects were also affected by spill versus non-spill conditions (synonymous with generation and non-generation periods) with slight increases in DO associated with spill conditions.

Step change increases and decreases in DO and pH were documented in the tailrace stations at each of the three Projects, and at the impoundment stations at PUF and PLF, and were associated with transitions between generating and non-generating periods. When power generation was interrupted, there were documented increases in DO of 0.5-2.0 mg/L at these five stations and there were corresponding similar decreases in DO when power generation resumed. A similar effect was documented with pH at the PUF and PLF impoundment and tailrace stations with increases of 0.2-0.5 s.u. when generation was interrupted and a corresponding similar decrease when power generation resumed. These step change increases and decreases in DO and pH are likely an effect of the transition in flow sources from primarily tailrace to primarily bypass. While operations effects on water quality were documented, DO and pH levels were generally comparable between stations during generating periods and were similar to the upstream reference station (RC-US). There were no exceedances of DO standards at any station aside from the RC-INT (during a non-generating period) and RC-IMP (bottom water only).

Water chemistry data indicate that nitrogen concentrations were generally low while phosphorous concentrations were consistently high and were within or above the eutrophic range for lakes in NH (eutrophic range = 0.012-0.028 mg/L). Chlorophyll a was measured at low levels consistently below the NH numeric threshold for an oligotrophic lake of <3.3 ug/L.

The water quality study completed in 2021 and presented in this report was successful in completing the objectives of the SAP, i.e., to assess the effects of Project operations on water quality in the Contoocook River and other potentially affected water bodies, both spatially and temporally, under a variety of operating conditions (in terms of flow, impoundment elevation and power generation) and demonstrate compliance with NH water quality standards.

23 Variances from the Approved Study Plan

The water quality study was completed in accordance with the SAP to maximum extent practicable; however, there were some variances from the SAP as summarized below.

- No pH logger was deployed at Station RC-HCC2 during this study. The addition of Station RC-HCC2 was requested by NHDES on June 30, 2021. There was a supply shortage for water quality instruments in 2021 and no additional pH loggers were available from the manufacturer or equipment suppliers in the interim between NHDES' request for the addition of Station RC-HCC2 and the completion of the study.

- The pH logger at RC-BP2 was moved to PUF-BP on 8/12/21 and no replacement logger was deployed at RC-BP2. The addition of Station RC-BP2 was requested by NHDES on June 30, 2021. There was a supply shortage for water quality instruments in 2021 and no additional pH loggers were available from the manufacturer or equipment suppliers in the interim between NHDES' request for the addition of Station RC-BP2 and the completion of the study. A pH logger was initially deployed at RC-BP2 and later moved to PUF-BP after high flows receded and the station was safely accessible. PUF-BP was determined to be a higher priority station than RC-BP2 as RC-BP1 was collecting pH data immediately upstream of RC-BP2.

- Station PUF-IMP was initially instrumented inside the PUF buoy line and deployed from a shore-mounted cable. This location was chosen as high flows prevented boat access during the first two weeks of the study. The instruments were moved to the final location in deep spot above the buoy line on 8/12/21 when flows receded enough for safe boat access to the site.

- Station PUF-TR was initially located adjacent to the right bank in the tailrace area below the PUF powerhouse and was deployed from a shore-mounted cable. The instrument was moved laterally into the center of the channel (the final location) after flows receded enough for safe site access.

- Lab samples were not collected from Station PUF-IMP until 8/12/21 due to high flows in early August. 8 total samples were collected at PUF-IMP, rather than 10 as specified in the SAP, due to the high flows and inability to safely access the site during the first two weeks of the study.

- In the SAP it was stated that data corrections would be applied to instruments that failed to meet side-by-side QC readings and fouling/drift error QC criteria. However, none of the QC checks indicated data correction was necessary or appropriate for the water quality data collected. In some instances, data was flagged as suspect data that could not be corrected with a weighted linear correction as specified in the SAP. Suspect data are presented in the time series figures (presented and identified as suspect data) but are not included in statistical summaries. Suspect data are summarized in Tables 5-3 and 5-6 and are also presented in Appendix E.

24 References

NHDES (New Hampshire Department of Environmental Services). 2020. 2018 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology. New Hampshire Department of Environmental Services. Available at: https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/r-wd-19-04.pdf.

Normandeau Associates, Inc. 2021. Water Quality Sampling and Analysis Plan: Penacook Lower Falls Hydroelectric Project (FERC Project No.3342); Penacook Upper Falls Hydroelectric Project (FERC Project No. 6689); Rolfe Canal Hydroelectric Project (FERC Project No. 3240). July 2021.

Winter, I.A. and A. M. Kennedy. 1933. Improved type of flow meter for hydraulic turbines. American Society of Civil Engineers, Proceedings. Vol. 59, no. 4. April 1933.

25 Appendices

Appendix A. Water Quality Data.

Appendix B. Instrument Calibration Data.

Appendix C. Instrument QC Summary.

Appendix D. River and Operational Conditions.

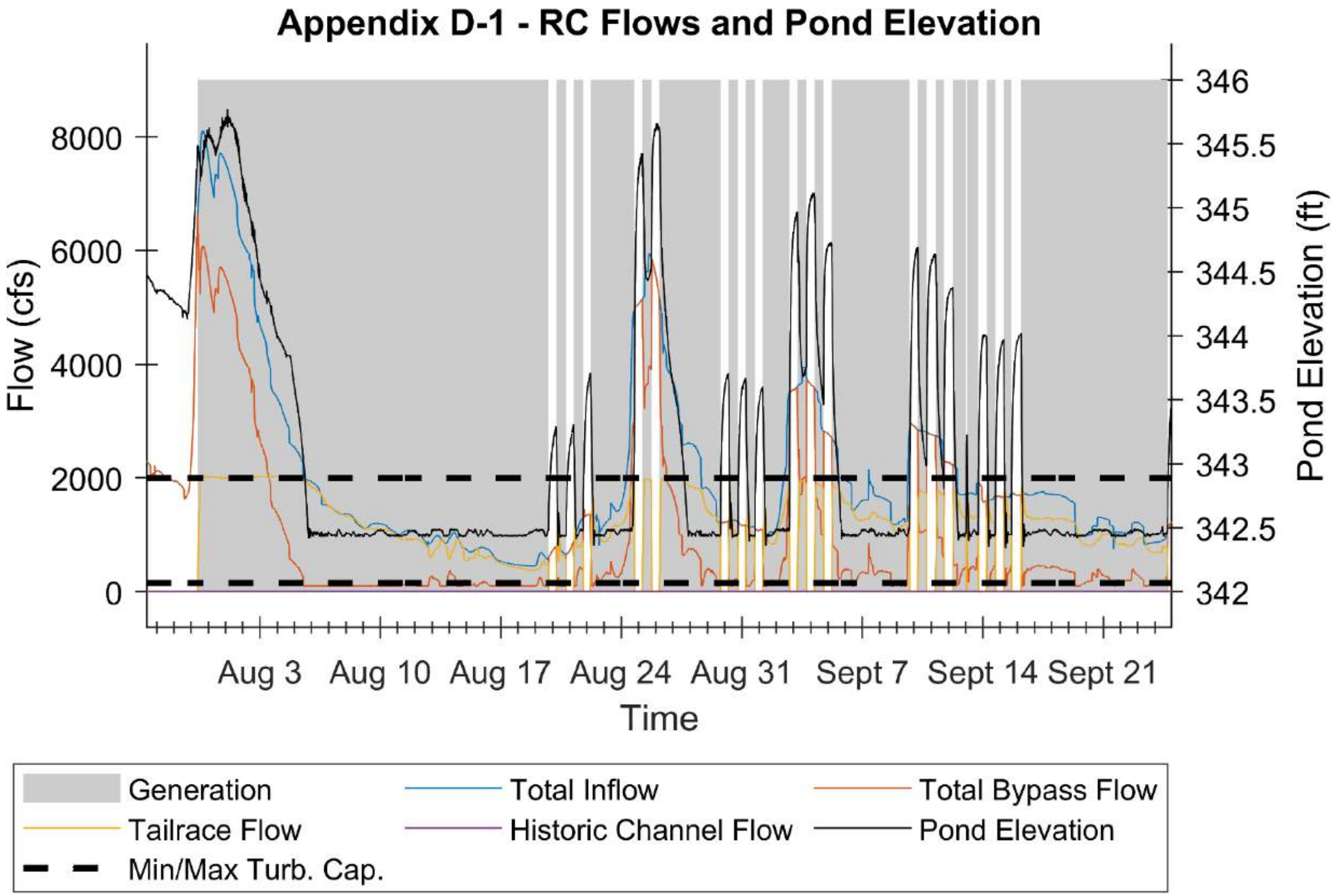


Figure D-1. Rolfe Canal. Pond elevation (ft), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

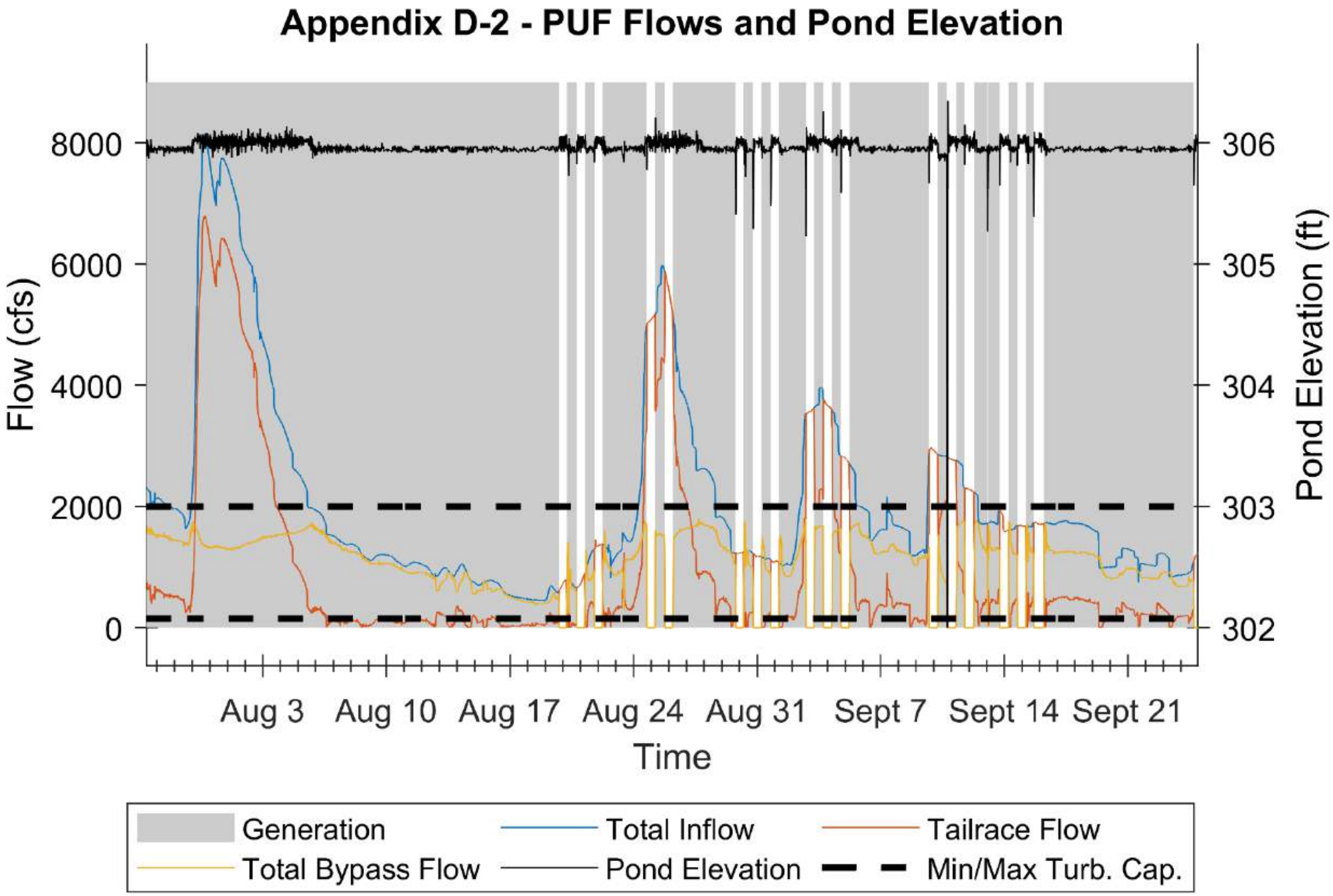


Figure D-2. Penacook Upper Falls. Pond elevation (ft), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

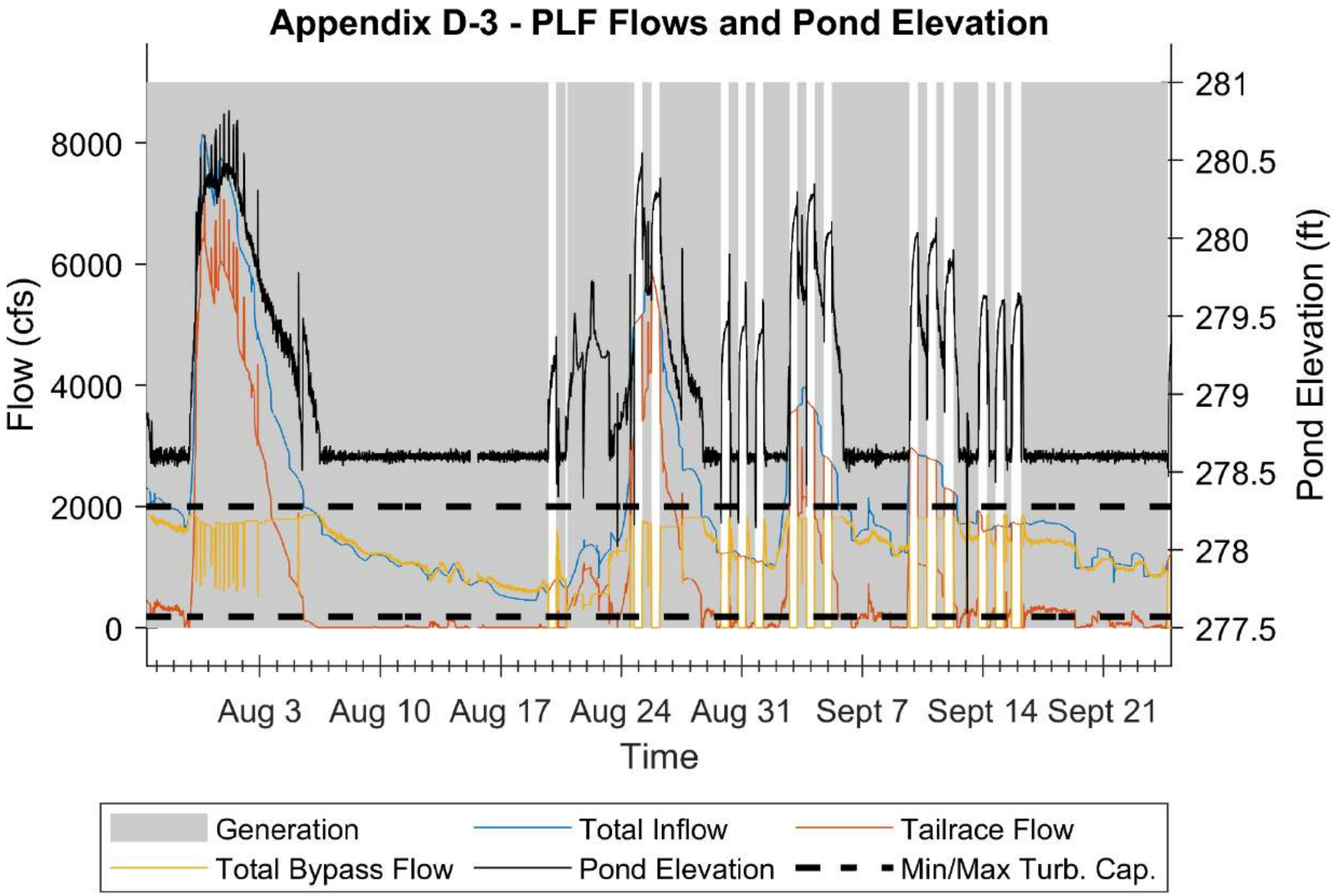


Figure D-3. Penacook Lower Falls. Pond elevation (ft), total inflow (cfs), total bypass flow (cfs), tailrace flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis. Periods of power generation shaded.

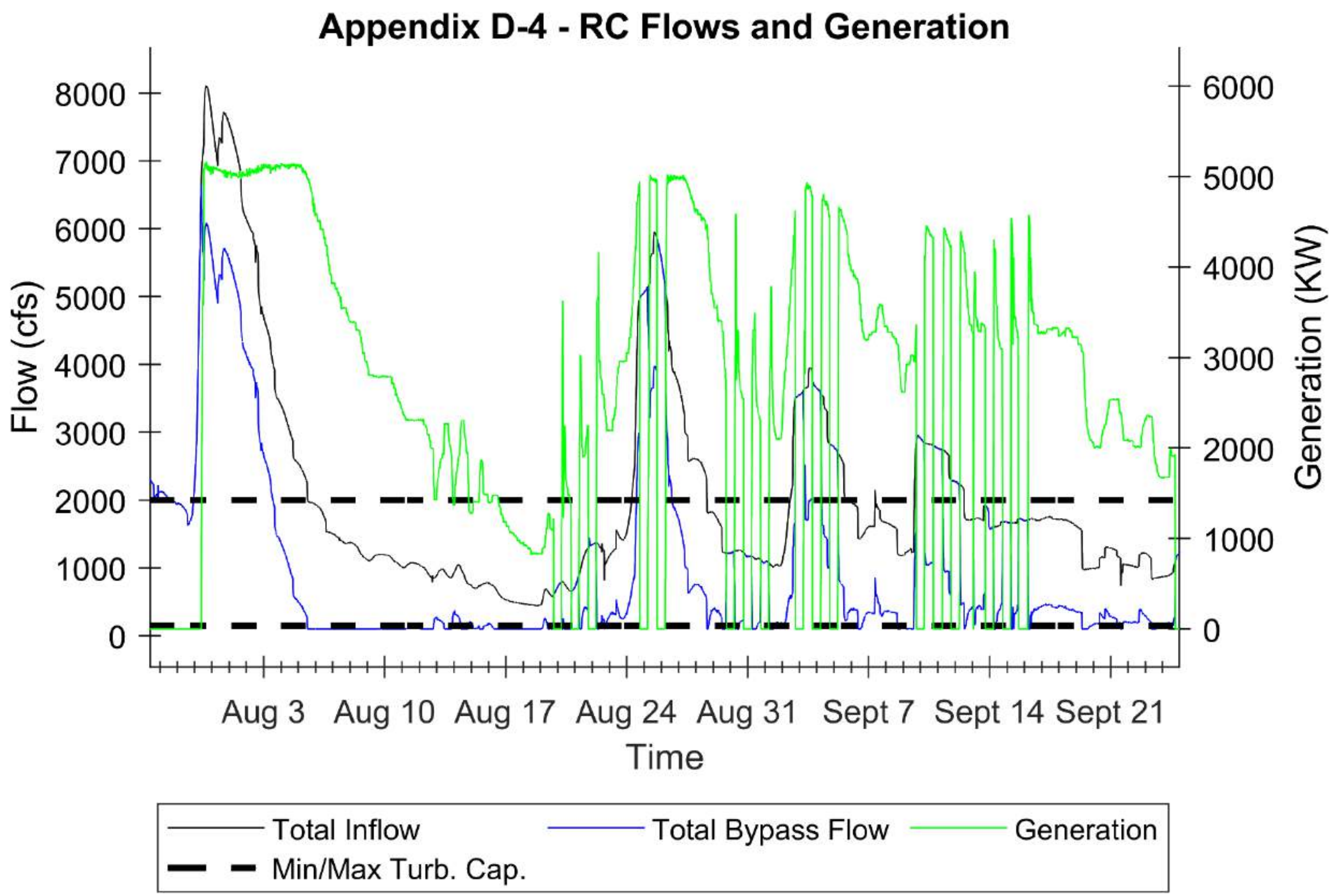


Figure D-4. Rolfe Canal. Generation (KW), total inflow (cfs), total bypass flow (cfs), and minimum and maximum turbine capacity (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis.

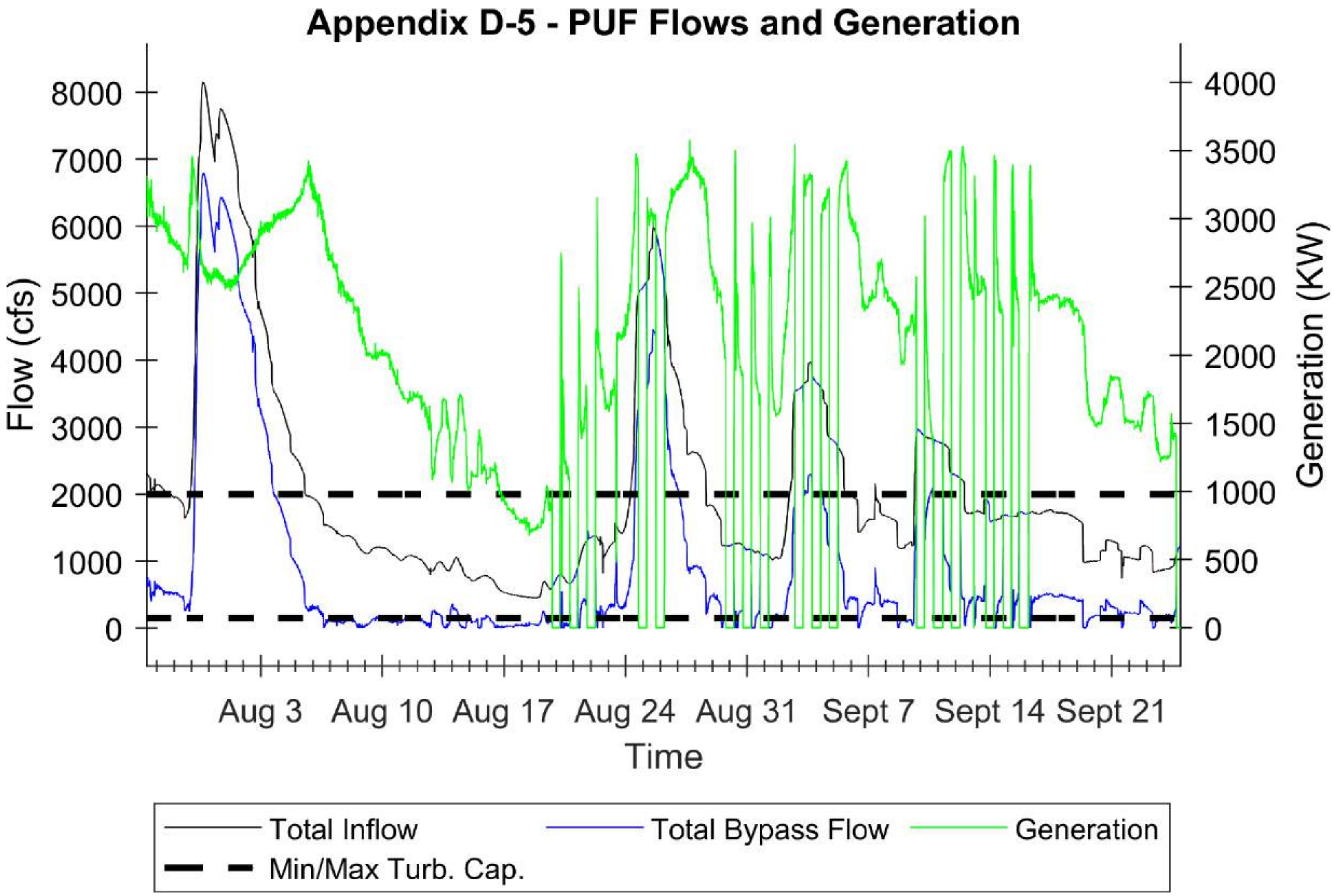


Figure D-5. Penacook Upper Falls. Generation (KW), total inflow (cfs), and total bypass flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis

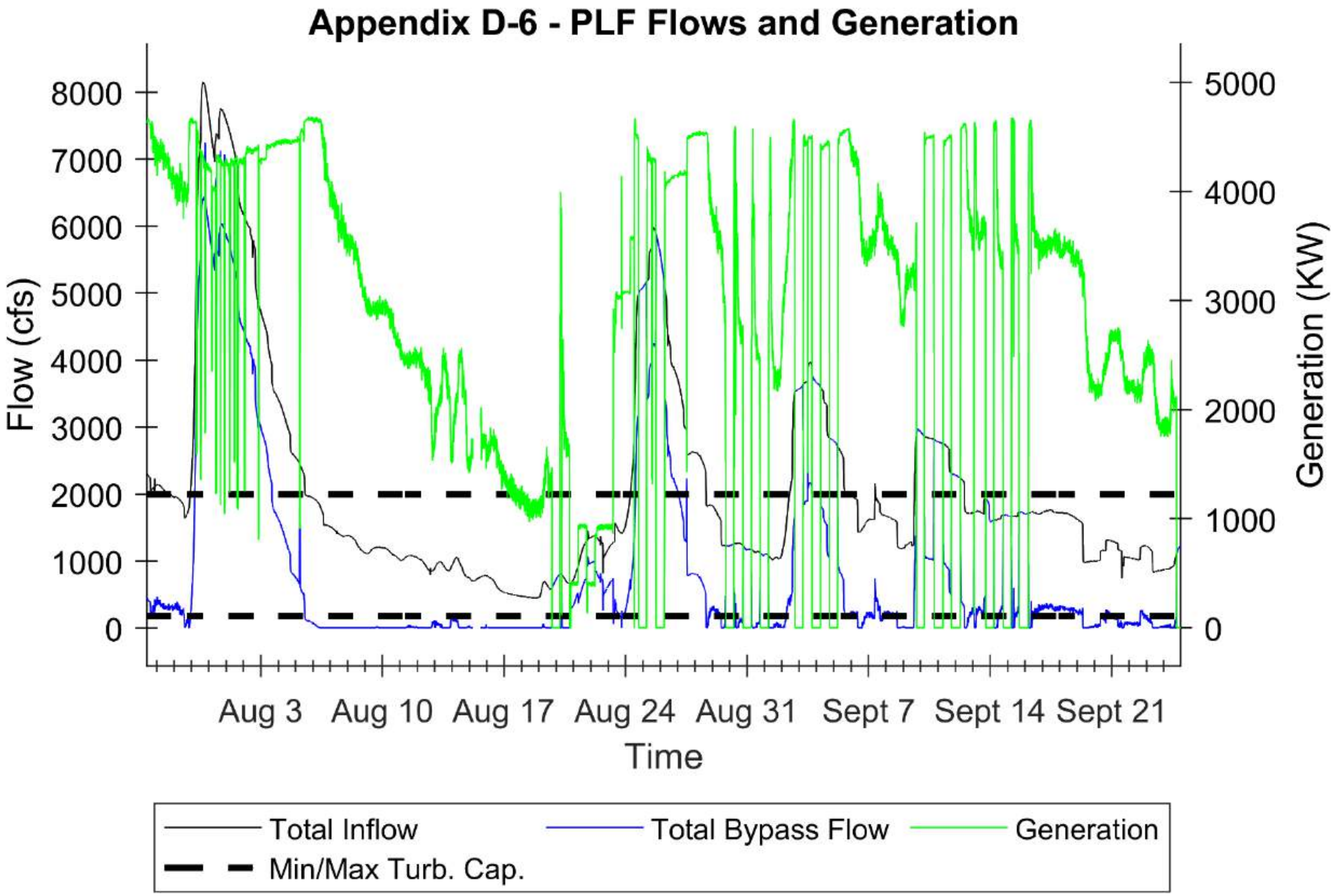


Figure D-6. Penacook Lower Falls. Generation (KW), total inflow (cfs), and total bypass flow (cfs) observed during 2021 study. Minimum and maximum turbine capacity (cfs) shown as solid dotted lines along the horizontal x-axis.Appendix E. Suspect DO and pH records.

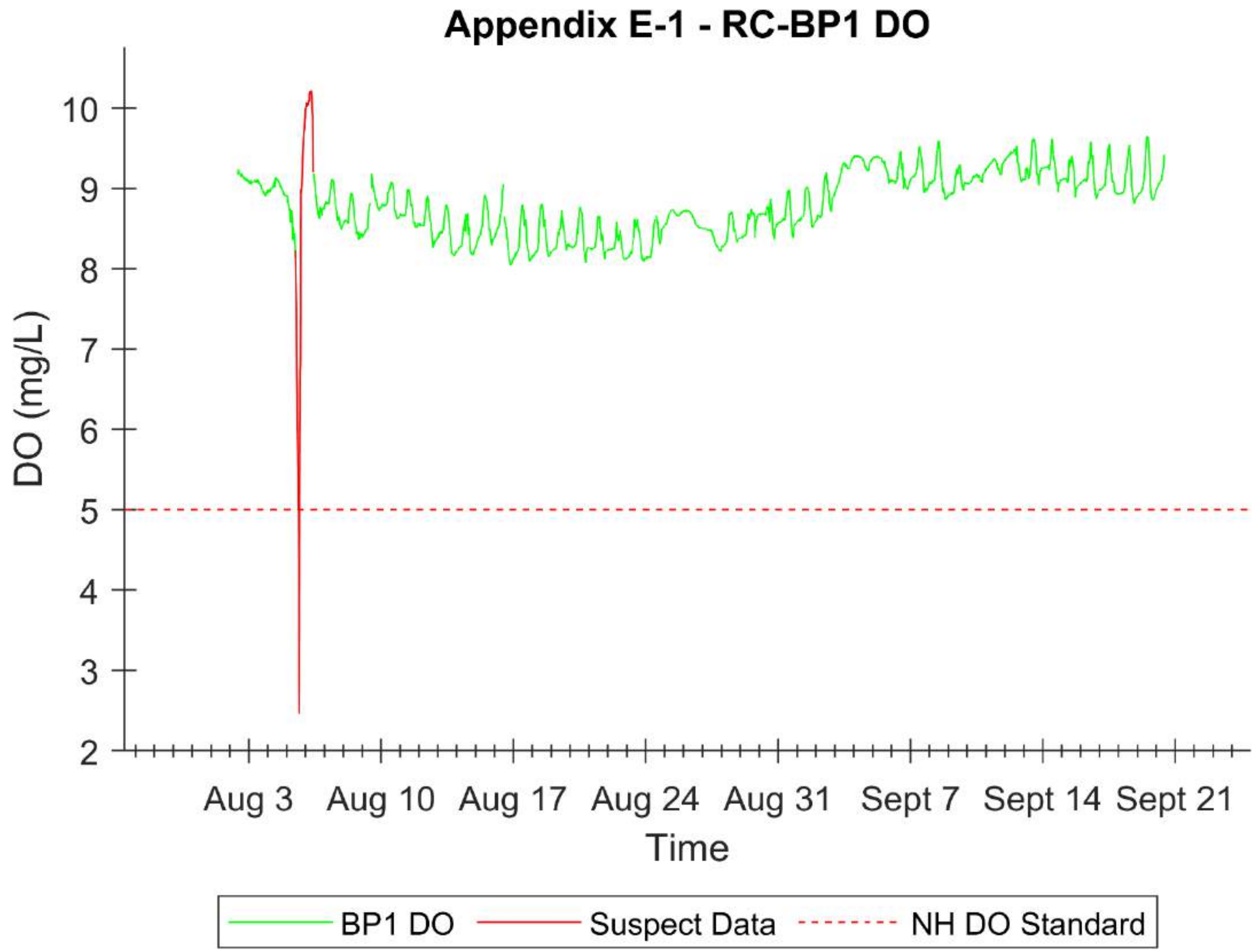


Figure E-1. RC-BP1 DO and suspect DO (mg/L) observed during the 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L.

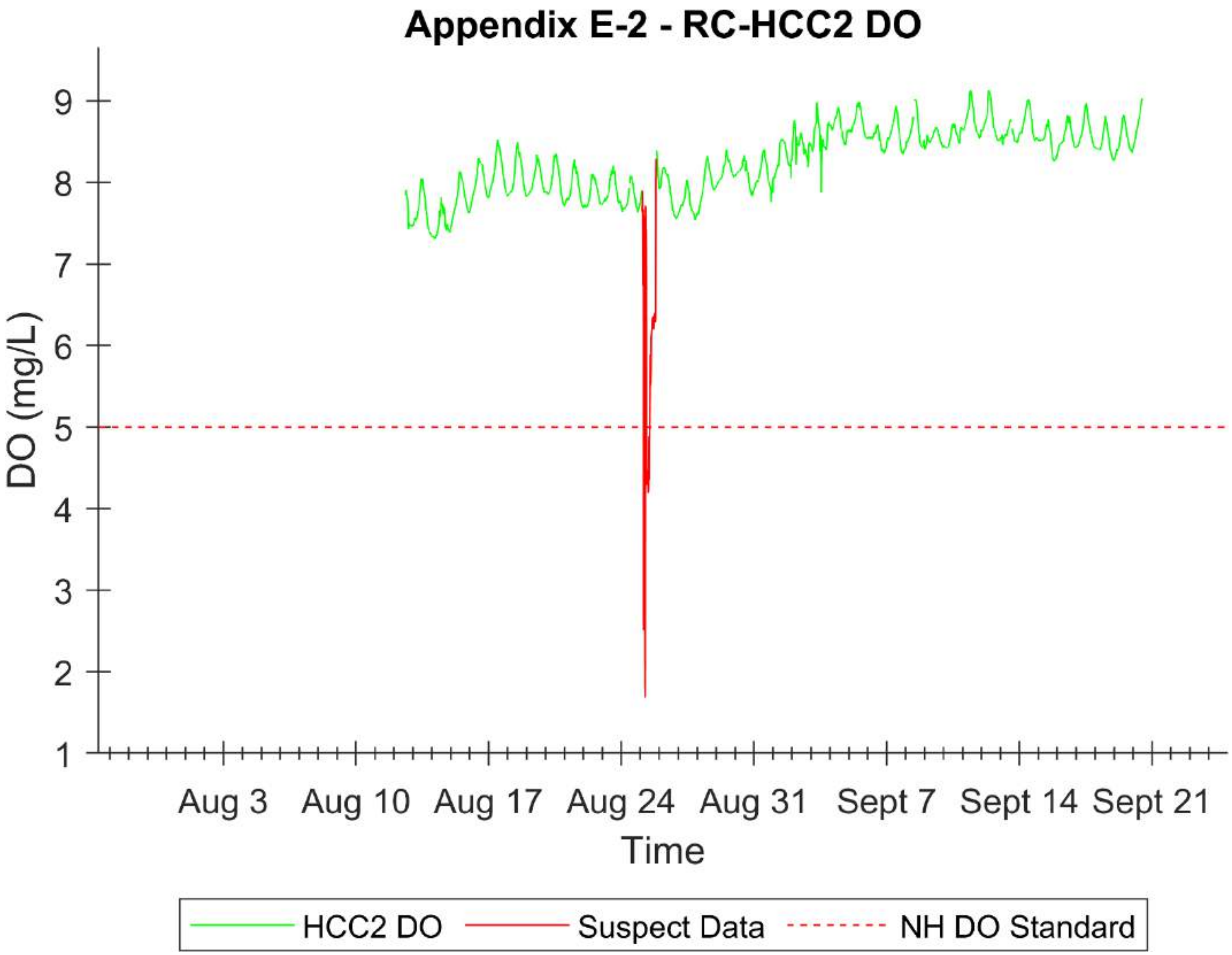


Figure E-2. RC-HCC2 DO (mg/L) and suspect DO (mg/L) observed during the 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L.

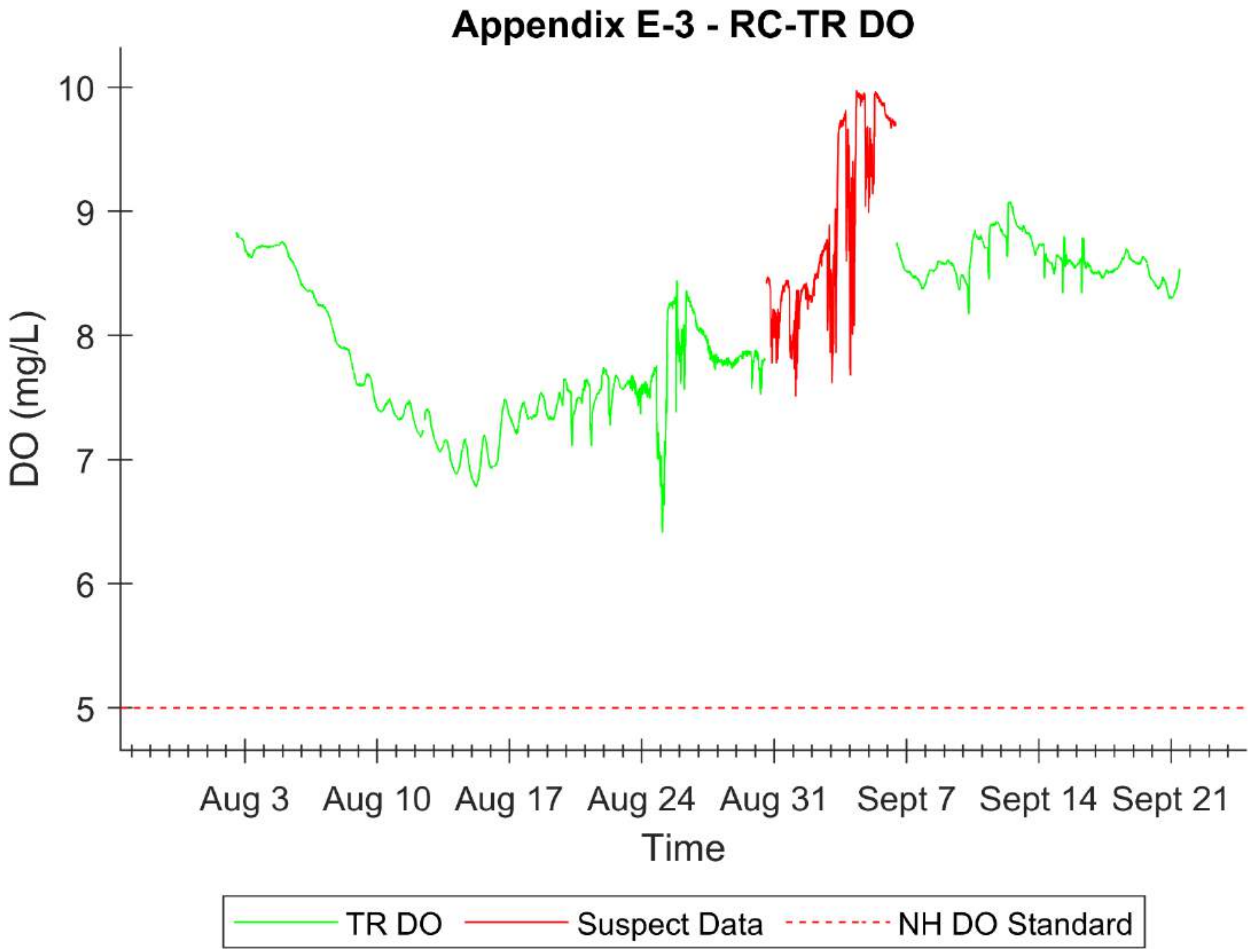


Figure E-3. RC-TR DO (mg/L) and suspect DO (mg/L) observed during the 2021 study. NH instantaneous DO water quality standard shown at 5 mg/L.

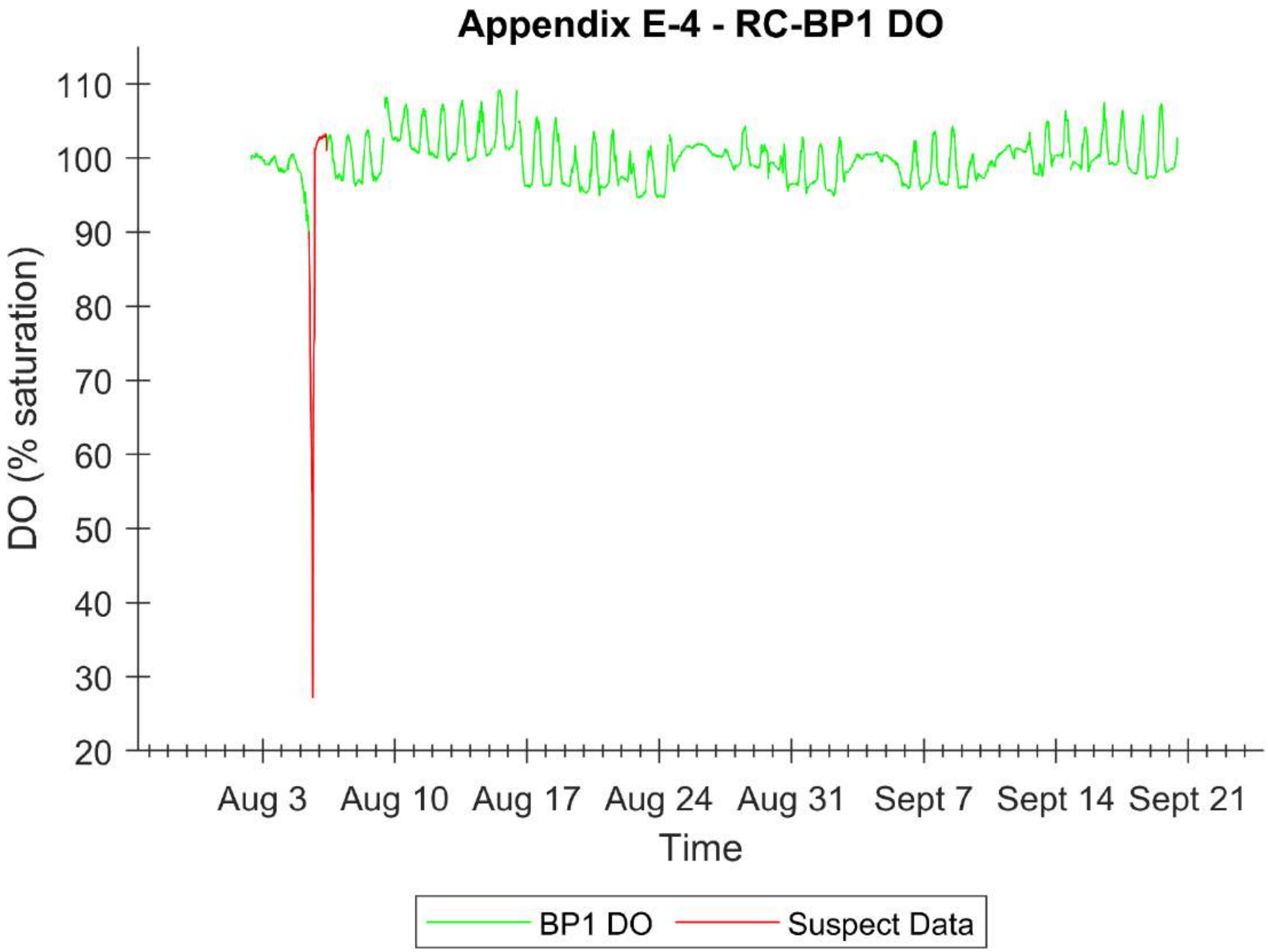


Figure E-4. RC-BP1 DO saturation (%) and suspect DO saturation observed during the 2021 study.

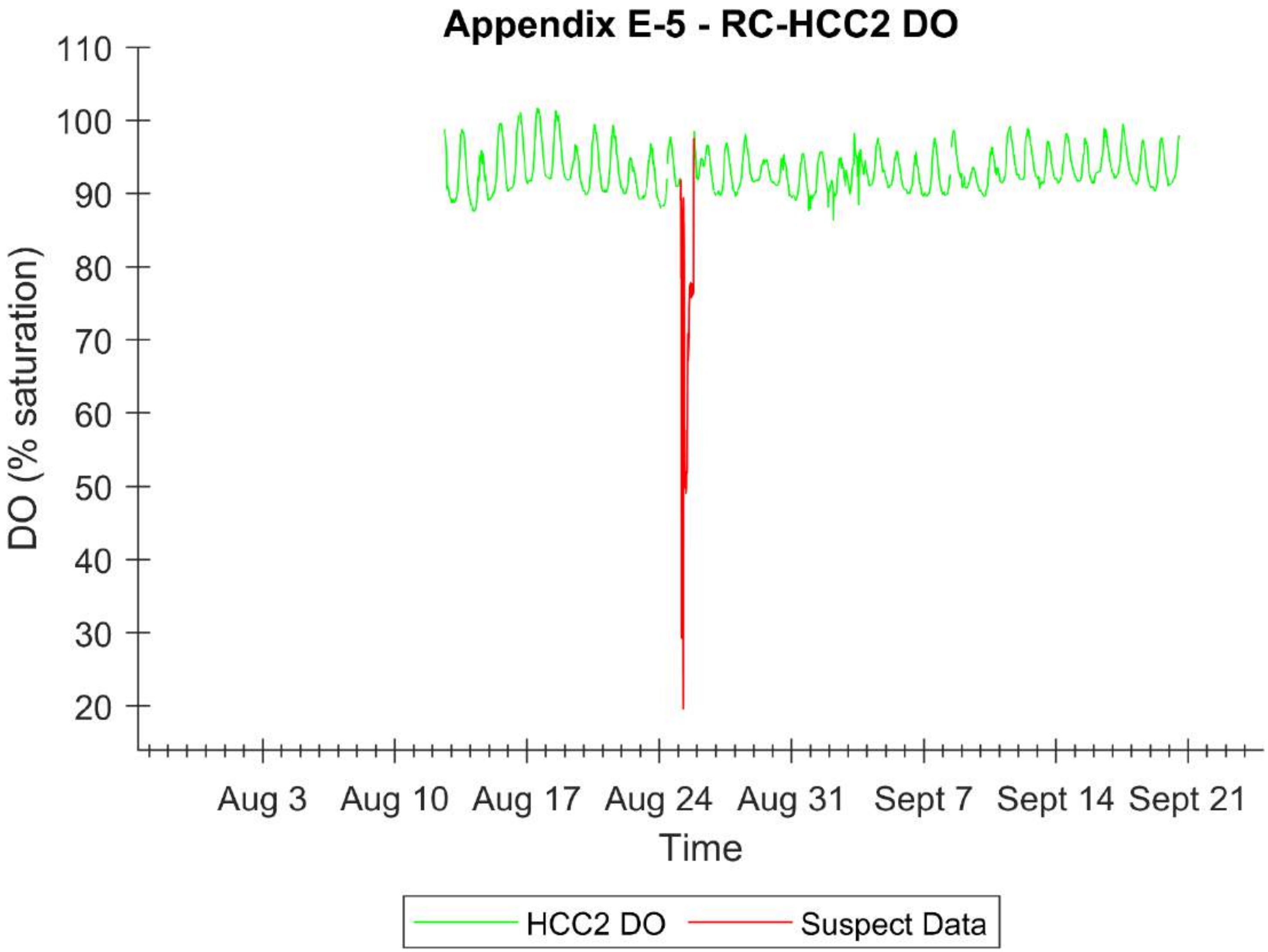


Figure E-5. RC-HCC2 DO saturation (%) and suspect DO saturation observed during the 2021 study.

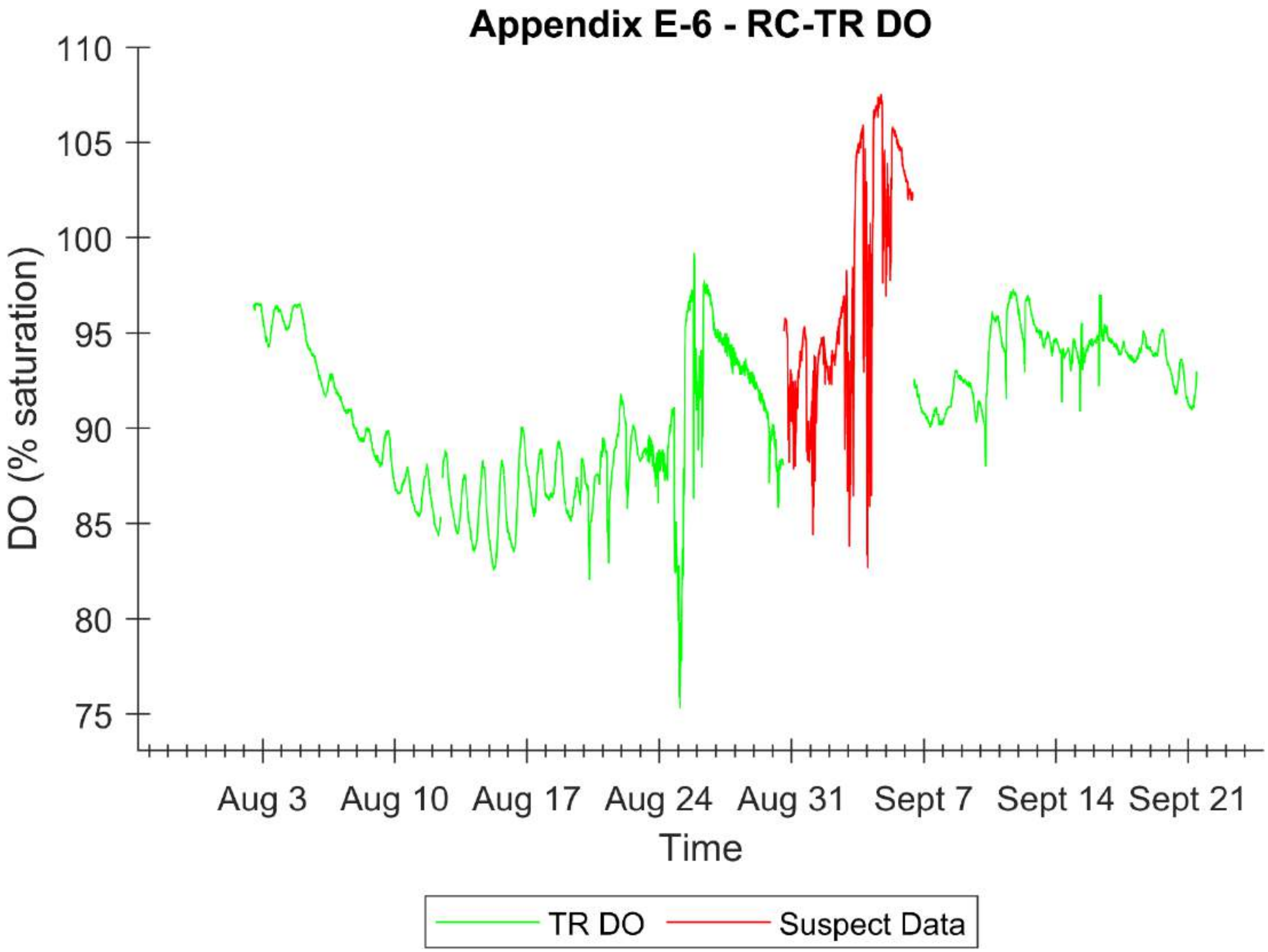


Figure E-6. RC-TR DO saturation (%) and suspect DO saturation observed during the 2021 study.

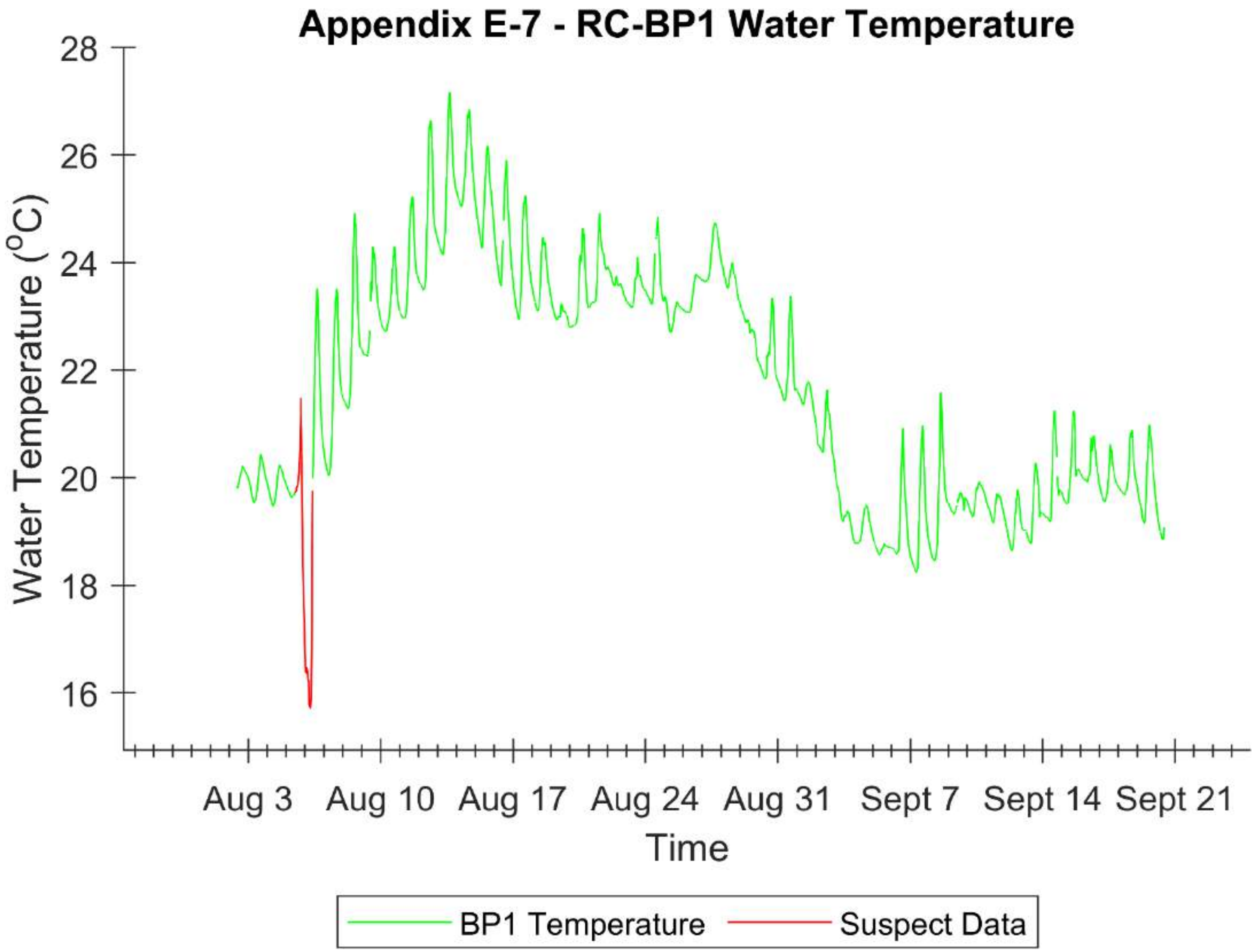


Figure E-7. RC-BP1 Temperature (°C) and suspect temperature observed during the 2021 study.

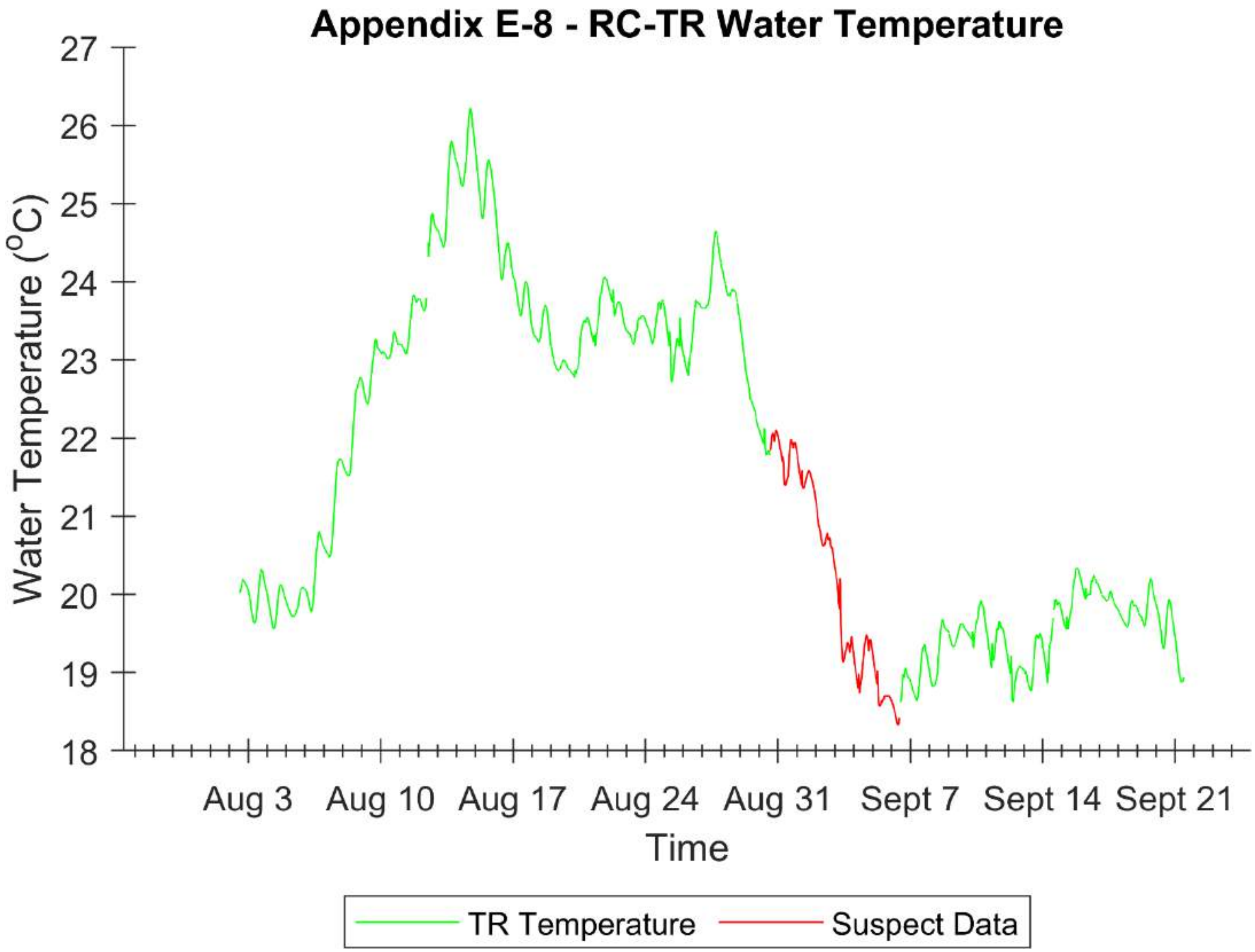


Figure E-8. RC-TR Temperature (°C) and suspect temperature observed during the 2021 study.

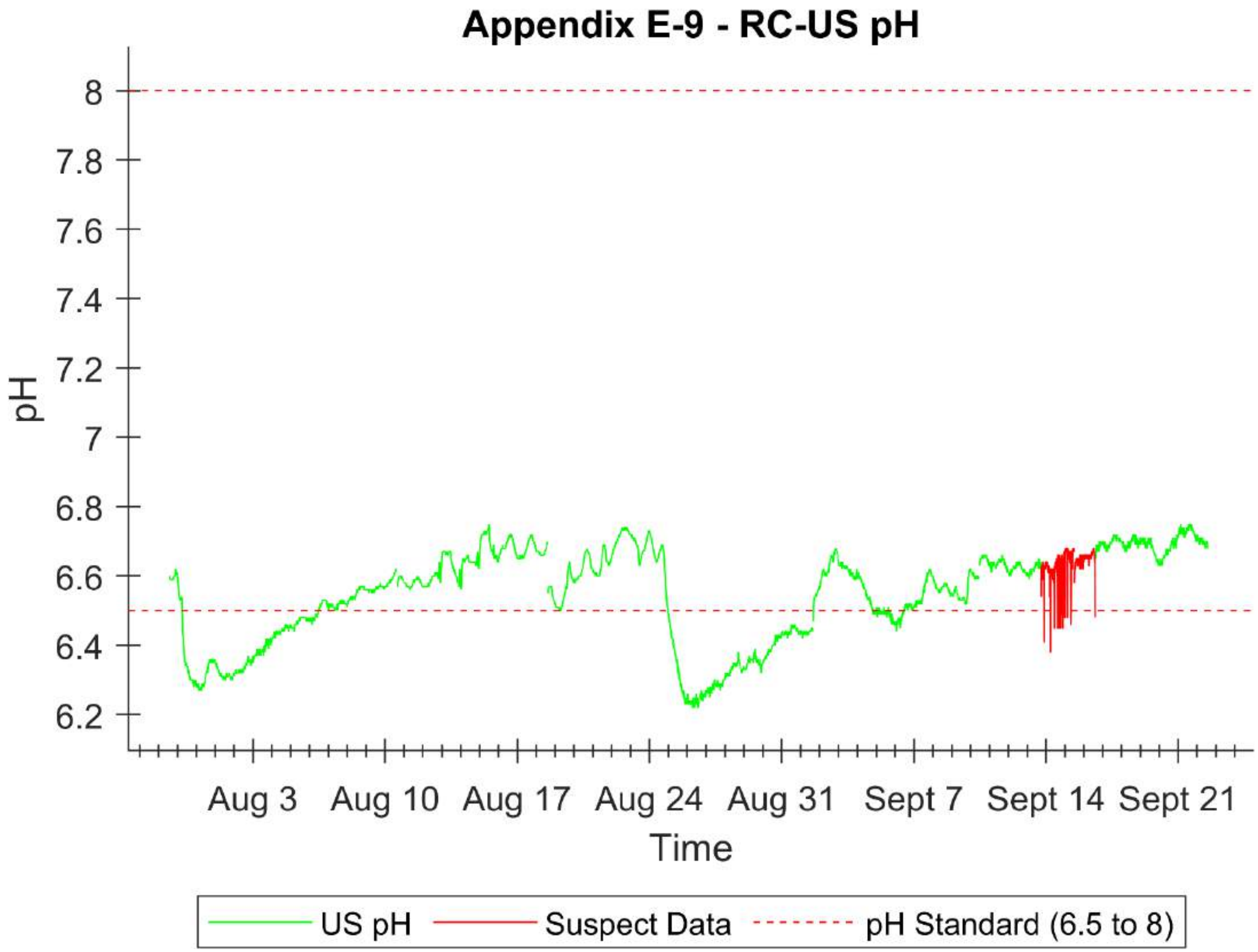


Figure E-9. RC-US pH (s.u.) and suspect pH observed during the 2021 study. NH water quality pH standard shown at 6.5 to 8.

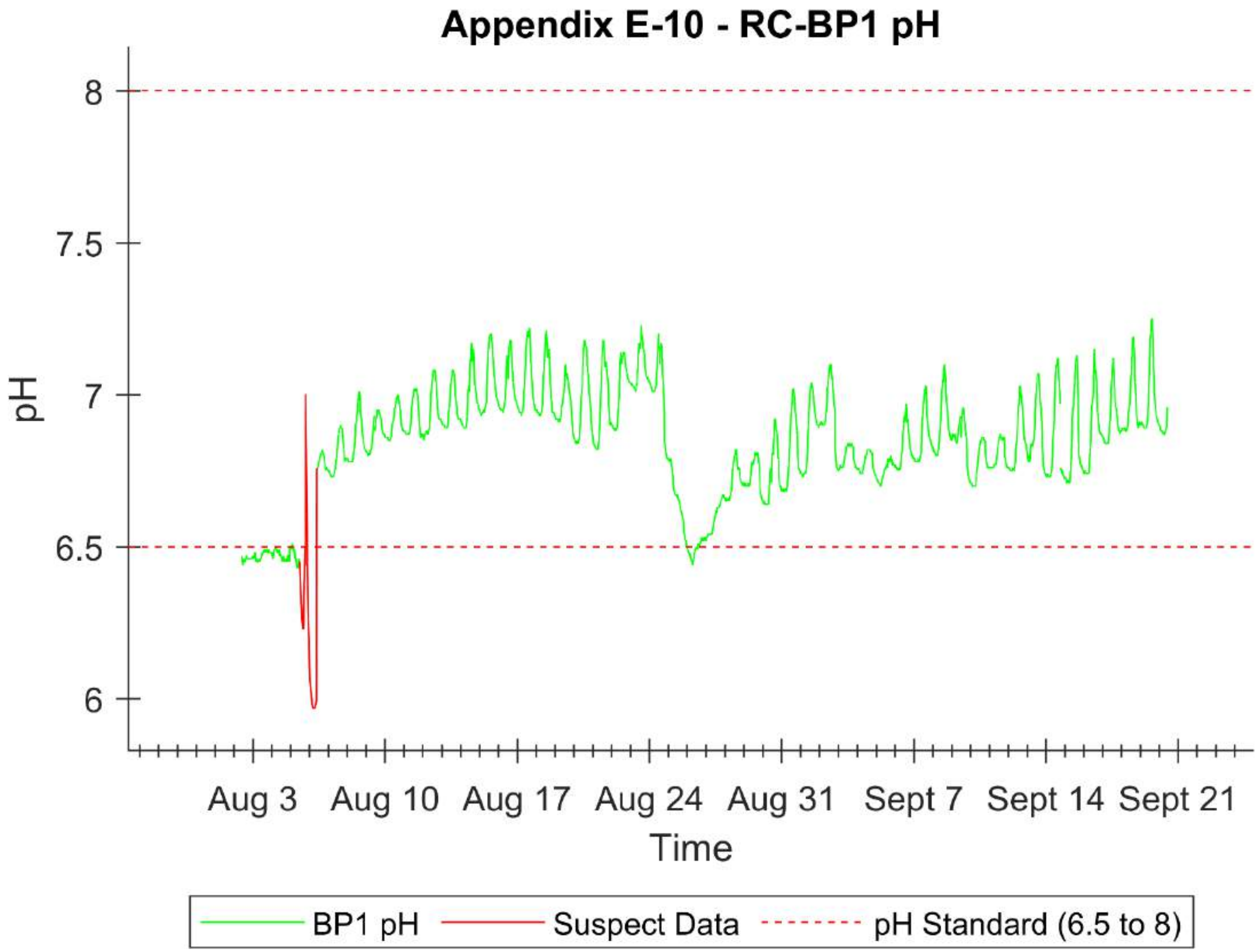


Figure E-10. RC-BP1 pH (s.u.) and suspect pH observed during the 2021 study. NH water quality pH standard shown at 6.5 to 8.

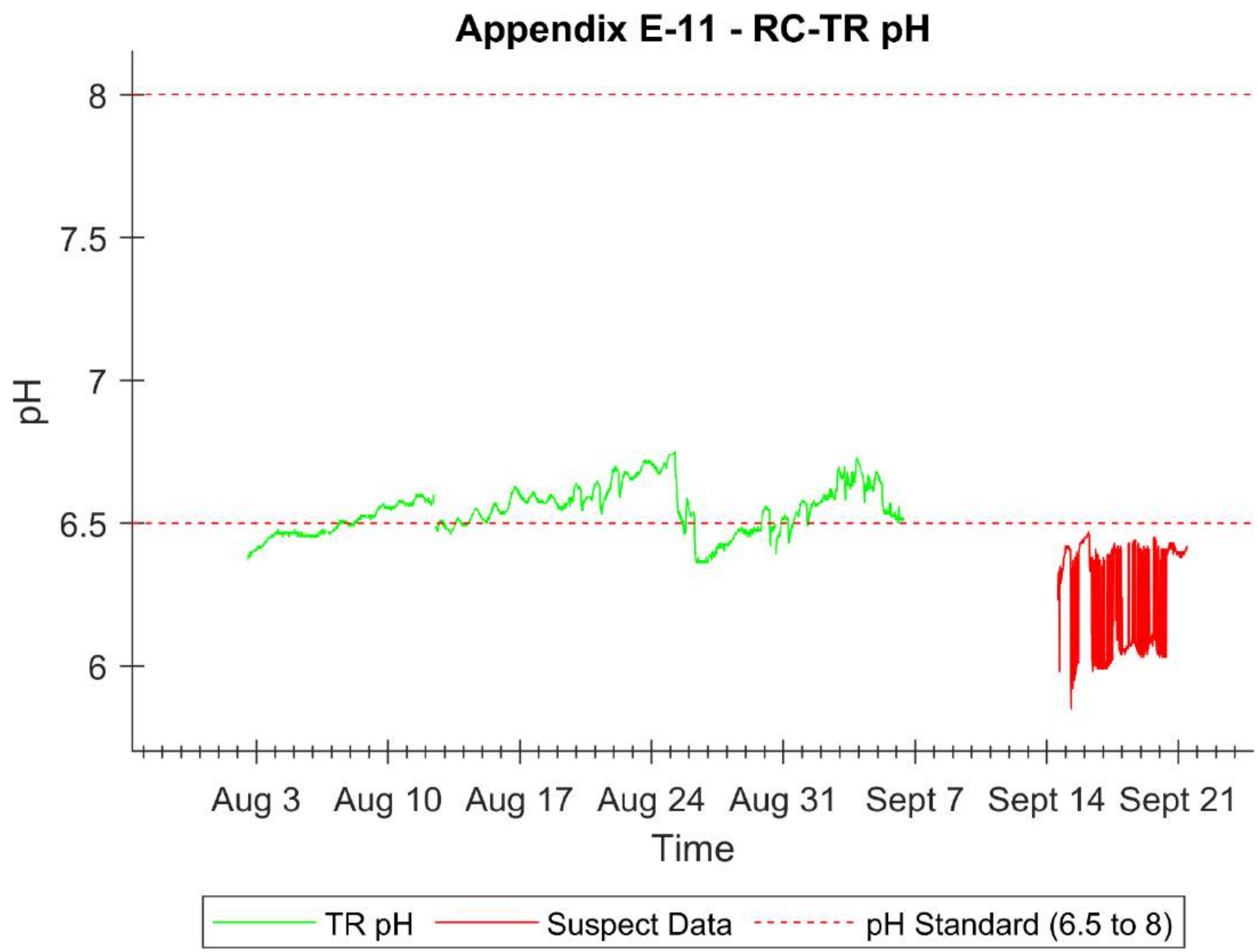


Figure E-11. RC-TR pH (s.u.) and suspect pH observed during the 2021 study. NH water quality pH standard shown at 6.5 to 8.

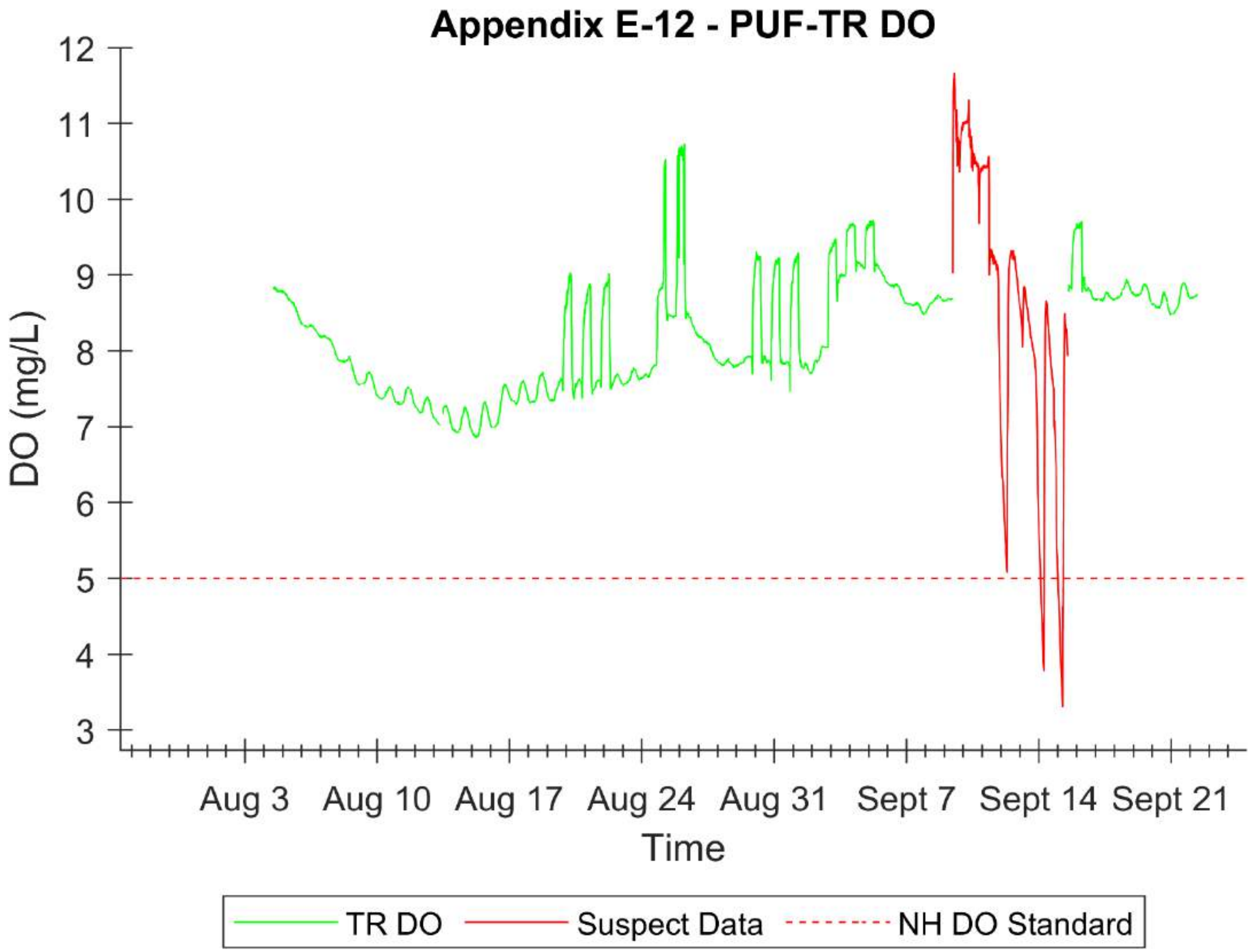


Figure E-12. PUF-TR DO (mg/L) and suspect DO (mg/L) observed during the 2021 study.

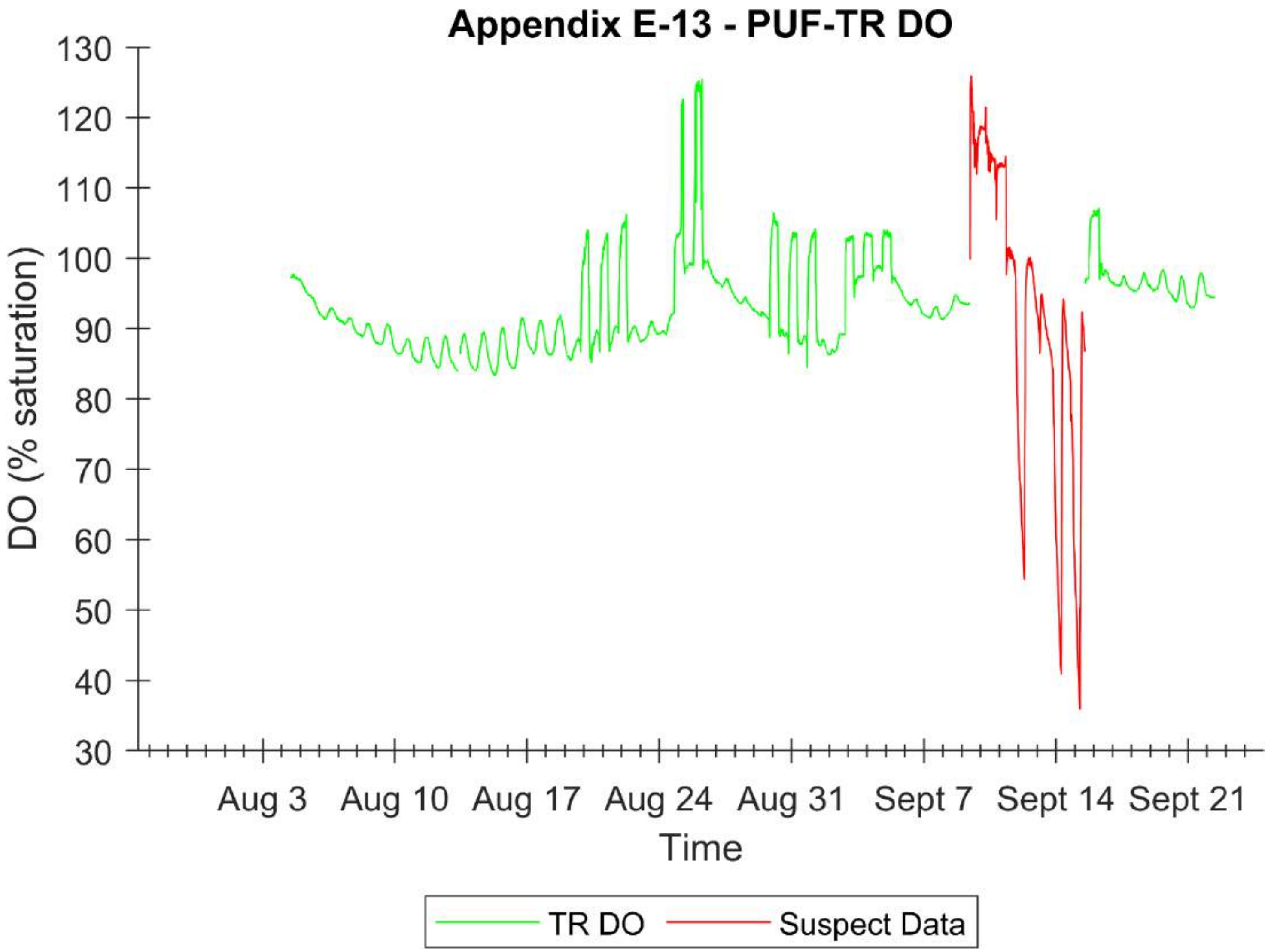


Figure E-13. PUF-TR DO saturation (%) and suspect DO saturation observed during the 2021 study.

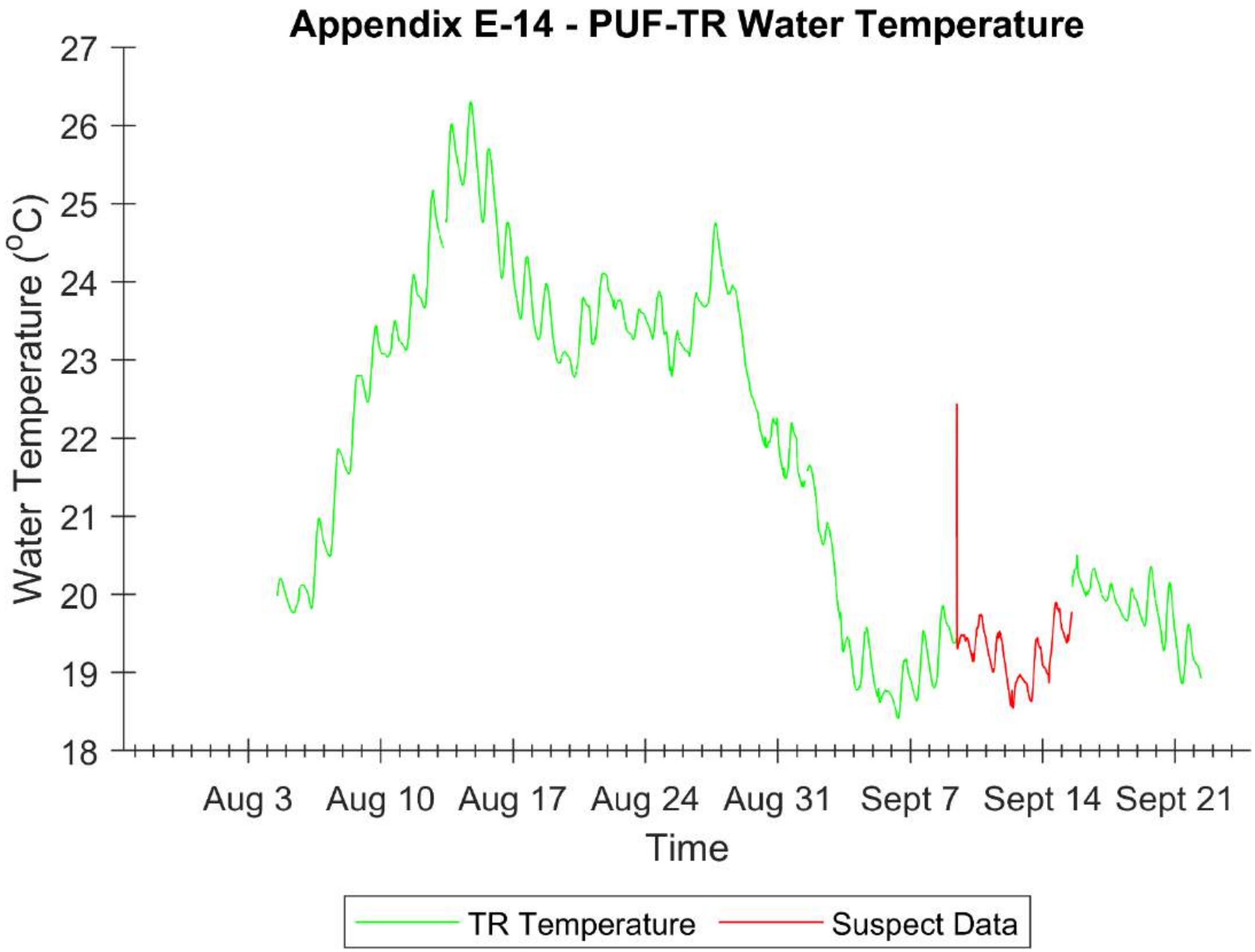


Figure E-14. PUF-TR Temperature (°C) and suspect temperature observed during the 2021 study.

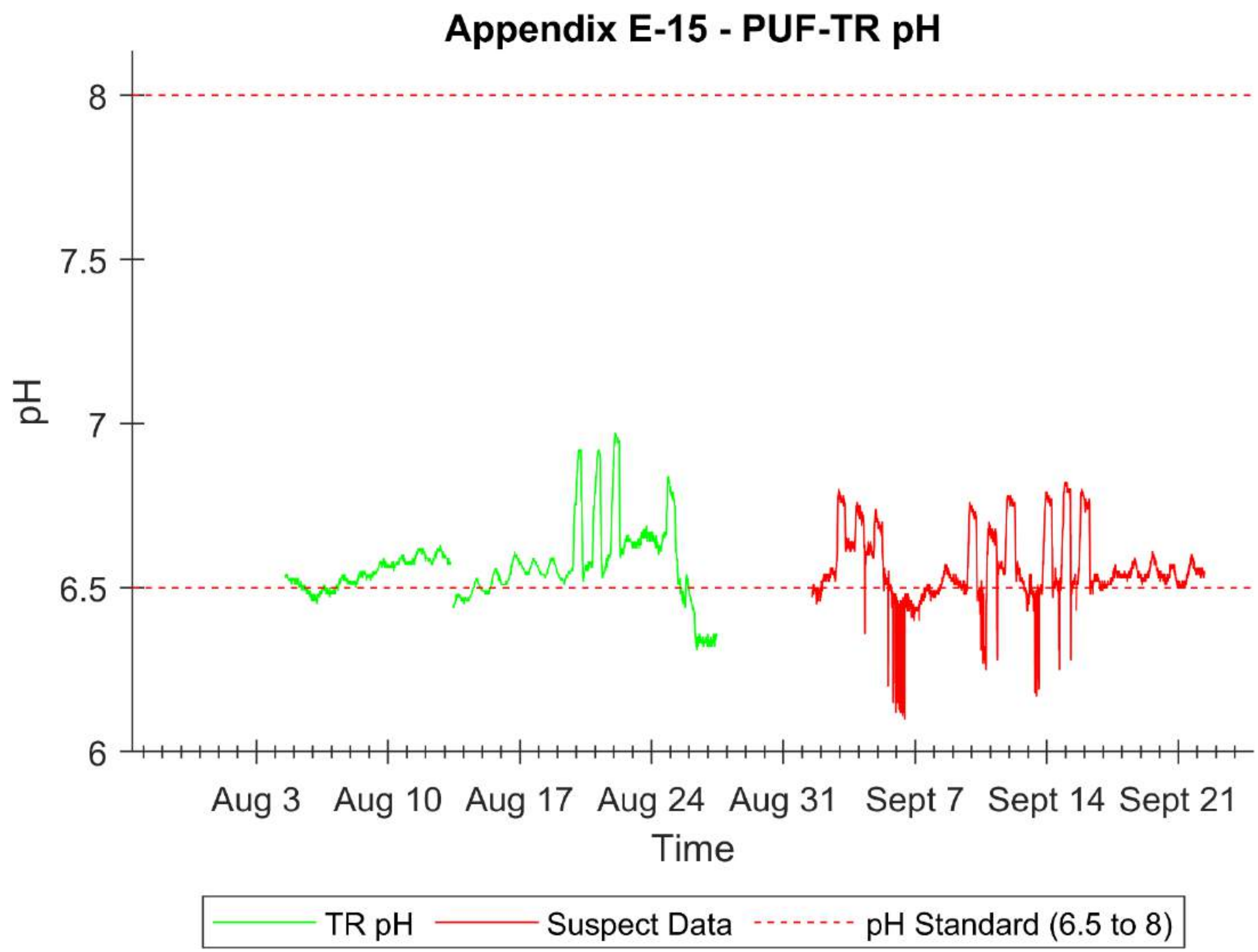


Figure E-15. PUF-TR pH (s.u.) and suspect pH observed during the 2021 study. NH water quality pH standard shown at 6.5 to 8.

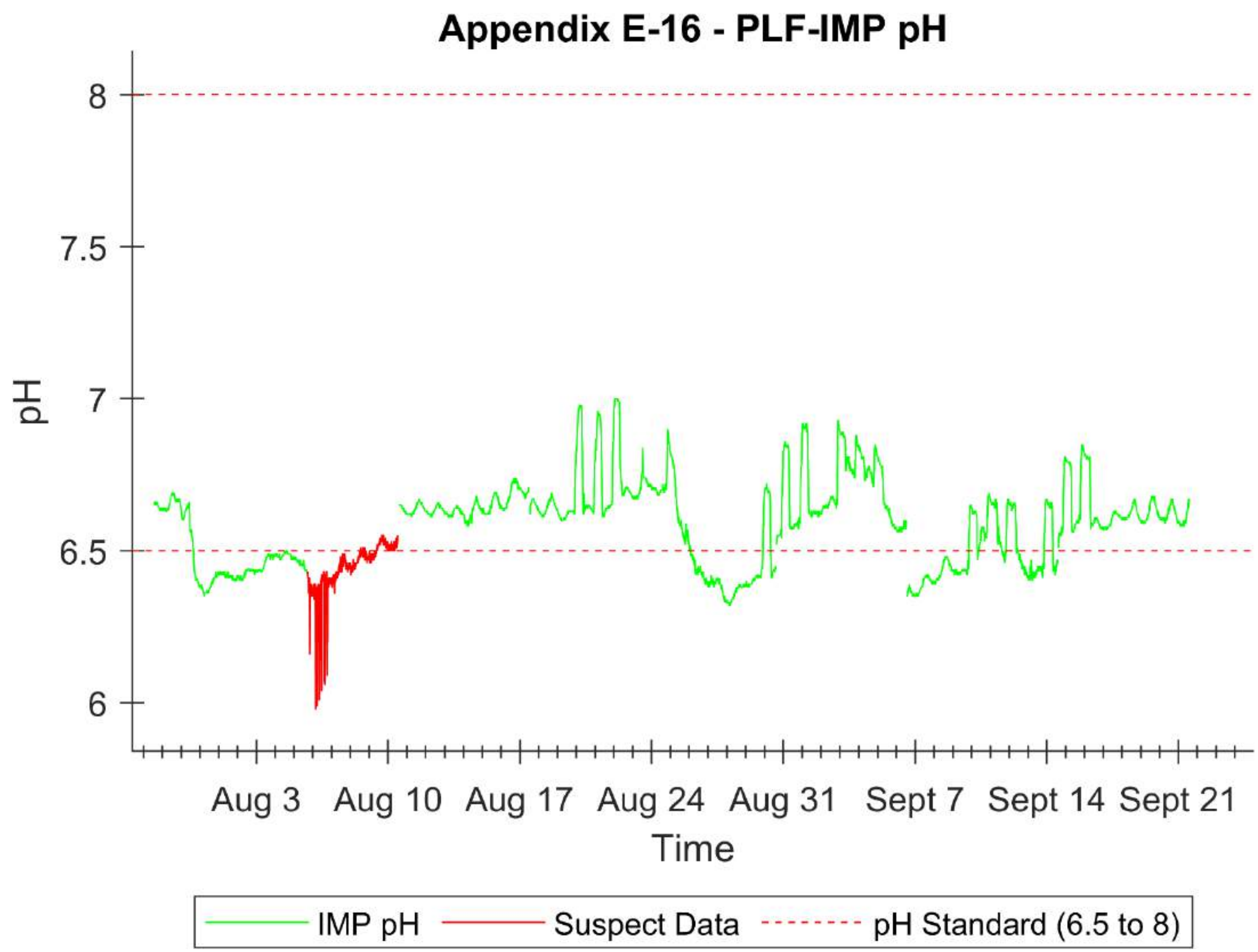


Figure E-16. PLF-IMP pH (s.u.) and suspect pH observed during the 2021 study. NH water quality pH standard shown at 6.5 to 8.

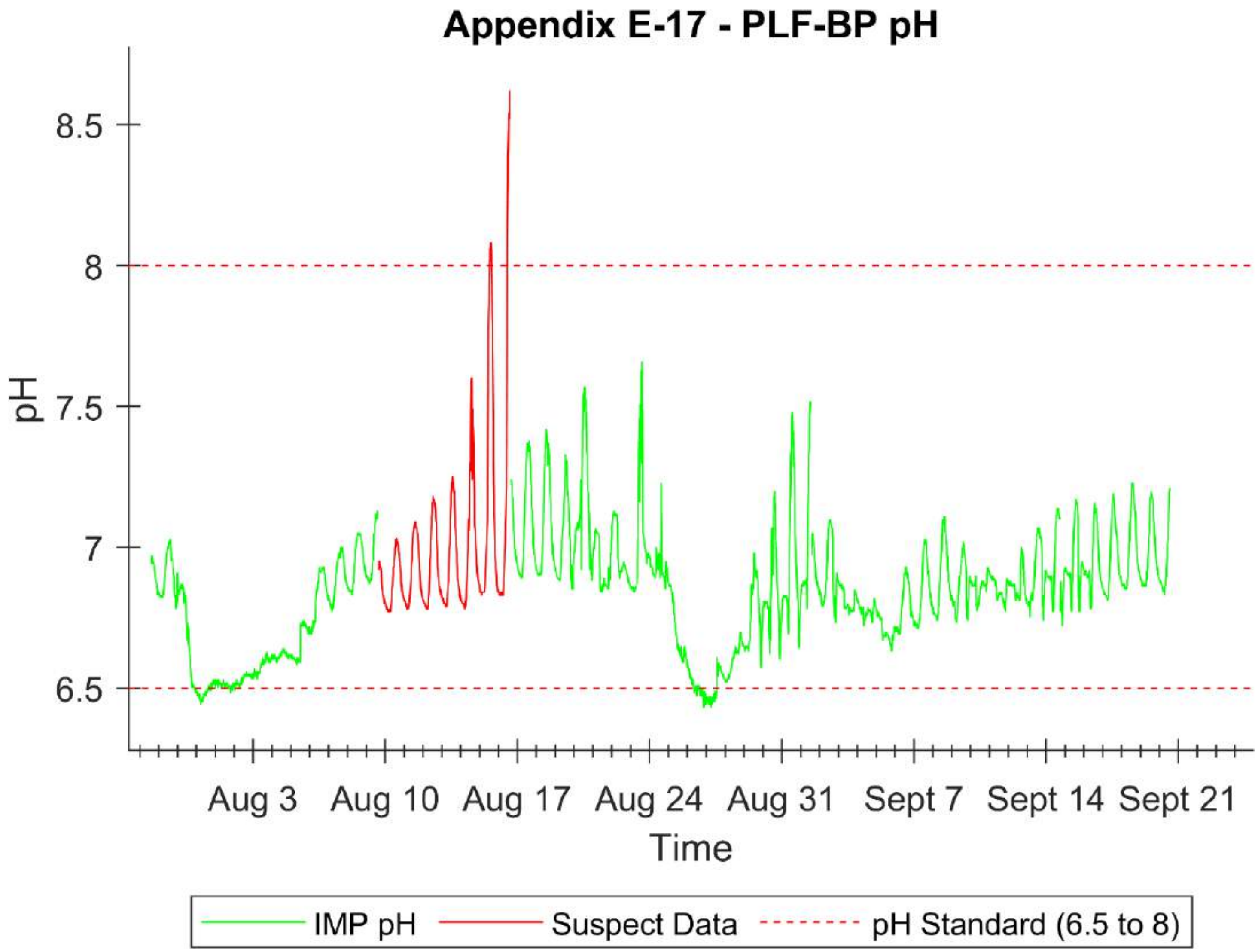
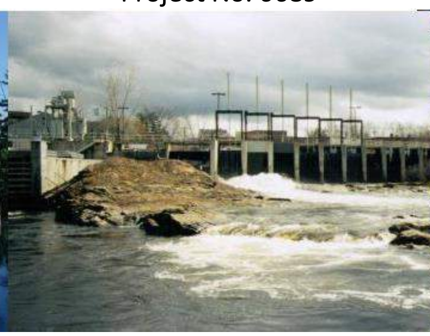
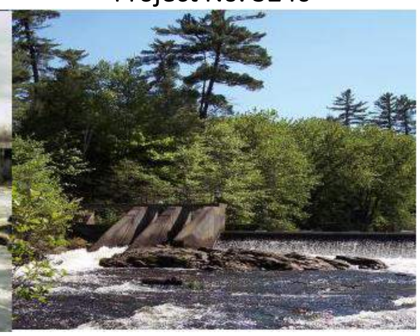


Figure E-17. PLF-BP pH (s.u.) and suspect pH observed during the 2021 study. NH water quality pH standard shown at 6.5 to 8

Instream and Habitat Assessment Study

Briar Hydro Associates

Penacook Lower Falls	Penacook Upper Falls	Rolfe Canal
Hydroelectric Project	Hydroelectric Project	Hydroelectric Project
Project No. 3342	Project No. 6689	Project No. 3240

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February 2022

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Acronyms and Abbreviations

1-D	1-Dimensional (hydraulic modeling)
ADCP	Acoustic Doppler Current Profiler
AWS	Area Weighted Suitability
BMI	Benthic Macro-Invertebrates
cfs	Cubic Feet per Second
FERC	Federal Energy Regulatory Commission
ft	Foot/Feet
fps	Foot per Second/Feet per Second
ftp	File Transfer Protocol
GPS	Global Positioning System
HSC	Habitat Suitability Criteria
IFIM	Instream Flow Incremental Methodology
IFS	Instream Flow Study
NHDES	New Hampshire Department of Environmental Services
NMFS	National Marine Fisheries Service
PLF	Penacook Lower Falls
PSP	Preliminary Study Plan
PUF	Penacook Upper Falls
RSP	Revised Study Plan
SEFA	System for Environmental Flow Analysis
SZF	Stage of Zero Flow
TLP	Traditional Licensing Process
USFWS	U.S. Fish and Wildlife Service
WUA	Weighted Usable Area
XS	Cross-Section

26 Introduction and Background

Briar Hydro Associates (Briar Hydro or Licensee) is in the process of relicensing the Rolfe Canal (FERC No. 3240), Penacook Upper Falls (PUF; FERC No. 6689), and Penacook Lower Falls (PLF; FERC No. 3342) Hydroelectric Projects (Project; collectively, Projects) with the Federal Energy Regulatory Commission (FERC or Commission). The Projects are located on the Contoocook River in Boscawen and Concord, New Hampshire. PLF sits at river mile 0 of the Contoocook River, above the confluence with the Merrimack River. The Upper Penacook and Rolfe Canal Projects are located upstream at river miles 1.0 and 2.0, respectively.

The current Project licenses were issued by the Federal Energy Regulatory Commission (FERC or Commission) in accordance with the Commission’s delegated authority under the Federal Power Act on November 17, 1982 (PLF) and December 5, 1984 (Rolfe Canal and PUF). By FERC order the original April 17, 2018 license expiration for PLF was extended from October 31, 2022 to November 30, 2024 and matching the expiration for the Rolfe Canal and PUF Projects. Briar Hydro is pursuing a new license for the three Projects through the Commission’s Traditional Licensing Process (TLP).

In response to requests provided by the resource agencies as part of the TLP process, Briar Hydro prepared a Preliminary Study Plan (PSP). The intent of the PSP was that the goals, methodology, scope, and schedule would be refined in consultation with interested stakeholders, as necessary. Briar Hydro distributed a copy of the PSP to representatives from the representatives from the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFGD) and the New Hampshire Department of Environmental Services (NHDES) on December 14, 2020. Following receipt and consultation related to comments on the PSP, Briar Hydro prepared a Revised Study Plan (RSP) which was finalized in March 2021 and filed with FERC on July 6, 2021. This report describes the Incremental Instream Flow Methodology (IFIM) and Habitat Assessment Study conducted in support of obtaining a new license for the Project.

27 Goals and Objectives

The goal of this study was to determine an appropriate flow regime that will protect and enhance aquatic resources within the Rolfe Canal Project bypass reach. The specific objective of this study was to conduct an instream flow study (IFS) to assess effects of bypass flow releases on the wetted area, optimal habitat, and/or passage opportunities for target species in the Project bypass reaches.

28 Study Area

The Rolfe Canal Project is located at river mile 2.0 of the Contoocook River upstream of its confluence with the Merrimack River. As noted in the preceding section, the primary study area for this instream flow study (IFS) includes the mainstem Rolfe Canal bypass reach (Rolfe Bypass) from York Dam downstream approximately 4,000 feet to its confluence with the PUF headpond. This reach drops approximately 28 feet for an average gradient of 0.7%. Currently, Briar Hydro releases 100 cfs downstream of York Dam (or inflow if less) when not in spill conditions. The upper half of the Rolfe Bypass is composed of alternating short sections of bedrock ledge and rapids habitat and deeper pool/run habitat (Figure 3-1). The lower half of the bypass is predominantly composed of shallow, cobble/boulder-dominated riffle and run habitat. Channel widths range from 50 feet to over 150 feet. Both banks are lined with mature deciduous and coniferous riparian trees, with limited shrub vegetation on exposed bedrock ledges (Figure 3-2).

The Rolfe Canal bypasses a short, narrow Historic Channel approximately 1,800 ft in length (Figure 3-1). The upper one-third of this Historic Channel is a deep, backwater pool habitat; the lower two-thirds is a narrow (~20 ft wide) low gradient channel bordered by dense riparian vegetation (Figure 3-3). The PUF Bypass is a steep (3%-4%), bedrock-dominated reach 250 ft in length bordered by the powerhouse and outlet canal on the east bank (Figures 3-1, 3-4). The PLF Bypass is a steep (3%-4%), bedrock-dominated reach approximately 680 ft in length bordered by a forested bank on the east and the spillway on the west bank (Figures 3-1, 3-5).

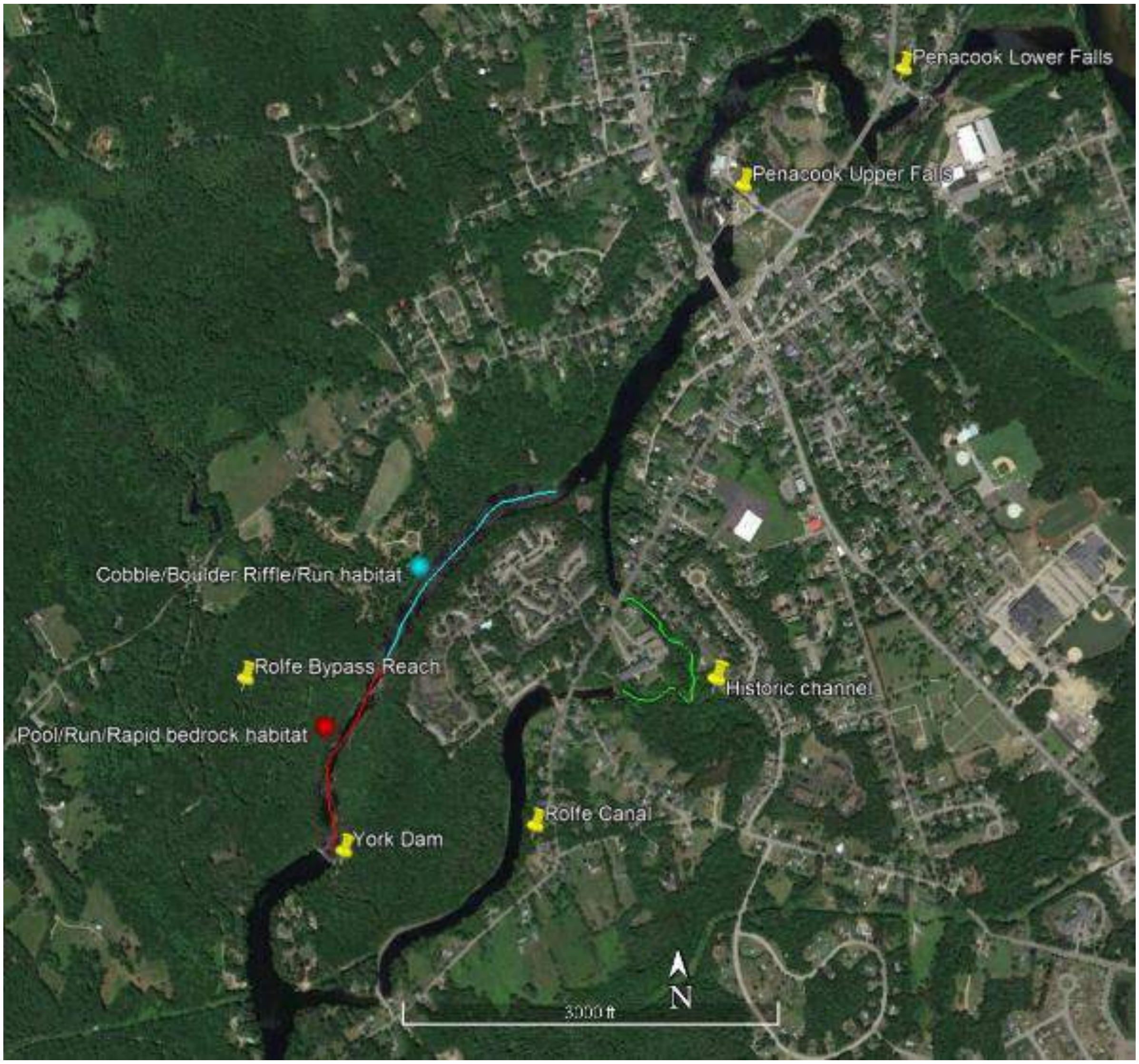


Figure 28–1. Overview of Project area showing Rolfe Bypass channel characteristics, Historic Channel, PUF Bypass, and PLF Bypass.

Figure 28–2. Example of bedrock habitat immediately below York Dam.

Figure 28–3. Historic Channel Bypass reach.

Figure 28–4. PUF Bypass reach.

Figure 28–5. PLF Bypass reach.

29 Methodology

Assessing aquatic habitat among the three Project bypass areas utilized different protocols depending on the specific goals of the study and the characteristics of each location. For example, the Rolfe Bypass was mapped and assessed using a quantitative methodology, 1-Dimensional hydraulic modeling (1-D), in order to estimate the relationship between bypass flows and the quantity and quality of habitat for target fish species and life stages. More qualitative assessments were conducted in the other three bypass reaches due to their short lengths of bedrock-dominated habitat (PUF and PLF), or due to the small size and silt-dominated habitat (historic channel). Qualitative passage assessments were also conducted in each of the four bypass reaches.

30 Habitat Mapping

Characterization of aquatic habitat was conducted in all four bypass reaches by walking along the bank or wading. The mapping data collected and the level of detail differed depending on which bypass was being mapped. Habitat mapping in the Rolfe Bypass was conducted in support of the quantitative instream flow assessment, whereas mapping in the remaining bypass reaches was more qualitative and descriptive in nature.

31 Rolfe Bypass

The Rolfe Bypass reach was mapped on September 1, 2021 under low flow conditions. The reach was delineated into individual mesohabitat units defined as pools, runs, riffles, or cascades (Table 4-1). Biologists walked or waded upstream while assessing habitat characteristics and marked the top and bottom of each habitat unit with a handheld GPS. Representative photographs were taken within each habitat unit[2], and descriptive notes were recorded on channel width, substrate composition, maximum velocity, maximum depth characteristics, and whether the habitat unit was suitable for hosting a 1-D transect. Units were assessed as not suitable for 1-D modeling if they were too steep and/or hazardous to sample under the proposed flow regimes, or if the unit possessed large changes in water surface elevations that could confound modeling efforts. Most units possessed locations that were judged to be applicable for 1-D modeling, with the exception of cascades or high-gradient riffles. Units with prominent (e.g., deep or entrenched) side channels that appeared to connect at relatively low flows were not selected for transect placement, although many selected units contained high flow channels that were traversed by 1-D transects. Unit lengths based on GPS coordinates were summed according to habitat

[2] Digital photographs of habitat units, transect locations, passage sites, etc. for each reach will be provided upon request.

type to determine the percentage (by length) of each habitat type that was available within the bypass reach. These proportions were used to allocate the distribution and number of 1-D transects among each of the habitat types and within individual habitat units, and to calculate transect weighting factors in the System for Environmental Flow Assessment (SEFA) analysis.

Table 29–1. Habitat mapping data for the Rolfe Canal Bypass reach, showing 1-D transect locations

Habitat Unit No.	Channel Type	Habitat Type	Length (ft)	Cumulative Distance (ft)	Width (ft)	Dominant Substrate	Est Max Depth (ft)	Est Max Velocity (fps)	OK for 1D XSEC (Y/N)	Transect No.	Notes
1	Boulder	Riffle	293	293	175	cob/bldr	2.5	3	Y	1	1
2	Boulder	Run	287	580	226	cob/bldr	2	2	Y	2	
3	Boulder	Riffle	125	705	186	cob/bldr	3	3	Y	3	2
4	Boulder	Run	528	1,233	142	cob/bldr	>3.5	2	Y	4	
5	Boulder	Riffle	130	1,363	168	cob/bldr	2.5	2.5	N		2,3
6	Boulder	Run	497	1,860	160	cob/bldr	2.5	2	Y	5	3
7	Bedrock	Pool	202	2,062	99	bldr/bed	-	-	Y	6	3
8	Bedrock	Run	133	2,195	42	bldr/bed	>3	4	N		4
9	Bedrock	Pool	96	2,291	-	bldr/bed	>4	1.5	N		4
10	Bedrock	Run	123	2,414	135	bed	>4	3	N		5
11	Bedrock	Pool	301	2,715	83	bldr/bed	>4	0.5	Y	7	3
12	Bedrock	Run	89	2,804	63	bldr/bed	>4	1.5	Y	8	
13	Bedrock	Pool	313	3,117	77	cob/bldr/bed	>4	2	Y	9	
14	Bedrock	Riffle	141	3,258	75	bldr/bed	2	>3	~N		6
15	Bedrock	Run	87	3,345	160	bldr/bed	2.5	1.5	~Y		7
16	Bedrock	Pool	159	3,504	133	bed	>4	-	N		8
17	Bedrock	Cascade	272	3,776	-	bed	-	-	N		9

[1] lower half w midchannel island

[2] riffles with slight increase in gradient and velocity from runs

[3] high flow channel w different WSEL along one or both banks through all or part of unit

[4] multiple bedrock channels

[5] angular/transverse flow

[6] may be possible to squeeze-in a transect at the very top of riffle

[7] bottom of split channel

[8] split channel

[9] cascade with numerous falls

32 Historic Channel

The Historic Channel was mapped on September 2, 2021, into pool, run, riffle, and glide habitats from the channels outlet into the Rolfe Canal tailrace up to the bottom of the long deep pool below the Rolfe Canal intake structure (Figure 3-1). The mapping was conducted on foot with habitat lengths measured with a 100 ft tape. Photographs were taken at regular intervals[3]. In addition to habitat type, representative channel widths were measured in each unit, and notes were recorded related to substrate composition, woody debris, riparian characteristics, and fish observations. Discharge during habitat mapping was measured at 5.5 cfs.

33 PUF Bypass

The PUF Bypass was assessed on September 2, 2021 at an estimated flow of 1.3 cfs, most of which was passing downstream as attraction flows associated with the upstream eel trap located on the west end of the spillway. Discharge from that area then flowed into the bedrock habitat via a stream channel that exited the west-side riparian area (Figure 4-1). Dominant substrate was assessed and wetted widths were measured at nine evenly spaced transects, with emphasis on refuge pool habitats (Figure 4-2). Photographs were taken at each location and maximum pool depths were measured where possible; however the large bedrock pool (Pool #2) exceeded 4 ft in depth and maximum depth was not measured. General characteristics of the small outflow channel through the riparian area along the west bank were also noted.

34 PLF Bypass

The PLF Bypass was mapped on September 2, 2021 at an estimated flow of 3.7 cfs. Habitat in the bypass was assessed in a like manner to the PUF, with overall channel widths and photographs taken at 23 evenly spaced transects (Figure 4-3), and refuge pool habitats assessed for maximum depth and dominant substrate (Figure 4-4).

[3] Digital photographs can be provided upon request.

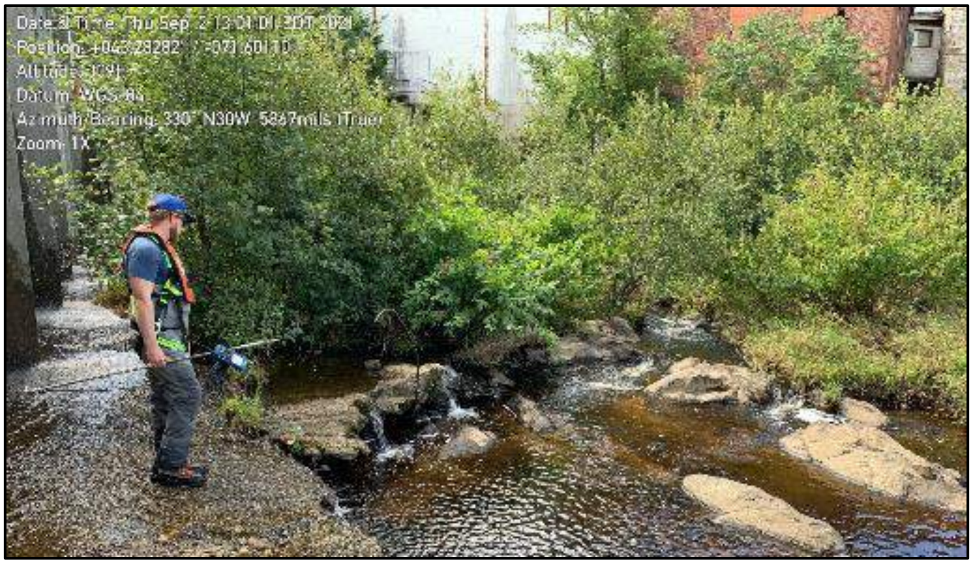


Figure 29–1. Stream channel entering bedrock habitat from west-bank of PUF spillway.

Figure 29–2. The PUF Bypass showing locations of width transects, pool units, outlet flows, and the riparian stream channel.

Figure 29–3. The PLF Bypass showing locations of width transects, pool units, and the passage outlet chute.

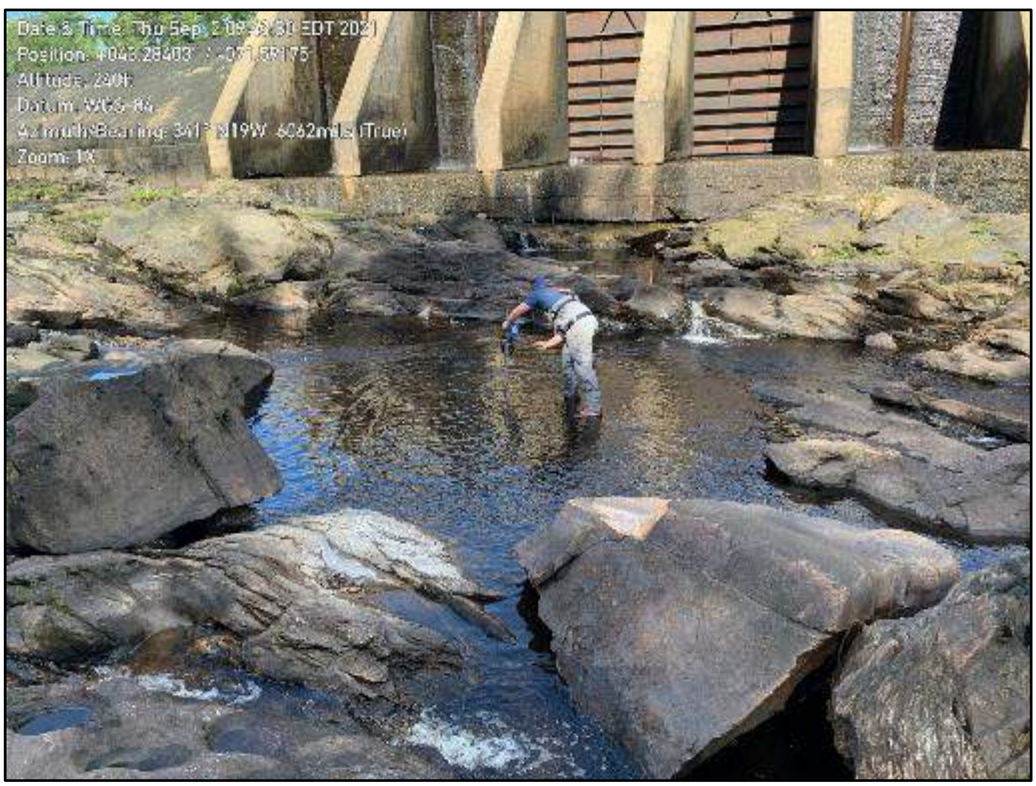


Figure 29–4. Assessing pool characteristics in PLF Bypass.

35 Passage Assessment

A qualitative assessment of passage impediments to upstream migrant river herring and American shad was conducted under low flow conditions in each of the four bypass reaches. Depths and mean column velocities were measured at the lowermost locations thought to represent a likely barrier to migrating fish (Figure 4-5). These measurements were compared to published passage criteria for adult alosines (USFWS 2019); those criteria are listed in Table 4-2.

Figure 29–5. Measuring depths and velocities at potential migration barriers in the Rolfe Bypass reach.

Table 29–2. Upstream passage criteria for river herring and American shad (USFWS 2019)

Species	Min Depth (ft)	Max Velocity (fps)
River Herring	1.0	6.0
American Shad	2.25	8.25

36 1-Dimensional Hydraulic Modeling

1-Dimensional hydraulic modeling was employed to assess the flow:habitat relationships in the Rolfe Bypass reach. As described above, qualitative habitat assessments were conducted in the Historic Channel, the PUF, and the PLF, due to the short bypass lengths and the limited availability of suitable, non-bedrock dominated habitat.

37 Transect Selection

Nine cross-sectional (XS) transects were proposed for 1-D hydraulic modeling within the Rolfe Bypass reach. The selected transects were distributed among pool, run, and riffle habitats roughly in proportion to the habitats occurrence in the bypass. Five transects were placed in the boulder channel, and four transects in the bedrock channel (Table 4-1). Overall, three transects were placed in pool habitats, four transects in run habitats, and two transects in riffle habitats (Figure 4-6). Transects were placed in order to be representative of the habitat they occurred in. Photographs and short video clips were recorded at each transect during initial selection and these files were made available to the relicensing participants for review. Following review, the nine proposed transects were accepted for use in the 1-D modeling[4] .

38 Target Flows

1-D hydraulic data was proposed to be collected in the Rolfe Canal Bypass reach at three flow levels: 50 cfs representing the low flow, 100 cfs the medium flow, and 200 cfs the high flow. Actual flows measured during the three data collection efforts were 60 cfs, 109 cfs, and 172 cfs. Typically a PHABSIM assessment can model habitat down to 50% of the low measured flow and up 250% above the high measured flow, which was expected to allow modeling of flows from a minimum of 25-30 cfs to a maximum of 430-500 cfs. Actual habitat modeling did encompass flows from 25 cfs to 500 cfs at 25 cfs increments.

39 Transect Data Collection

Field data collection and the form of data recording followed the general guidelines established in the IFIM field techniques manuals (Trihey and Wegner 1981; Milhous et al. 1984; Bovee 1997). The techniques for measuring discharge followed guidelines outlined by the USGS (Rantz 1982). Thirty or more stations were established during the high flow measurement in order to ensure that a minimum of 20 wetted stations occurred at the lowest measured flow. The boundaries of each station along each transect were

[4] Email to Briar Hydro dated October 6, 2021 from Gregg Comstock at NHDES and email dated October 7, 2021 from Ken Hogan at USFWS.

normally at even increments, but significant changes in velocity, substrate, depth, or other important stream habitat features dictated additional or modified stationing.

The standard method for determining mean column velocity along the transects used a single measurement at six-tenths of the water depth in depths less than 2.5 feet, and a two-tenths and eight-tenths measurement for depths between 2.5 feet and four feet. All three points were measured where depths exceeded four feet, or the velocity distribution in the water column was abnormal and one or two points were not adequate to derive an accurate mean column water velocity. For transects that could be safely waded, top setting wading rods were used in water up to four feet deep. For transects too deep or unsafe for wading (the upper two bedrock pools), a tethered Acoustic Doppler Current Profiler (ADCP) was used to collect velocity and bottom profile data. Complete velocity profiles were acquired at the low flow level, with water surface elevations and associated discharge measurements made at all three (high, middle, and low) target flows.

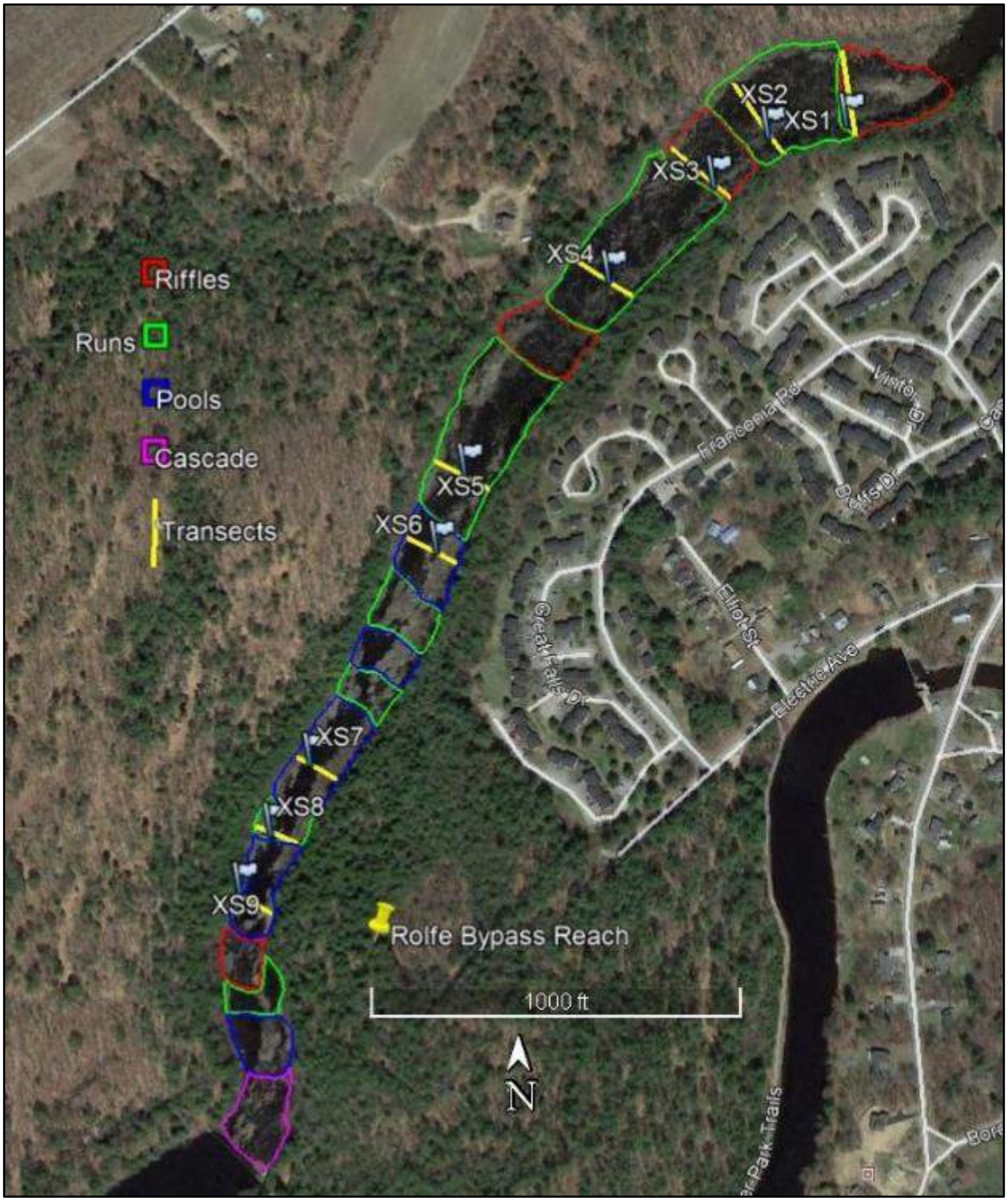


Figure 29–6. Habitat map of Rolfe Bypass reach showing habitat types and locations of 1-D transects (XS).

40 Substrate Coding

Dominant substrate type was assessed at measurement stations along each transect under middle flow conditions. The specific substrate code used was designed to match the code used in the Habitat Suitability Criteria (HSC) datasets. See Section 4.3.6 for substrate definitions and Appendix A for study HSC.

41 Model Development

Hydraulic habitat modeling for habitat assessment was independently developed by the Instream Flow Group of the U.S. Fish and Wildlife Service (now U.S. Geological Survey, Aquatic Systems and Technology Applications Group, Fort Collins Science Center) and by Ian Jowett of the National Atmospheric and Water Institute in New Zealand. PHABSIM and RHYHABSIM, respectively, calculate a habitat index by simulating water depths and velocities along 1-D transects, recording substrate and cover at all measurement points and linking the results to HSC for target species. The System for Environmental Flow Analysis (SEFA) was subsequently developed by Ian Jowett, Robert Milhous (of the Instream Flow Group), Thomas Payne, and (Spanish translation) Juan Manuel Diez Hernandez, which incorporated analytical procedures from PHABSIM and RHYHABSIM as well as several new procedures. SEFA version 1.5 build 7 was used for hydraulic model calibration and to generate the flow:habitat relationships described in this study.

Stage-Discharge Calibration

Stage-discharge relationships for all 1-D transects were developed from measured discharge and water surface elevations using a Stage-of-Zero-Flow (SZF) log/log regression rating formula using the SEFA default method of fitting the rating curve through the survey flow (i.e., the velocity accusation flow). The SZF method requires a minimum of three sets of stage-discharge measurements and an estimate of SZF for each transect. The quality of the SZF rating relationships was evaluated by examination of mean error (less than 10%), coefficient of determination (R^2) and slope output (generally between 2.0 and 5.0 and similar between transects) from the rating curves (Bovee and Milhous 1978). The SZF is the bottom elevation measured downstream of a transect that would control the water surface elevation if flow dropped to zero (assuming no percolation). It was used as a fourth point in the rating curve to reflect the water surface at zero flow.

Velocity Calibration

A 1-D model represents a stream by means of vertical slices (transects) across the channel. Depths are simulated with the rise and fall of a single, level (in most cases) water surface. The preferred method for simulating water velocities is the “one-flow” option, which uses a single set of measured velocities to predict individual station or vertical velocities over a range of flows. Simulated velocities are based on measured data and a relationship between a fixed roughness coefficient (Manning's n) derived from the measured velocities and depth. In some cases calibration roughness values were modified for individual verticals if substantial velocity errors are noted at simulated flows. Predicted velocities were examined to detect any significant and unrealistic deviations and determine if velocities remained consistent with stage and total discharge.

Habitat Suitability Modeling

Combining the hydraulic and HSC components generates the habitat suitability index, historically termed Weighted Usable Area (WUA) but in this report more accurately termed Area Weighted Suitability (AWS). Unlike hydraulic modeling and calibration, there are a limited number of decisions to make prior to AWS production runs. Transects are weighted according to the percentage of habitat types present in the reach. The range of flows modeled (and specific flows within that range) was determined largely by the suitability of the hydraulic data for extrapolation and the range of flows of interest. This 1-D analysis modeled a range of flows from 25 cfs to 500 cfs in 25 cfs increments. The standard option of multiplying individual variable suitabilities (velocity*depth* substrate/cover) for each transect station was used to calculate AWS.

42 Habitat Suitability Criteria

Per the revised study plan, Normandeau distributed a list of proposed target species and associated HSC to the relicensing participants on September 9, 2022[5]. Appendix A provides all HSC values and associated curves. The target species and life-stages selected to assess aquatic habitat in the Rolfe Bypass 1-D analysis are:

- Smallmouth bass (fry, juvenile, adult, spawning)
- Fallfish (fry, juvenile, adult, spawning)
- White sucker (fry, juvenile/adult, spawning)
- Longnose Dace (juvenile, adult)
- Benthic Macro-invertebrates (BMI)

The rearing and spawning life-stage HSC for all species utilized the classification listed below for describing the dominant substrate type:

[5] Distributed via email sent by Mark Allen (Normandeau) with attached 20210921_Briar Hydro Instream Flow Study – Mapping Memo.docx

- Organics (ORG)
- Mud/Clay (MUD)
- Silt (SLT) (<0.002 inches)
- Sand (SND) (0.002-0.1 inches)
- Gravel (GRV) (0.1-2.5 inches)
- Cobble (COB) (2.5-10 inches)
- Boulder (BLD) (>10 inches)
- Bedrock (BED)

43 Quality Control

To assure quality control in the collection of field data for the instream flow study, the following data collection procedures and protocols were implemented:

- Staff gauges were established and continually monitored throughout the course of collecting data on each transect. If significant changes occurred, water surface elevations were re-measured following collection of transect water velocity measurements.
- Hach FH950 electromagnetic current meters were used in the collection of velocity data in wadable areas, with an RDI 1200 kHz Rio Grande ADCP deployed in deep pool habitats.
- Meters were continually monitored during the daily course of data collection to ensure that they were functioning properly.
- An independent benchmark was established for each set of transects. This benchmark was an immovable tree, boulder, or other naturally occurring object that would not be subject to tampering, vandalism, or movement. Upon establishment of headpin and tailpin elevations, a level loop was shot to check the auto-level for measurement accuracy. Allowable error tolerances on level loops are set at 0.02 feet. This tolerance was also applicable to both headpin and tailpin measurements, unless extenuating circumstances (pins under sloped banks, shots through dense foliage, etc.) explain discrepancies and the accompanying headpin or tailpin was free of excessive error.
- Multiple water surface elevations were measured across each transect. The more complex and uneven the transect water surface, the greater the number of measurement locations. For example, a riffle transect typically required more frequent water surface measurements, while a

pool transect required fewer. Water surface elevation measurements at each calibration flow were made at the same location across each transect.

- All pin elevations and water surface elevations were calculated during field measurement and compared to previous measurements. Changes in stage since the previous flow measurement were also calculated. Patterns of stage change were compared between transects to determine if reasonable. If any discrepancies were discovered, potential sources of error were explored and noted.
- All calculations were completed in the field (given adequate time and daylight). Pin elevations and changes in water surface elevations were compared between flows on the same transects. With few exceptions, no more than 10% of total discharge was measured in any individual station.
- Photographs were taken of all transects looking across the transect, upstream of the transect, and downstream of the transect, under each flow regime. Attempts were made to shoot each photograph from the same location at each of the three levels of flow. These photographs recorded the streamflow conditions (including velocity and depth), water surface levels, and channel configurations that may have needed confirmation during hydraulic model calibration.

44 Results

Following are the results from the 1-D hydraulic modeling in the Rolfe Bypass reach and the qualitative habitat assessments in the Historic Channel, the PUF Bypass, and the PLF Bypass. Also described are fish passage measurements collected in each of the four bypass reaches.

45 1-Dimensional Hydraulic Modeling

The relationship between bypass flow and instream habitat quantity and quality in the Rolfe Bypass reach was assessed using 1-Dimensional hydraulic modeling, as provided in the SEFA software package. Evaluation of the hydraulic model, including the fit of stage-discharge relationships, and the steps taken during model calibration, are presented followed by the AWS curves for each target species and life-stage.

46 1-D Model Calibration

One pool transect, #7, was dropped from the study due to incomplete bottom and velocity profiles. Depth and velocity data collected by the ADCP were not detailed enough to produce an adequate hydraulic model. Although ADCP's are often used for data collection, they do have limitations under certain circumstances such as abrupt changes in depth (vertical drops) and water turbulence. Since three pool transects were originally selected for modeling, it was assumed the loss of this single location had a limited effect on habitat modeling results.

Stage-Discharge Relationships

Three calibration flows, 59.95 cfs (velocity acquisition), 108.7 cfs, 172.3 cfs and associated water levels (WSE) were measured to calculate stage-discharge relationships. In all cases mean error and coefficient of determination (R^2) were well within normal parameters (Table 5-1). Because each transect was measured independent of others, there was no corresponding relationship to measured WSE or SZF.

Velocity Calibration

Velocity acquisition occurred at a lower flow level than anticipated (59.9 versus 172 cfs). Generally higher flow levels allow for velocity data to be collected in areas that may be dry at lower flows, allowing for more accurate velocity simulation. However, due to relatively steep banks in the study reach the ability to collect complete velocity measurements across transects was not an issue. Normandeau field staff did collect additional velocity measurements at bank side locations under the high flow (172 cfs) condition.

In a few instances velocity calibration required adjusting individual point manning's N values to produce realistic velocities at high simulation flows. For example, a velocity of over 8.0 fps at 400 cfs was estimated for a point on riffle T3 which appeared to be an anomaly compared to other point simulations. In the case of pool T6, photos from high flow were used to confirm that a backwater area on the left bank would retain relatively low velocities at higher simulation flows. The general spikiness of velocity profiles for most transects was a function of dominant boulder and bedrock substrate in the reach, creating velocity chutes adjacent to and over boulders, and quiet areas behind. Transect bottom profiles with predicted velocities and WSE over a range of flows are presented in Appendix B.

Table 44–1. Rating curve statistics for transects. Mean error (%) and coefficient of determination (R^2) show the goodness of fit of the rating to the gagings

Cross Section	Survey Flow	Calibration Flows		SZF rating				
	WSE (ft)	WSE (ft)	WSE (ft)	exp	A	SZF	R^2	Mean error
T1- Riffle	99.03	99.19	99.30	5.470	14.273	97.73	0.996	2.128
T2 - Run	98.88	99.10	99.22	4.628	12.633	97.48	0.984	4.402
T3 - Riffle	98.13	98.36	98.47	6.048	1.236	96.23	0.977	5.304
T4 - Run	97.67	97.90	97.99	5.691	2.831	95.96	0.960	6.913
T5 - Run	97.96	98.28	98.48	4.512	2.351	95.91	0.992	3.209
T6 - Pool	98.29	98.62	98.75	4.797	1.961	96.25	0.959	6.980

T8 - Run	94.67	95.07	95.35	4.457	0.834	92.06	0.996	2.159
T9 - Pool	95.79	96.32	96.68	5.762	0.010	91.25	0.996	2.198

Rating Formula: Flow = A x (WSE - SZF)^{exp}. Fitted through survey stage and flow with best fit to rating calibration stages and flows, and SZF.
The mean error in Q is the average percentage absolute error in predicted and rating calibration discharges as a % of the rating calibration discharges.
The coefficient of determination is derived by comparing measured and predicted stages.

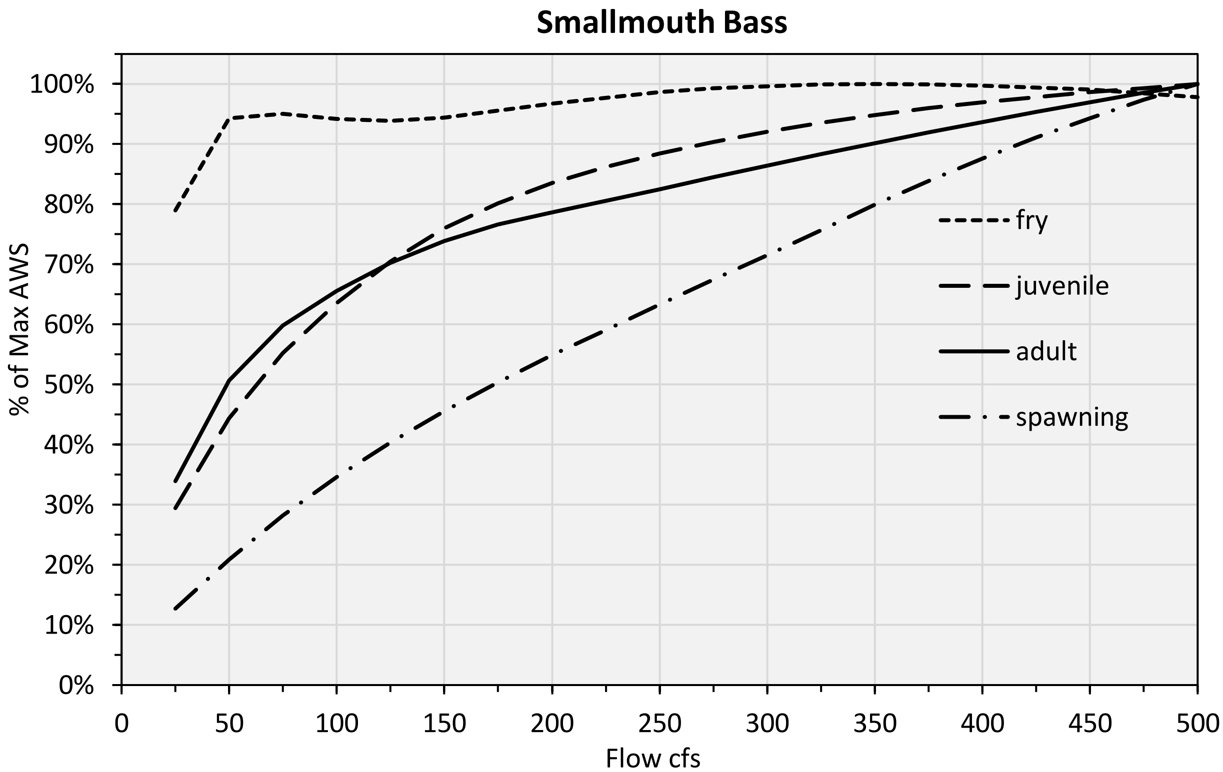
47 Area-Weighted Suitability Results

Estimated AWS values ranged from a minimum of 1.1 ft^2/ft for white sucker spawning at 25 cfs to a maximum of 68.9 ft^2/ft for BMI at 500 cfs (Table 5-2). AWS peaked at the maximum simulated flow (500 cfs) for nine of the 14 target species/life-stages, with the remaining five species/life-stages maximizing habitat as flows from 50 cfs to 350 cfs. For comparison, 80% of the maximum AWS occurred at flows of 250 cfs or less for 12 of the 14 species/life-stages, and eight species/life-stages showed 90% of maximum AWS at flows of 250 cfs or less. Figure 5-1 and Figure 5-2 show the percentage of maximum AWS according to flow for each of the target species and life-stages.

Table 44–2. AWS values (ft^2/ft) by flow and species/life-stage[1]; values representing maximum AWS are bold with yellow highlight, blue highlighted values show flows achieving at least 80% of maximum AWS

Flow (cfs)	SMB fry	SMB juv	SMB adult	SMB spawn	FF fry	FF juv	FF adult	FF spawn	SKR fry	SKR juv / adult	SKR spawn	Dace juv	Dace adult	BMI
25	35.9	14.1	6.7	0.4	6.0	11.2	18.0	0.5	61.6	15.0	0.1	13.7	18.3	1.3
50	42.9	21.3	10.0	0.7	8.9	17.5	25.1	0.6	**65.8**	19.9	0.1	22.9	31.7	6.9
75	43.2	26.4	11.8	0.9	10.1	22.9	29.1	0.9	65.7	21.6	0.2	29.0	41.4	14.9
100	42.9	30.4	12.9	1.2	10.5	27.6	31.6	1.1	65.3	22.2	0.2	32.8	48.2	22.9
125	42.7	33.7	13.8	1.4	10.7	31.7	33.2	1.3	64.8	22.6	0.3	35.1	53.1	30.0
150	43.0	36.4	14.6	1.5	10.8	35.0	34.4	1.4	64.2	23.0	0.3	36.3	56.8	35.7
175	43.5	38.4	15.1	1.7	10.8	37.6	35.4	1.4	63.6	23.4	0.3	**36.7**	59.4	40.5
200	44.0	40.0	15.5	1.8	10.9	39.7	36.2	1.4	62.8	23.8	0.3	36.7	61.3	44.6
225	44.5	41.3	15.9	2.0	**10.9**	41.3	36.8	1.5	62.0	24.2	0.3	36.4	62.4	48.1
250	44.9	42.4	16.3	2.1	10.8	42.6	37.3	1.5	61.2	24.5	0.3	35.9	63.2	51.1
275	45.2	43.3	16.6	2.3	10.8	43.6	37.6	1.6	60.3	24.9	0.3	35.4	63.6	53.8
300	45.4	44.1	17.0	2.4	10.7	44.3	37.9	1.6	59.2	25.2	0.4	34.8	**63.8**	56.3
325	45.5	44.8	17.4	2.5	10.7	44.9	38.1	1.7	58.1	25.6	0.4	34.3	63.7	58.4
350	**45.5**	45.4	17.8	2.7	10.6	45.5	38.3	1.7	56.9	25.9	0.4	33.6	63.5	60.4
375	45.5	45.9	18.1	2.8	10.5	45.8	38.4	1.7	55.6	26.2	0.4	32.9	63.2	62.2
400	45.4	46.4	18.4	2.9	10.4	46.1	38.5	1.8	54.3	26.5	0.4	32.3	62.8	63.7
425	45.3	46.8	18.8	3.1	10.2	46.3	38.6	1.8	53.0	26.7	0.4	31.6	62.4	65.2
450	45.1	47.2	19.1	3.2	10.1	46.4	38.6	1.8	51.8	26.8	0.4	31.0	62.0	66.5
475	44.8	47.6	19.4	3.3	10.0	46.5	38.7	1.8	50.5	26.9	0.4	30.4	61.5	67.8
500	44.5	**47.9**	**19.7**	**3.4**	9.9	**46.6**	**38.7**	**1.9**	49.4	**26.9**	**0.4**	29.9	61.1	**68.9**

[1] Species: SMB=smallmouth bass, FF=fallfish, SKR=white sucker, Dace=longnose dace, BMI=benthic macroinvertebrates.



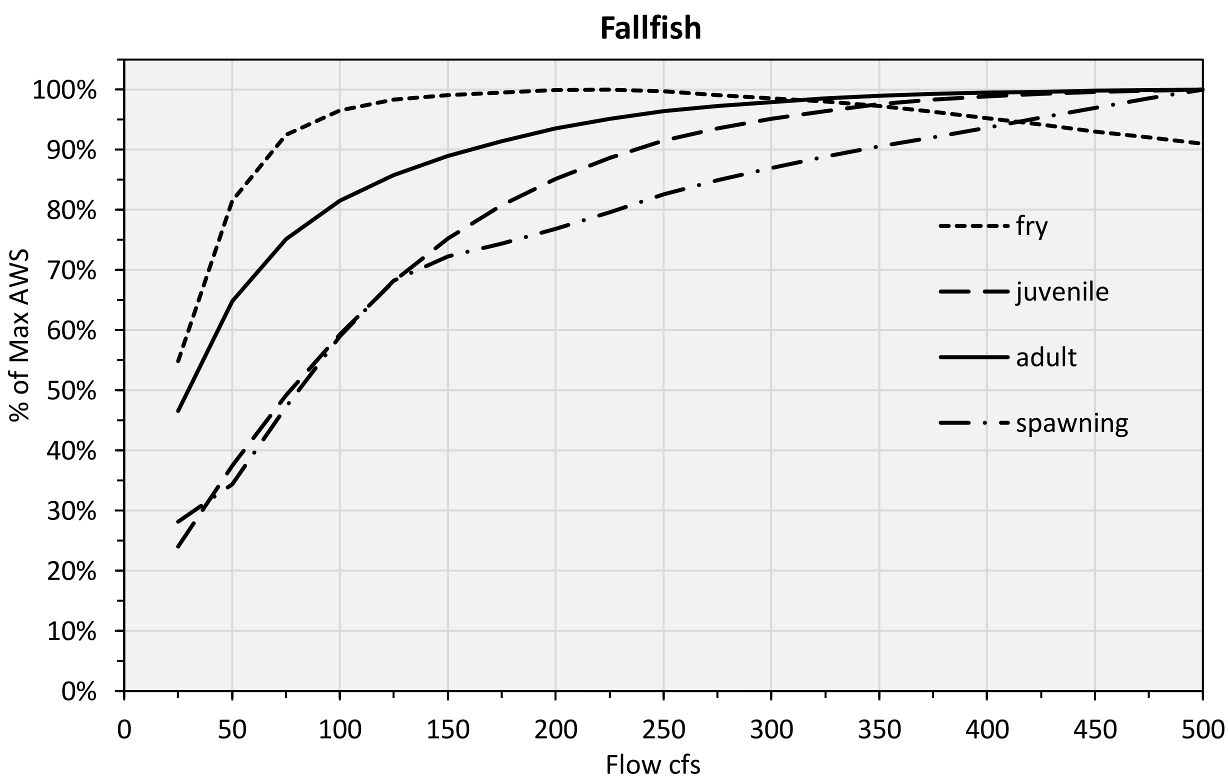
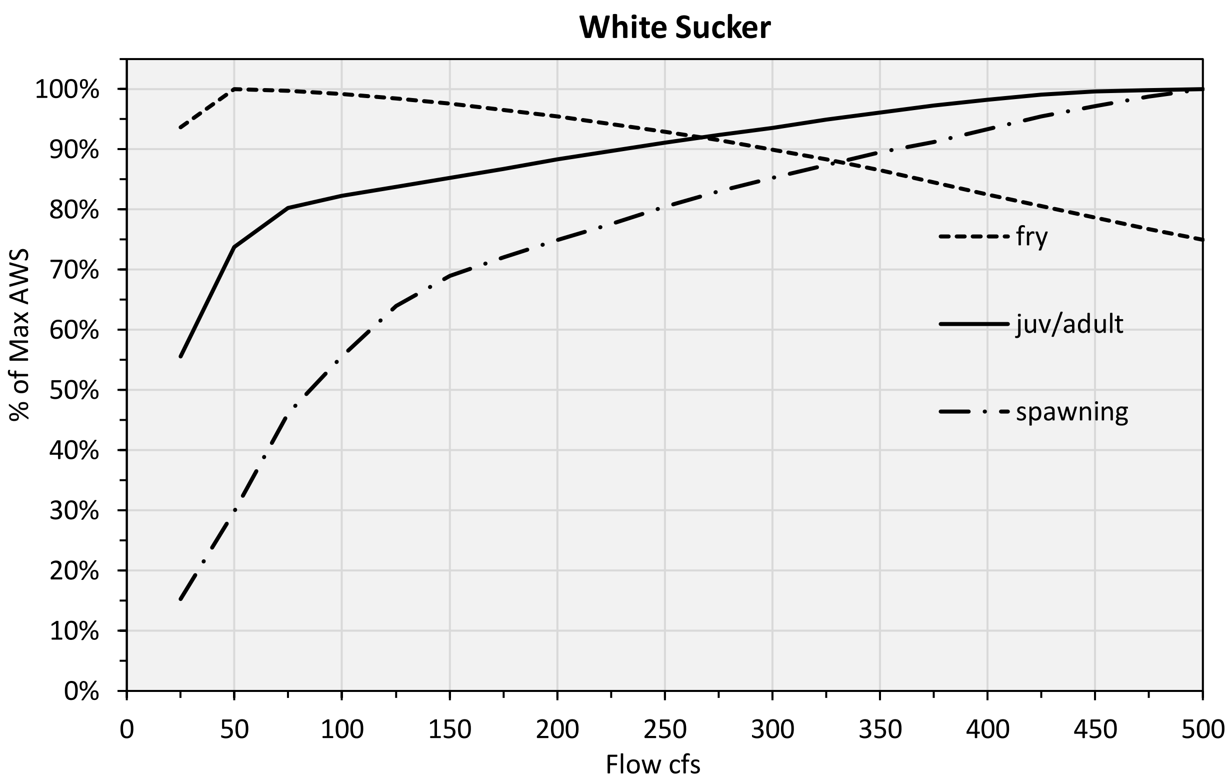


Figure 44–1. Percent of maximum AWS according to flow for life-stages of smallmouth bass (upper figure) and fallfish (lower figure).



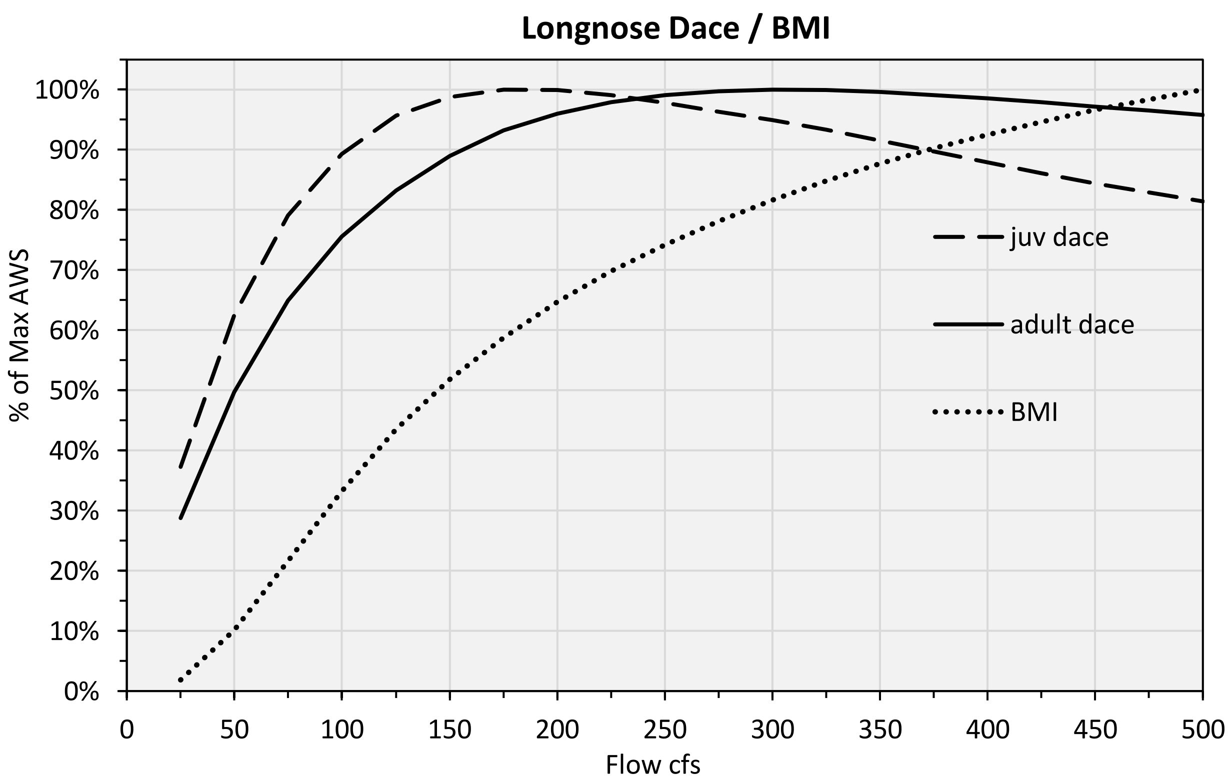


Figure 44–2. Percent of maximum AWS according to flow for life-stages of white sucker (upper figure) and longnose dace or BMI (lower figure).

Smallmouth bass showed increasing AWS with flow for all life-stages (Figure 5-1, upper), although the fry life-stage had an initial plateau at 50 cfs with a gradual increase in AWS at flows over 200 cfs. Habitat for juvenile and adult smallmouth bass increased rapidly at flows up to 200 cfs then increased more gradually to the maximum modeled flow of 500 cfs. Fallfish fry likewise showed more defined maxima at about 150 cfs, with near peak AWS at 250 cfs for the juvenile and adult life-stages. Similar to bass, fallfish spawning AWS continued to increase with higher flows after an inflection point of 70% of maximum AWS at 150 cfs (Figure 5-1, lower). AWS curves for white sucker showed inflection points at 70% and 80% of maximum AWS at 150 cfs and 75 cfs for juvenile/adult fish and for spawning, respectively. Similar to bass and fallfish, white sucker fry showed maximum AWS under low flows (Figure 5-2, upper). Longnose dace AWS peaked at 175 cfs for juveniles and 275 for adults, whereas AWS for BMI was near zero at 25 cfs and continued to increase to the maximum modeled flow of 500 cfs (Figure 5-2, lower).

The relatively low AWS values shown in Table 5-2 were due in part to the dominance of bedrock substrate in the upper half of the Bypass reach. For most species the assumed suitability of bedrock substrate was 0.5 or less, with zero suitability for several life-stages including smallmouth bass spawning; fallfish fry, juvenile, and spawning; longnose dace juvenile and adult; and white sucker spawning (Appendix A). Consequently, many of the transect points in the upper reach were estimated to contribute zero or minimal suitable habitat due to the bedrock substrate. Although bedrock substrate is clearly of minimal value for spawning among the target species, the relative importance of bedrock (or any substrate type) for rearing life-stages is more ambiguous; consequently a comparison of non-spawning AWS results with and without the inclusion of substrate HSC can be informative.

In the Rolfe Bypass reach, AWS values for the non-spawning life-stages were generally similar (e.g., within 10%-40%) with or without the application of substrate HSC, except for fallfish fry which showed much less habitat when substrate was incorporated. Although the inclusion or exclusion of substrate HSC had an effect on the magnitude of AWS for rearing among some species, the substrate variable had minimal effect on the shape of the AWS curves (i.e., the peak locations) for the non-spawning life-stages. Overall, when assuming equal importance for all species and life-stages, the average percent AWS for all 14 species and life-stages combined with substrate included reveals that 70%, 80%, and 90% of maximum AWS was provided by bypass flows of approximately 98 cfs, 150 cfs, and 275 cfs, respectively (Figure 5-3).

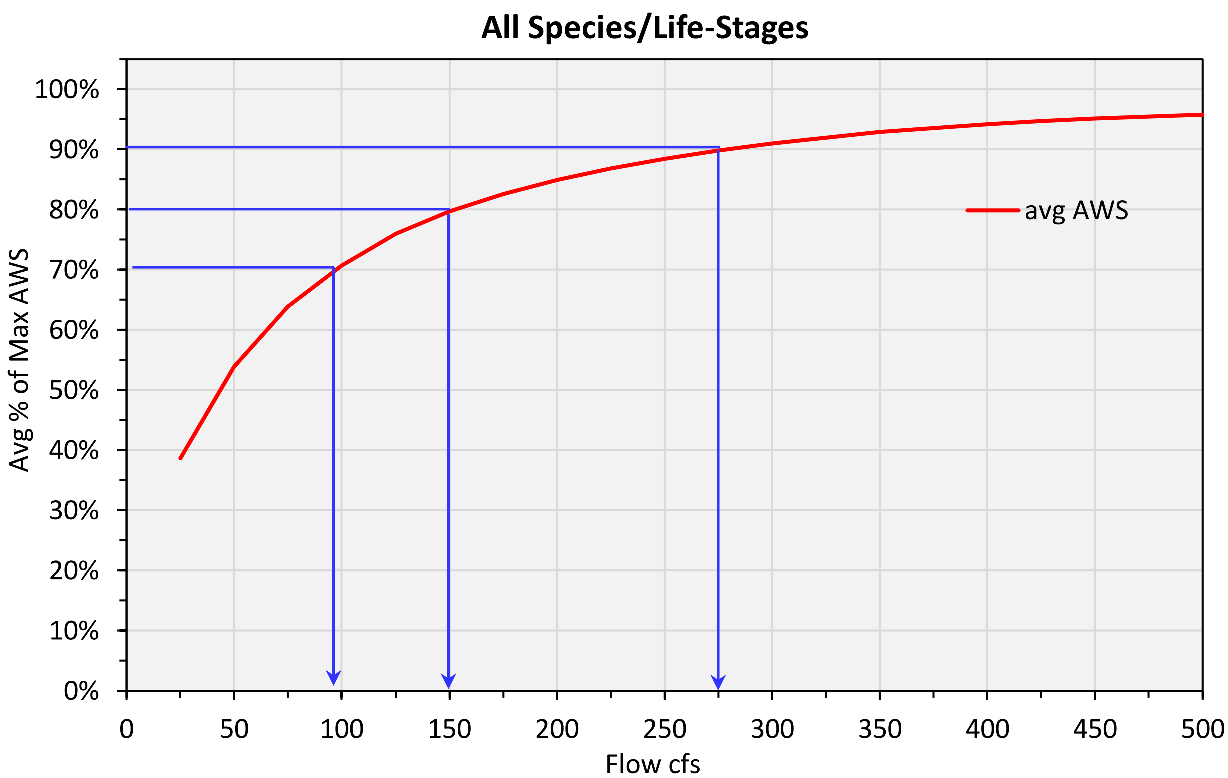


Figure 44–3. Average percent of maximum AWS according to flow for all species and life-stages combined, including substrate HSC. Flows approximating 70%, 80%, and 90% of maximum AWS are shown.

48 Qualitative Habitat Assessments

Qualitative assessments of habitat availability and suitability were conducted in the Historic Channel, PUF, and PLF bypass reaches.

49 Historic Channel

The Historic Channel (Figure 3-1) was mapped on September 2, 2021 at a flow of approximately 5.5 cfs (the year-round flow). The Historic Channel was mapped for 1,112 ft into pool, run, and riffle habitats, including unit lengths and widths, mean channel thalweg depths, and dominant/subdominant substrate. Mapping concluded at a beaver dam that led into a long (670 ft) deep pool extending upstream to the canal dam.

Excluding the long upper pool, 18 habitat units were mapped averaging 62 ft in length and 23 ft in wetted width with thalweg depths averaging 0.6 to 1.8 ft (Table 5-3). Habitat type proportions (by length) were 66% run, 18% pool, and 16% riffle. Substrate was dominated by fines (silt and sand) in 11 of the 18 units, with 7 units (mostly riffles) dominated by cobbles or boulders. All units contained various amounts of silt, which were ankle to shin-deep in pools, slow runs, and on the grassy bars that extending along much of the banks (Figure 5-4). Woody debris was present in five units as well as the beaver dam at the head of the mapped channel. Unlike the PUF and PLF bypass reaches, fish were regularly observed in the Historic Channel. Although not captured and verified, the fish appeared to be cyprinids or juvenile suckers. Representative photos show aquatic habitat, riparian habitat, and substrate characteristics; these photos were made available to the agencies via a Normandeau ftp site[6].

[6] Email sent to agencies notifying ftp site availability on September 22, 2021

Table 44–3. Habitat mapping data for the Historic Channel Bypass reach

Habitat Unit No.	Habitat Type	Length (ft)	Cumulative Distance (ft)	Width (ft)	Thalweg Depth (ft)	Dominant Substrate	Sub-Dominant Substrate
1	RN	40	40	13.5	1.0	BLDR	FINES
2	RF	78	118	12	0.8	BLDR	COB
3	RN	33	151	18.5	1.1	COB	FINES
4	PL	22	173	30	1.2	FINES	FINES
5	RN	53	226	24	1.2	FINES	BLDR
6	RF	44	270	30	0.7	COB	FINES
7	RN	66	336	24	1.1	FINES	BLDR
8	RF	37	373	22	0.6	BLDR	COB
9	RN	35	408	18	1.1	BLDR	FINES
10	RF	20	428	26	1.0	BLDR	COB
11	RN	64	492	30	1.2	FINES	BLDR
12	RN	111	603	38	1.1	FINES	FINES
13	PL	134	737	50	0.9	FINES	BLDR
14	RN	185	922	12	1.2	FINES	LWD
15	PL	17	939	33	1.6	FINES	LWD
16	RN	102	1,041	9.5	1.2	FINES	FINES
17	PL	22	1,063	7	1.8	FINES	LWD
18	RN	79	1,142	8	1.1	FINES	FINES
19	PL	670 [1]	1,812	55 [1]	-	-	-

[1] not surveyed, length and width estimated from aerial imagery

Figure 44–4. Representative photo of the Historic Channel, showing silt substrate, emergent vegetation, woody debris, and riparian canopy.

50 PUF Bypass

The PUF assessment was conducted on September 2nd, 2021, with an estimated bypass (leakage) flow of approximately 1.3 cfs. The substrate throughout most of the bypass, with the exception of the riparian zone in the southwest corner, was largely dominated by bedrock, with some boulders in pool areas and at the outlet (Figure 4-2).

Table 5-4 lists the bankfull widths (top of bedrock to top of bedrock, excluding power outlet backwaters), pool widths, as well as pool depths and lengths. A dominant feature of the PUF Bypass was a large (almost 10,000 ft^2) bedrock pool that exited directly into the mainstem Contoocook River. Depths and velocities measured at the bypass's main pool outlet ranged from 0.1 to 0.3 ft deep and 1.37 to 3.96 fps. Although depths were well below passage criteria, it appeared that a relatively minor increase in water surface elevation (~1.5-2 ft) in the powerhouse outlet channel would inundate the bypass pool outlet, thereby allowing fish to enter the main pool. Maximum depth in the main bypass pool was not measured, however it appears that the depth and size of the main pool could provide refuge for fish under all but the highest spill flows.

The small stream formed from dam leakage along the west bank extended approximately 78 ft with a channel 4-6 ft wide and 0.6 to 0.9 ft in depth, with 70% fines dominating the substrate (Figure 5-5). The moderate flow (<2 cfs), water depths, and riparian cover suggests the stream could support cyprinids and juvenile fish of other species, although no fish were observed during the site visit in the stream or in any of the pools. The presence of thick riparian vegetation also suggests that this portion of the bypass does not get scoured during spill events.

Table 44–4. Pool and outlet characteristics in the PUF Bypass reach

Transect No.	Pool No.	Bankfull Width (ft)	Pool Width (ft)	Pool Length (ft)	Max Depth (ft)	Photo
547	1	135	-	-	2.2	PUF PL 1
548	2	105	72	123	>4	PUF PL 2a
549	2	135	96			PUF PL 2b
550	2	171	96			PUF PL 2c
551	2	156	69			PUF PL 2d
552	2	147	66			PUF PL 2e
553	2	132	84			PUF PL 2f
554	outlet	117	-	-	-	PUF outlet a
555	outlet	93	-	-	-	PUF outlet b
-	3	-	25	5	>4	PUF PL 3
-	4	-	20	12	2.3	PUF PL 4
-	5	-	87	32	>4	PUF PL 5

Figure 44–5. Small stream channel below PUF dam.

51 PLF Bypass

In like manner to the PUF, data recorded in the PLF Bypass focused on bankfull widths, refuge pool depths, substrate composition, and passage impediments (Figure 4-3). The PLF Bypass reach was surveyed on September 2, 2021, at a leakage flow of approximately 3.7 cfs. Total (~bankfull) widths were measured at 23 cross-sections (Table 5-5), most of which were aligned to cross over bedrock pools which were measured for maximum depth. The dominate substrate was bedrock at all transects except the uppermost transect in the north split channel, which was largely cobble and boulder. Boulder substrate, and to a lesser extent cobble substrate, was present on just over one-half of the transects.

Maximum pool depths ranged from 0.6 ft to 4.5 ft (or greater), although mean maximum depth was approximately 2.7 ft, thus it is unlikely that habitat is sufficient to allow most fish species to persist in the pool habitats under periods of significant spill. Although other pool dimensions were not measured, most pools were less than 20 ft in width or length, and wetted widths in between pools were typically less than 10 ft in width.

Table 44–5. Pool and transect characteristics in the PLF Bypass reach

Transect No.	Bankfull Width (ft)	Pool No.	Max Depth (ft)	Dominant Substrate	Photo
524	65	1	2.9	bed	PLF PL524
525	129	2	3.1	bed/bldr	PLF PL525
526	131	3	2.9	bed	PLF PL526
527	126	4	4.5	bed	PLF PL527
528	120	5	>4	bed	PLF PL528
529	122	-	-	bed/bldr	-
530	117	-	-	bed/bldr/cob	-
531	118	6	2.5	bed/bldr/cob	PLF PL531
532	48	7	3	bed/bldr	PLF PL532
533	61	-	-	bed	-
534	38	8	1.8	bed	PLF PL534
535	24	-	-	bed	-
536	18	-	-	cob/bldr	-
537	82	9	0.6	bed/bldr	PLF PL537
538	66	10	1.7	bed/bldr	PLF PL538
539	62	11	1.5	bed/bldr	PLF PL539
540	72	-	-	bed/bldr	-
541	101	12	1.7	bed/bldr	PLF PL541
542	105	13	2.3	bed/bldr	PLF PL542
543	99	13	1.8	bed/bldr	PLF PL543
544	77	-	-	bed/bldr	-
545	99	14	4.5	bed	PLF PL545
546	118	14	3.2	bed	PLF PL546

52 Passage Assessment

53 Rolfe Bypass

Impediments to upstream passage by adult river herring and American shad in the Rolfe Bypass reach were not observed until the cascade habitat immediately below the York Dam (Figure 5-6). Passage data was collected at eight locations mostly along the downstream lip of the bedrock cascade/falls (Figure 5-7) at the mapping flow of approximately 60 cfs. Passage channel width, depth, and velocity data are presented in Table 5-6.

Results from the passage measurements illustrate that few locations met passage criteria for either herring or shad, except for the channel along the northwest bank, which leads up to the face of the dam. Fish movement from the north channel towards the southeast bank is prohibited by the bedrock drop, which extends diagonally from the southeast bank to the dam face adjacent to the north channel. Although passage depths would become more favorable at higher flows, velocities along the bedrock drop would be expected to exceed the passage criteria, whereas the lower gradient north channel may remain passable at higher flows (Figure 5-8).

Table 44–6. Fish passage measurements in the Rolfe Canal Bypass reach at 60 cfs. Numbers in red do not meet species passage criteria

Channel No.	Waypoint	Depth (ft)	Velocity (fps)	Width (ft)	Length (ft)	Photo No.	Notes
1	517	0.2	5.50	6.0	30	517a	[1] south side chutes
"		0.5	4.80	"			
2	518	0.6	1.25	1.5	7	518a	
"		0.3	3.68	"			
3	519	0.5	9.15	2.5	25	519a	
"		0.5	7.30	"			
"		0.5	4.50	4.0			
"		0.7	4.00	"			
"		0.7	1.87	"			
4	520	0.9	3.90	"		520a	
5		0.5	5.00	1.5	10	520b	
5	521	2.0	4.50	3.0	16	521a	[2] north side, main chute
6	-	2.6	2.90	5.0	12		
7	-	0.5	1.50	8.0	8		
8	-	0.5	2.75	10.0	10	N side a	far bank-lower gradient
"		0.5	3.30	"	"		
9	-	0.2	1.30	8.0	5		
10	-	0.6	0.65	6.0	8		
"		1.0	2.14				
"		2.0	-			N side b	[3] top main chute
"		0.6	3.50				

[1] did not measure vertical falls-assumed impassable

[2] much of north channel generally appeared passable up to face of dam (pics N side a, N side b)

[3] cross-over from north side channel to south side channels or dam face appeared difficult (pics 520a, 520b)

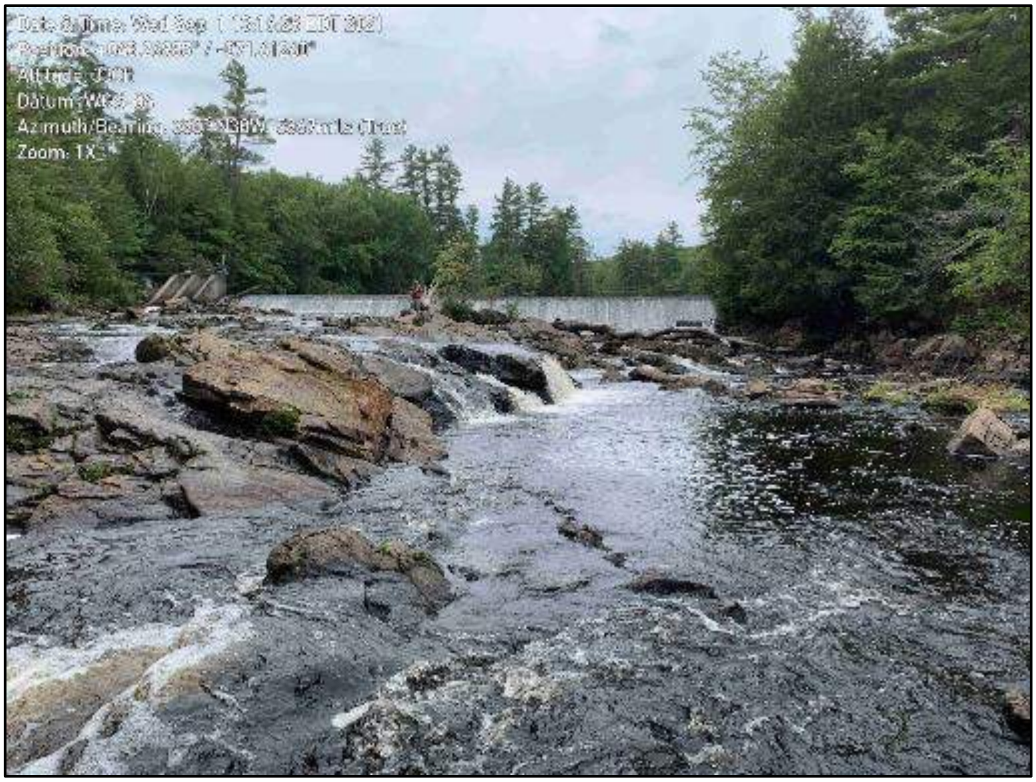


Figure 44–6. Terminal bedrock cascade immediately below York Dam.

Figure 44–7. Approximate locations of passage measurements in the terminal bedrock.

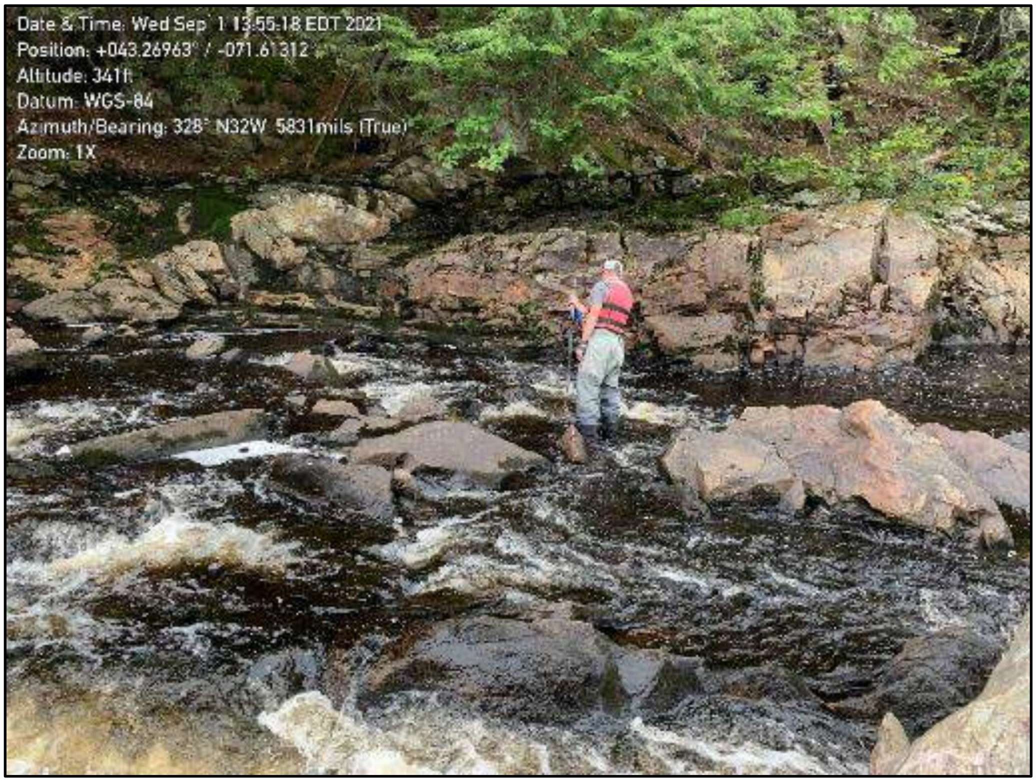


Figure 44–8. North channel showing possible passage routes to face of dam.

54 Historic Channel

Passage into the Historic Channel from the Rolfe Canal tailrace is effectively prevented by a concrete sill producing a 3.5 ft vertical drop into the tailrace (Figure 5-9). No other impediments to upstream migration were observed in the channel, with the possible exception of the beaver dam at the upstream end of the mapped channel as well as the upstream dam.

55 PUF Bypass

Upstream passage into the large bedrock pool in the PUF Bypass appeared somewhat limiting at low flow due to shallow depths at the bedrock pools primary outlet; however at higher flows fish passage into the pool via the main outlet by adult alosines appeared favorable.

56 PLF Bypass

The most limiting passage location in the PLF Bypass occurred at the steep whitewater chute at the very bottom of the bypass (Figure 5-10). The chute was approximately 10 ft in length with a vertical drop of approximately six ft. Depths ranged from 0.25 ft to 0.6 ft with velocities of 1.59 fps to 4.56 fps. Although chute depths would increase with spill flows the velocities are likely to quickly exceed the passage limits for shad and river herring, thus upstream passage into the PLF Bypass reach appeared unlikely.

Figure 44–9. Concrete sill where Historic Channel drops into Rolfe power canal.

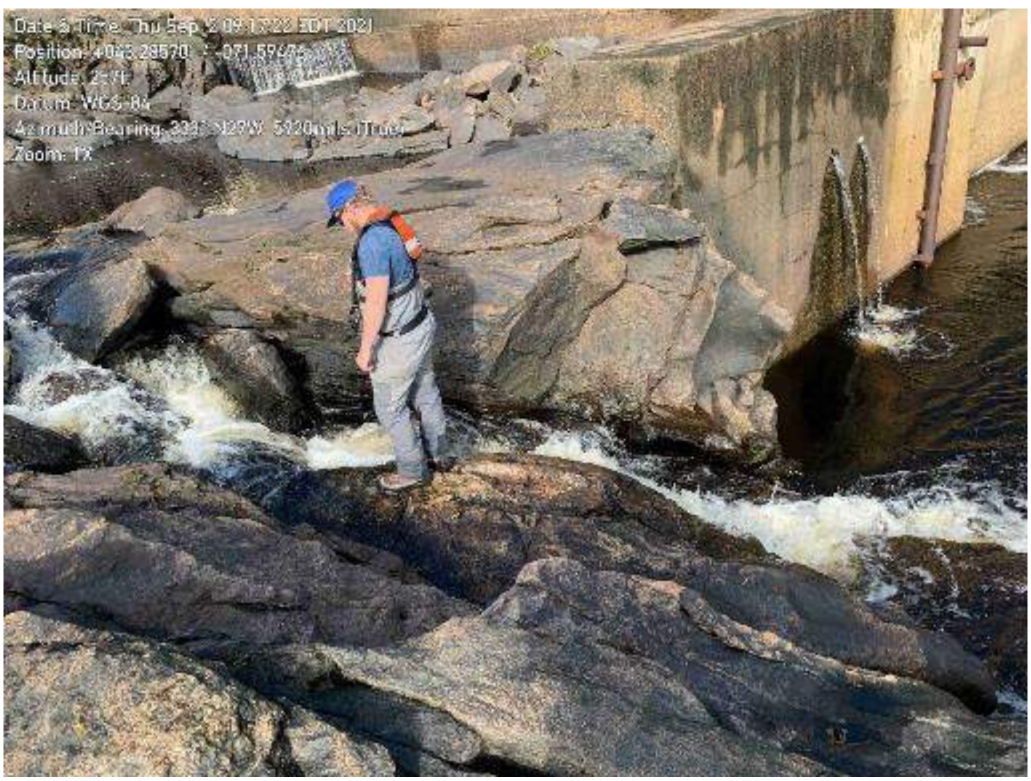


Figure 44–10. Passage chute at bottom of PLF Bypass.

57 Summary

The 3,800 ft long Rolfe Bypass reach was mapped and found to contain 28% pool habitat (by length), 46% run habitat, 18% riffle habitat, and 7% cascade habitat. Nine 1-D transects were distributed among habitats roughly proportional to availability. The hydraulic data collected at transects under low (60 cfs), middle (109 cfs), and high (172 cfs) flows were combined with habitat suitability criteria for four target fish species (and BMI) and their associated life-stages, to produce flow:habitat relationships. These relationships, or Area Weighted Suitability (AWS), were estimated for each species and life-stage over a range of discharges from 25 cfs to 500 cfs.

As expected, the relationships between flow and aquatic habitat in the Rolfe Bypass reach varied among species and life-stages, with most fry life-stages showing highest AWS at relatively low flows (50-100 cfs) compared to adult or spawning life-stages that generally approached peak AWS at flows over 300 cfs. AWS peaked at the maximum simulated flow (500 cfs) for nine of the 14 target species/life-stages, with the remaining five species/life-stages maximizing habitat as flows from 50 cfs to 350 cfs. For comparison, 80% of the maximum AWS occurred at flows of 250 cfs or less for 12 of the 14 species/life-stages, and eight species/life-stages showed 90% of maximum AWS at flows of 250 cfs or less. After averaging the percent AWS for all 14 species and life-stages combined, 70%, 80%, and 90% of maximum AWS was provided by bypass flows of approximately 98 cfs, 150 cfs, and 275 cfs, respectively. The low magnitude of AWS for spawning among the target species (<5 ft^2/ft) was largely due to the abundance of unsuitable bedrock substrate in the upper half of the Rolfe Bypass reach.

Upstream passage through the Rolfe Bypass by adult river herring or American shad appeared unhindered until reaching the cascade habitat immediately below York Dam. A likely passage route to the face of the dam appeared available along the northwest side of the river channel, but access to the dam along the southeast side did not appear feasible due to the bedrock drop, shallow depths, and high velocities.

Habitats within the Historic Channel were mapped along 1,112 ft of stream channel, where 17% of habitat units were pools, 67% were runs, and 16% were riffles. Under the bypass flow of 5.5 cfs, habitat units in the Historic Channel averaged 62 ft in length and 23 ft in width. A range of substrate types were present but the channel was heavily dominated by a thick layer of fine sediments. Juvenile fish were observed in the Historic Channel, likely due to passage over the upstream dam, or spawning by small cyprinid species, but immigration from downstream sources was prevented by a 3.5 ft vertical drop into the Rolfe powerhouse tailrace.

The PUF Bypass is relatively short (~250 ft) and dominated by a large (123 ft by 81 ft) bedrock pool of unknown depth (but >4 ft). Four other smaller pools with maximum depths from 2.2 ft to over 4 ft were also present, as well as a small stream channel 4-6 ft in width and 78 ft long that flowed from the base of the dam at its southwest corner through a vegetated area into the bedrock habitat. Passage from the powerhouse tailrace and downstream habitat into the large bedrock pool appeared suitable for adult alosines under a range of bypass flows. Most of the flow exiting the bedrock pool into the tailrace area (1.3 cfs) appeared to originate from the small stream. The large bedrock pool and the riparian stream channel appeared to offer refuge to fish from higher flows through the bypass.

The PLF Bypass reach is a 680 ft bedrock pool-cascade feature that averaged 87 ft in bankfull width. Under the leakage flow of 5.5 cfs, 14 pools averaging 10-20 ft in width had maximum depths of 0.6 ft to over 4 ft, with an average of 2.5 ft. Few pools appeared to offer refuge to fish under a spill flow regime. Also, a long, steep chute with shallow depths and high velocities appeared to offer a formidable challenge to upstream migrant river herring and American shad.

58 Variances from Approved Study Plan

The following variances from the methodology originally specified in the revised study plan or in subsequent consultation with the resource agencies occurred.

- Velocity acquisition occurred at a lower flow level than anticipated (59.9 versus 172 cfs). However, due to relatively steep banks in the study reach the ability to collect complete velocity measurements across transects was not an issue. Normandeau field staff also collected additional velocity measurements at bank side locations under the high flow (172 cfs) condition.

- Pool transect 7 was dropped from the study due to incomplete bottom and velocity profiles. Depth and velocity data collected by the ADCP were not detailed enough to produce an adequate hydraulic model for that transect. Since three pool transects were originally selected for modeling, it was assumed the loss of this single location had a limited effect on habitat modeling results.

- Upstream passage measurements were only collected at one flow (60 cfs). Velocities would not allow safe measurements at the high flow (172 cfs), and the north channel appeared to remain passable at the middle flow (109 cfs).

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60 Appendices

Appendix A. Habitat Suitability Criteria for Target Species and Life-Stages

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USFWS. 2019. Fish passage engineering design criteria. USFWS Northeast Region R5, Hadley, MA. 224pp.

Table A-1. HSC for target species and life stages.

Species	Life-stage	Velocity (fps)	HSC	Depth (ft)	HSC	Substrate	HSC	Source
Smallmouth	Fry	0.00	0.60	0.00	0.00	Organics	0.10	Leonard et al. 1986
Bass		0.19	1.00	0.28	0.06	Mud/clay	0.10	
		0.59	1.00	1.31	1.00	Silt	0.10	
		1.00	0.00	2.95	1.00	Sand	0.20	
				3.25	0.95	Gravel	0.30	
				4.59	0.40	Cobble	1.00	
				6.56	0.00	Boulder	1.00	
				10.00	0.00	Bedrock	0.50	
Smallmouth	Juvenile	0.00	0.30	0.00	0.00	Organics	0.10	Groshens and Orth 1994 (V), Leonard et al. 1986 (D,S)
Bass		0.17	0.66	0.52	0.00	Mud/clay	0.10	
		0.33	0.90	0.67	0.03	Silt	0.10	
		0.50	0.93	2.15	1.00	Sand	0.20	
		0.66	1.00	10.00	1.00	Gravel	0.30	
		0.83	1.00			Cobble	1.00	
		0.98	0.93			Boulder	1.00	
		1.15	0.87			Bedrock	0.50	
		1.31	0.84					
		1.47	0.77					
		1.64	0.70					
		1.81	0.62					
		1.98	0.47					
		2.30	0.27					
		2.62	0.17					
		2.95	0.09					
		3.94	0.03					
		4.59	0.00					

Species	Life-stage	Velocity (fps)	HSC	Depth (ft)	HSC	Substrate	HSC	Source
Smallmouth	Adult	0.00	0.12	0.00	0.00	Organics	0.10	Groshens and Orth 1994 (V), Leonard et al. 1986 (D,S)
Bass		0.17	0.66	0.92	0.00	Mud/clay	0.10	
		0.33	0.90	1.31	0.08	Silt	0.10	
		0.50	1.00	2.03	0.56	Sand	0.20	
		0.66	0.93	2.82	1.00	Gravel	0.30	
		0.83	0.82	6.00	1.00	Cobble	1.00	
		0.98	0.65	10.00	1.00	Boulder	1.00	
		1.15	0.53			Bedrock	0.50	
		1.31	0.46					
		1.47	0.42					
		1.64	0.36					
		1.81	0.32					
		1.98	0.25					
		2.30	0.15					
		2.62	0.08					
		2.95	0.06					
		3.94	0.04					
		4.59	0.04					
		5.00	0.00					
Smallmouth	Spawning	0.00	1.00	0.22	0.00	Organics	0.00	Allen 1996 (V,S), Edwards et al. 1983 (D)
Bass		0.45	1.00	0.50	0.02	Mud/clay	0.00	
		0.55	0.96	0.74	0.05	Silt	0.00	
		0.65	0.89	1.10	0.12	Sand	0.20	
		0.75	0.69	1.32	0.22	Gravel	1.00	
		0.85	0.34	1.53	0.34	Cobble	0.30	

Species	Life-stage	Velocity (fps)	HSC	Depth (ft)	HSC	Substrate	HSC	Source
		0.95	0.25	1.70	0.54	Boulder	0.00	
		1.05	0.20	1.90	0.90	Bedrock	0.00	
		1.15	0.16	2.05	0.97			
		1.25	0.14	2.18	0.99			
		1.65	0.11	2.40	1.00			
		1.85	0.09	4.75	1.00			
		2.35	0.04	4.95	0.97			
		2.55	0.02	5.10	0.91			
		2.75	0.00	5.40	0.62			
				5.80	0.40			
				6.10	0.27			
				6.50	0.17			
				6.95	0.09			
				7.30	0.04			
				7.75	0.02			
				8.00	0.00			
Fallfish	Fry	0.00	0.00	0.00	0.00	Organics	0.00	Gomez & Sullivan 2007
		0.10	1.00	0.25	1.00	Mud/clay	0.00	
		0.60	1.00	1.65	1.00	Silt	0.50	
		0.90	0.94	2.30	0.82	Sand	1.00	
		1.20	0.46	4.60	0.00	Gravel	1.00	
		2.90	0.00			Cobble	0.20	
						Boulder	0.00	
						Bedrock	0.00	
	Juvenile	0.00	0.00	0.00	0.00	Organics	0.10	Gomez & Sullivan 2007
		0.10	0.60	0.40	0.00	Mud/clay	0.00	
		0.20	0.88	0.60	0.11	Silt	0.10	

Species	Life-stage	Velocity (fps)	HSC	Depth (ft)	HSC	Substrate	HSC	Source
		0.60	1.00	1.00	1.00	Sand	0.50	
		1.60	1.00	3.00	1.00	Gravel	1.00	
		2.00	0.40	4.00	0.27	Cobble	1.00	
		3.50	0.04	7.00	0.24	Boulder	0.20	
		4.30	0.00	8.00	0.07	Bedrock	0.00	
				100.00	0.07			
Fallfish	Adult	0.00	0.00	0.00	0.00	Organics	1.00	Gomez & Sullivan 2007
		0.10	1.00	0.50	0.00	Mud/clay	1.00	
		0.80	1.00	3.00	1.00	Silt	1.00	
		1.50	0.40	100.00	1.00	Sand	1.00	
		3.00	0.00			Gravel	1.00	
						Cobble	1.00	
						Boulder	1.00	
						Bedrock	1.00	
Fallfish	Spawning	0.00	0.00	0.40	0.00	Organics	0.00	Gomez & Sullivan 2007
		0.10	0.80	0.80	1.00	Mud/clay	0.00	
		1.00	1.00	2.30	1.00	Silt	0.00	
		1.50	1.00	4.50	0.00	Sand	0.00	
		2.50	0.20			Gravel	1.00	
		3.00	0.00			Cobble	0.00	
						Boulder	0.00	
						Bedrock	0.00	
White Sucker	Fry	0.00	1.00	0.00	0.00	Organics	1.00	Twomey et al. 1984
		0.30	1.00	1.00	1.00	Mud/clay	1.00	
		1.00	0.00	100.00	1.00	Silt	1.00	
						Sand	1.00	

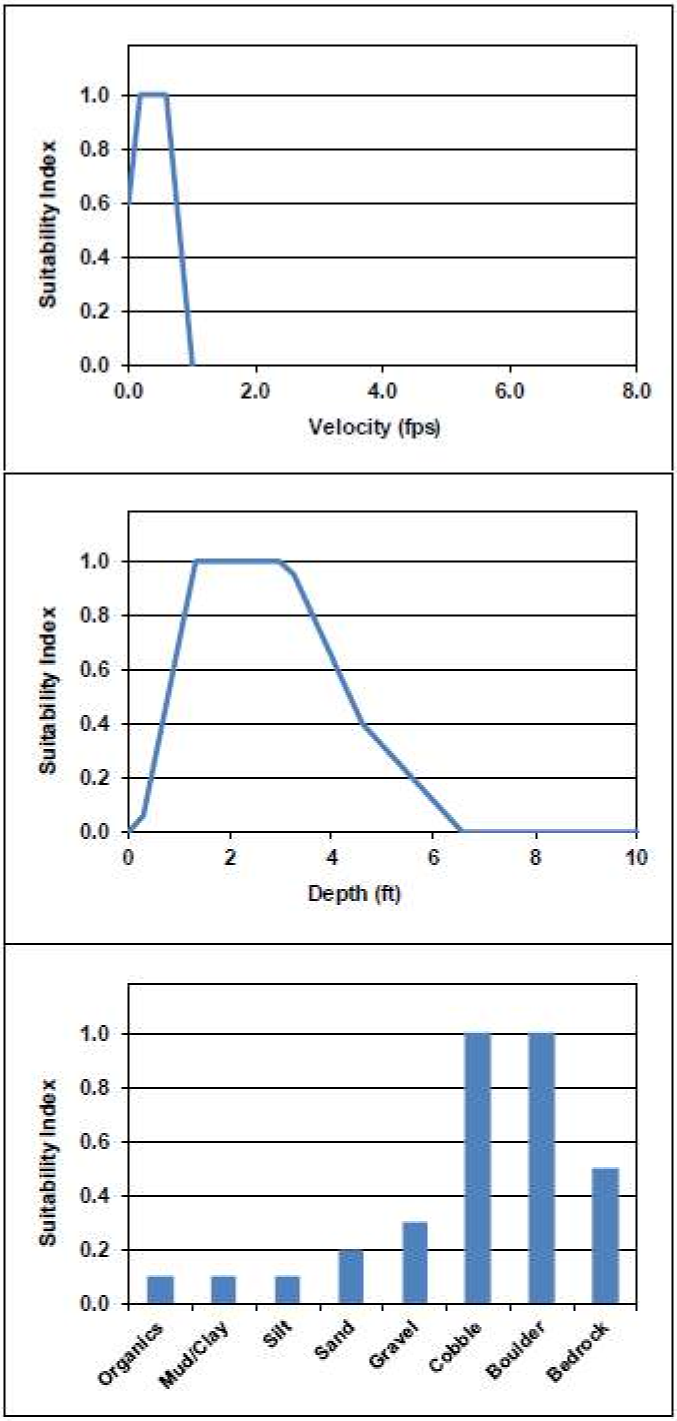
Species	Life-stage	Velocity (fps)	HSC	Depth (ft)	HSC	Substrate	HSC	Source
						Gravel	1.00	
						Cobble	1.00	
						Boulder	1.00	
						Bedrock	1.00	
White Sucker	Juvenile/	0.00	0.00	0.00	0.00	Organics	1.00	Twomey et al. 1984
	Adult	0.16	0.70	0.50	0.00	Mud/clay	1.00	
		0.33	1.00	2.30	1.00	Silt	1.00	
		0.49	1.00	3.30	1.00	Sand	1.00	
		0.66	0.70	9.80	0.50	Gravel	1.00	
		1.31	0.00	16.40	0.00	Cobble	1.00	
						Boulder	1.00	
						Bedrock	1.00	
White Sucker	Spawning	0.00	0.00	0.00	0.00	Organics	0.00	Twomey et al. 1984 (V,D), Gomez & Sullivan 2007 (S)
		0.50	0.40	0.50	1.00	Mud/clay	0.00	
		1.00	1.00	0.80	1.00	Silt	0.50	
		2.00	1.00	1.00	0.80	Sand	1.00	
		3.00	0.00	2.00	0.00	Gravel	0.90	
						Cobble	0.00	
						Boulder	0.00	
						Bedrock	0.00	
Longnose	Juvenile	0.00	0.00	0.00	0.00	Organics	0.00	Gomez & Sullivan 2007
Dace		0.75	1.00	0.75	1.00	Mud/clay	0.00	
		1.50	1.00	1.15	1.00	Silt	0.00	
		2.00	0.35	1.50	0.40	Sand	0.18	
		2.20	0.20	1.75	0.20	Gravel	1.00	

Species	Life-stage	Velocity (fps)	HSC	Depth (ft)	HSC	Substrate	HSC	Source
		2.50	0.13	2.00	0.14	Cobble	1.00	
		3.00	0.05	3.00	0.00	Boulder	0.50	
		4.00	0.00			Bedrock	0.00	
Longnose	Adult	0.00	0.00	0.00	0.00	Organics	0.00	Gomez & Sullivan 2007
Dace		0.75	1.00	0.10	0.00	Mud/clay	0.00	
		1.75	1.00	0.75	1.00	Silt	0.00	
		3.00	0.28	1.60	1.00	Sand	0.60	
		3.60	0.08	2.50	0.00	Gravel	1.00	
		4.50	0.00			Cobble	1.00	
						Boulder	0.80	
						Bedrock	0.00	
BMI	Rearing	0.00	0.00	0.00	0.00	Organics	0.50	Gomez & Sullivan 2000
		0.50	0.00	0.10	0.00	Mud/clay	0.50	
		1.50	1.00	0.40	1.00	Silt	0.20	
		3.50	1.00	3.00	1.00	Sand	0.10	
		4.60	0.50	5.00	0.50	Gravel	0.60	
		8.00	0.00	6.50	0.25	Cobble	1.00	
				8.00	0.15	Boulder	0.90	
				10.00	0.15	Bedrock	0.50	
				100.00	0.00			

Smallmouth Bass Fry

Source:

Leonard et al, 1986



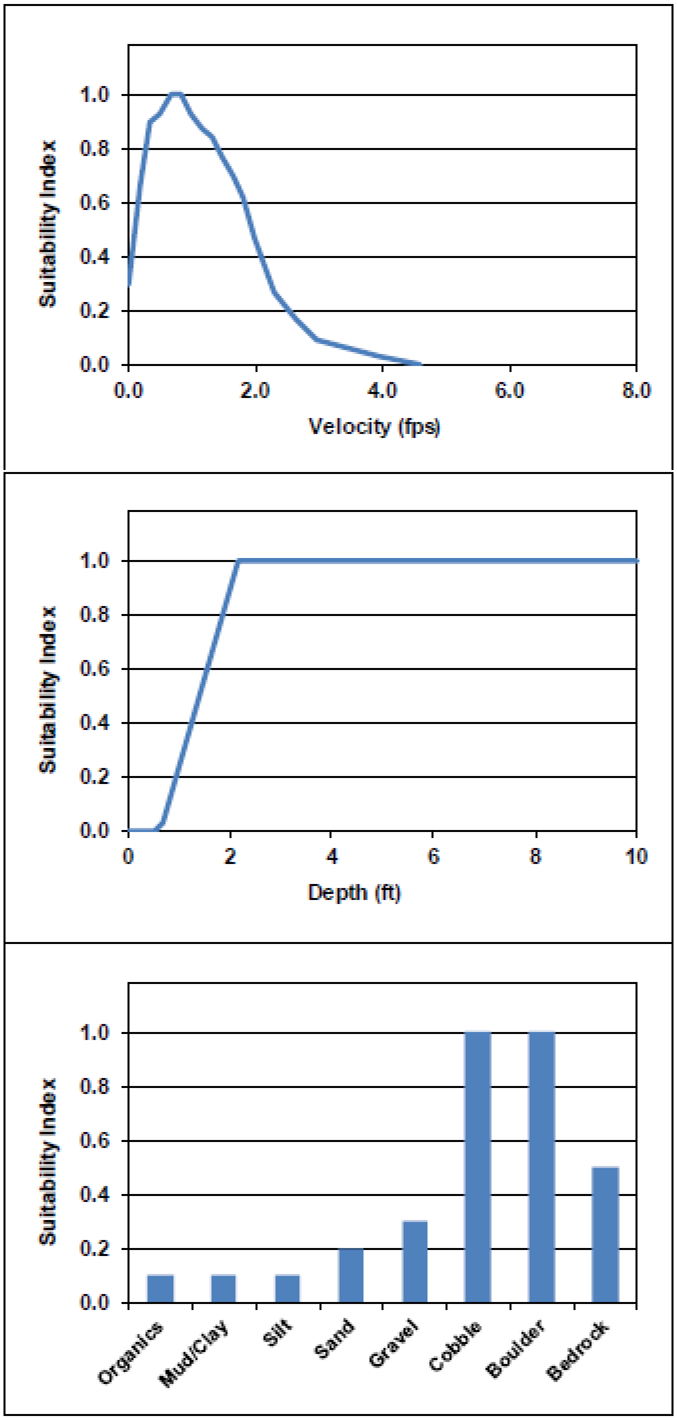
Velocity (ft/s)	SI
0.00	0.60
0.19	1.00
0.59	1.00
1.00	0.00

Depth (ft)	SI
0.00	0.00
0.28	0.06
1.31	1.00
2.95	1.00
3.25	0.95
4.59	0.40
6.56	0.00
10.00	0.00

Substrate	SI
Organics	0.10
Mud/Clay	0.10
Silt	0.10
Sand	0.20
Gravel	0.30
Cobble	1.00
Boulder	1.00
Bedrock	0.50

Figure A-1. HSC for smallmouth bass fry.

Smallmouth Bass Juvenile



Source:
Groshens and Orth 1994

Velocity (ft/s)	SI
0.00	0.30
0.17	0.66
0.33	0.90
0.50	0.93
0.66	1.00
0.83	1.00
0.98	0.93
1.15	0.87
1.31	0.84
1.47	0.77
1.64	0.70
1.81	0.62
1.98	0.47
2.30	0.27
2.62	0.17
2.95	0.09
3.94	0.03
4.59	0.00

Leonard et al, 1986

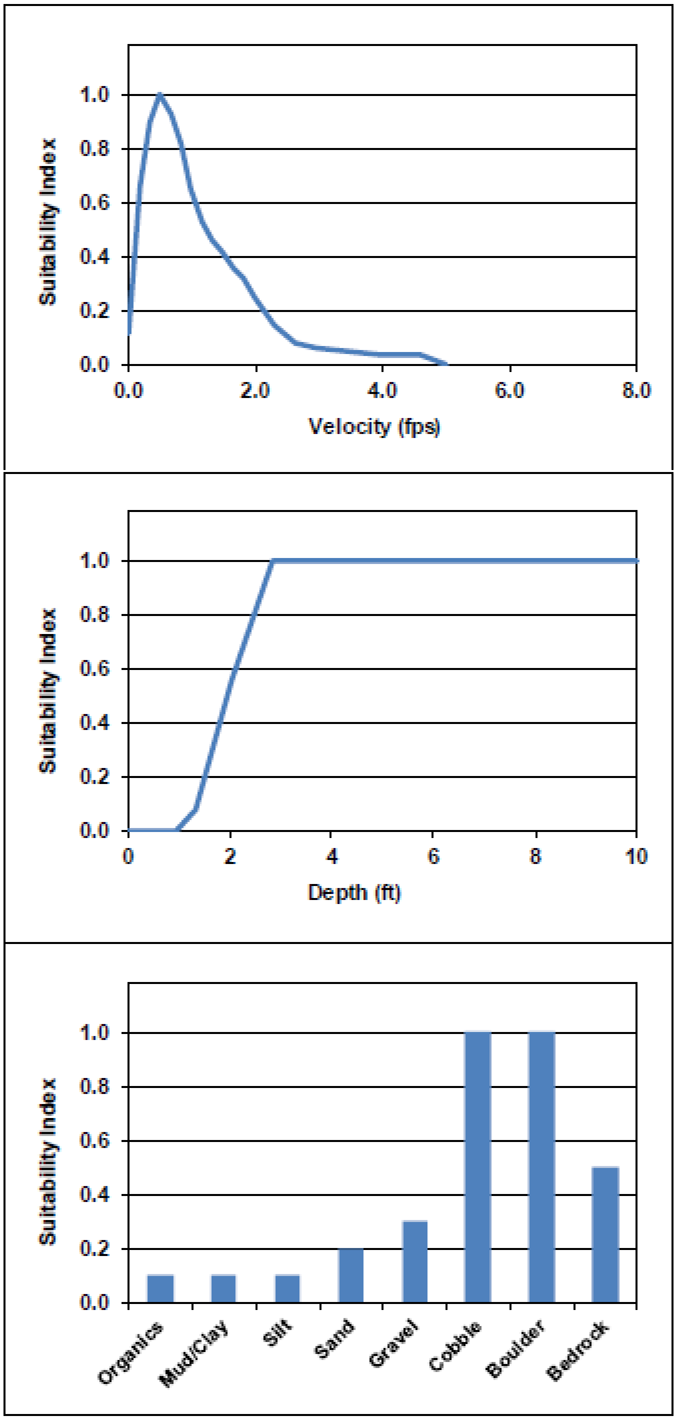
Depth (ft)	SI
0.00	0.00
0.52	0.00
0.67	0.03
2.15	1.00
10.00	1.00

Leonard et al, 1986

Substrate	SI
Organics	0.10
Mud/Clay	0.10
Silt	0.10
Sand	0.20
Gravel	0.30
Cobble	1.00
Boulder	1.00
Bedrock	0.50

Figure A-2. HSC for smallmouth bass juveniles.

Smallmouth Bass Adult



Source:

Groshens and Orth 1994

Velocity (ft/s)	SI
0.00	0.12
0.17	0.66
0.33	0.90
0.50	1.00
0.66	0.93
0.83	0.82
0.98	0.65
1.15	0.53
1.31	0.46
1.47	0.42
1.64	0.36
1.81	0.32
1.98	0.25
2.30	0.15
2.62	0.08
2.95	0.06
3.94	0.04
4.59	0.04
5.00	0.00

Leonard et al, 1986

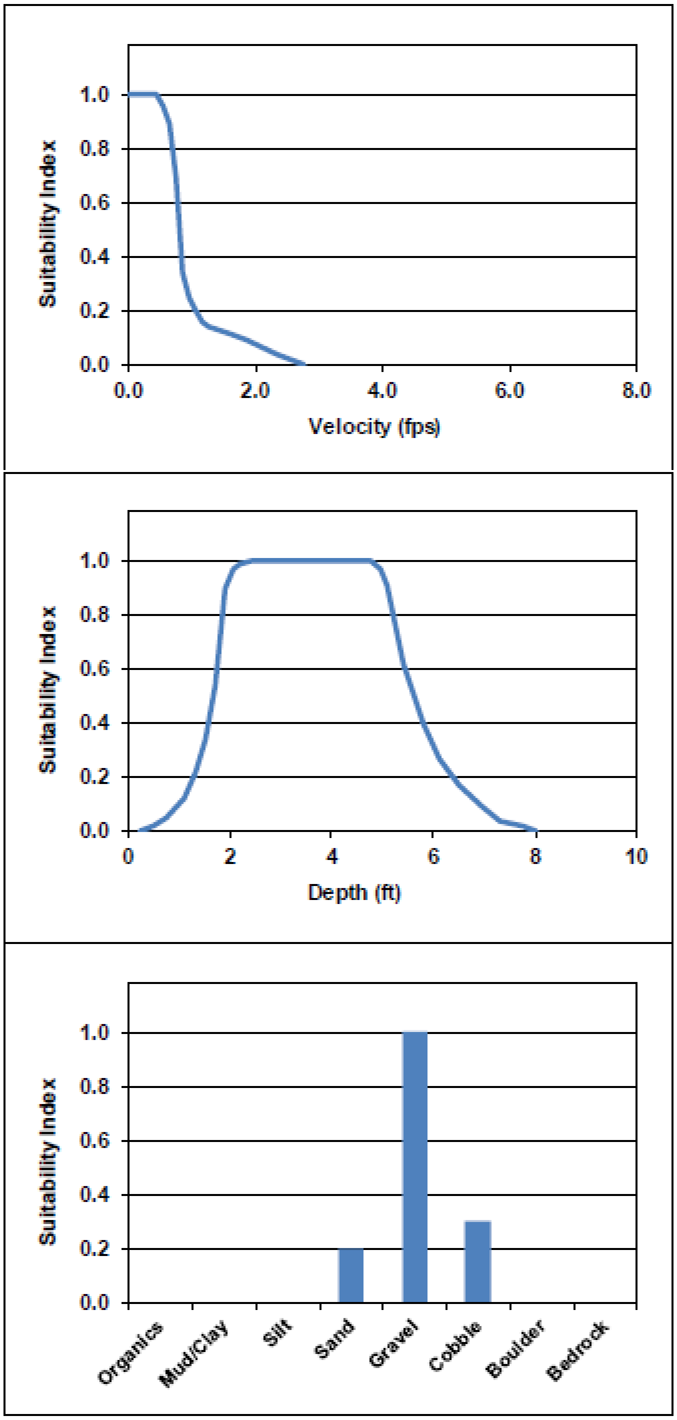
Depth (ft)	SI
0.00	0.00
0.92	0.00
1.31	0.08
2.03	0.56
2.82	1.00
6.00	1.00
10.00	1.00

Leonard et al, 1986

Substrate	SI
Organics	0.10
Mud/Clay	0.10
Silt	0.10
Sand	0.20
Gravel	0.30
Cobble	1.00
Boulder	1.00
Bedrock	0.50

Figure A-3. HSC for smallmouth bass adults.

Smallmouth Bass Spawning



Source:

Allen, 1996

Velocity (ft/s)	SI
0.00	1.00
0.45	1.00
0.55	0.96
0.65	0.89
0.75	0.69
0.85	0.34
0.95	0.25
1.05	0.20
1.15	0.16
1.25	0.14
1.65	0.11
1.85	0.09
2.35	0.04
2.55	0.02
2.75	0.00

Edwards et al., 1983

Depth (ft)	SI
0.22	0.00
0.50	0.02
0.74	0.05
1.10	0.12
1.32	0.22
1.53	0.34
1.70	0.54
1.90	0.90
2.05	0.97
2.18	0.99
2.40	1.00
4.75	1.00
4.95	0.97
5.10	0.91
5.40	0.62
5.80	0.40
6.10	0.27
6.50	0.17
6.95	0.09
7.30	0.04
7.75	0.02
8.00	0.00

Allen, 1996

Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.20
Gravel	1.00
Cobble	0.30
Boulder	0.00
Bedrock	0.00

Figure A-4. HSC for smallmouth bass spawning.

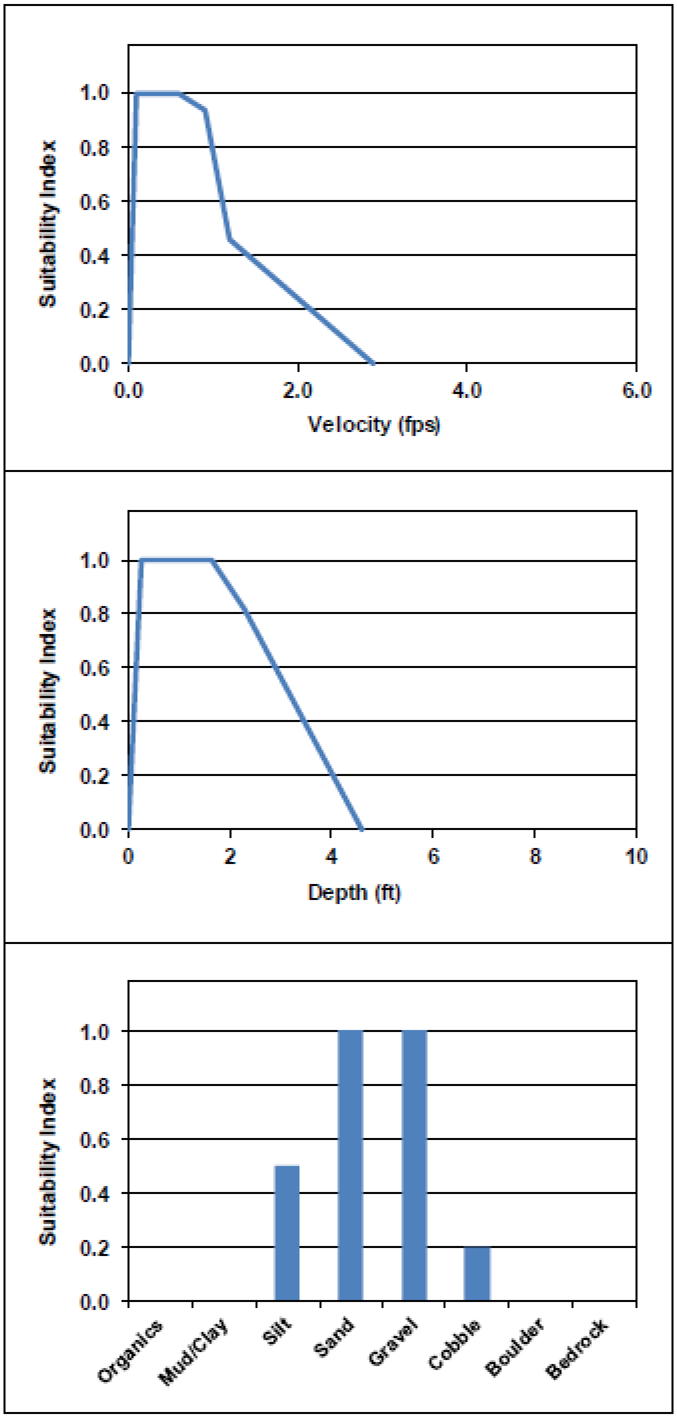
Fallfish Fry

Velocity and depth from brook trout fry curves (Deerfield River)

Substrate developed by Charles Ritzi

Source:

Gomez and Sullivan, 2007



Velocity (ft/s)	SI
0.00	0.00
0.10	1.00
0.60	1.00
0.90	0.94
1.20	0.46
2.90	0.00

Depth (ft)	SI
0.00	0.00
0.25	1.00
1.65	1.00
2.30	0.82
4.60	0.00
100.00	0.00

Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.50
Sand	1.00
Gravel	1.00
Cobble	0.20
Boulder	0.00
Bedrock	0.00

Figure A-5. HSC for fallfish fry.

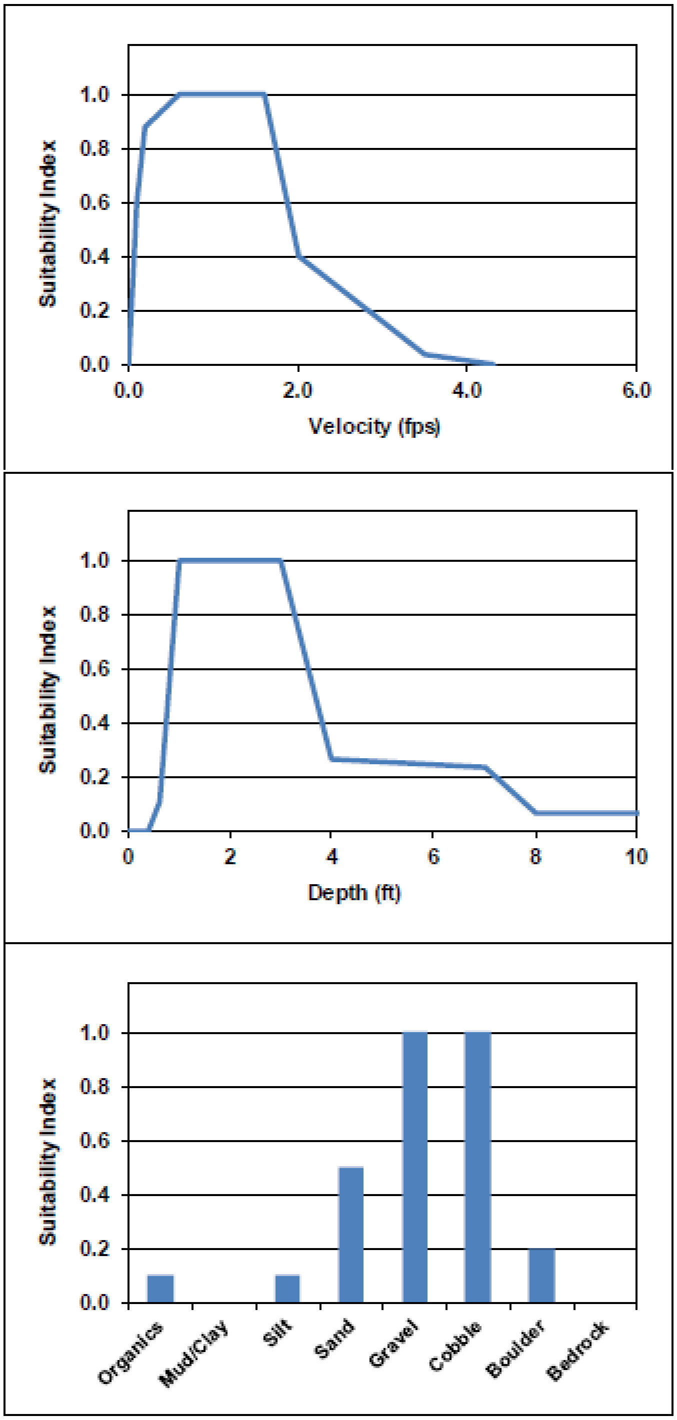
Fallfish Juvenile

Velocity and depth from brook trout fry curves (Deerfield River)

Substrate developed by Charles Ritzi

Source:

Gomez and Sullivan, 2007



Velocity (ft/s)	SI
0.00	0.00
0.10	0.60
0.20	0.88
0.60	1.00
1.60	1.00
2.00	0.40
3.50	0.04
4.30	0.00

Depth (ft)	SI
0.00	0.00
0.40	0.00
0.60	0.11
1.00	1.00
3.00	1.00
4.00	0.27
7.00	0.24
8.00	0.07
20.00	0.07
100.00	0.07

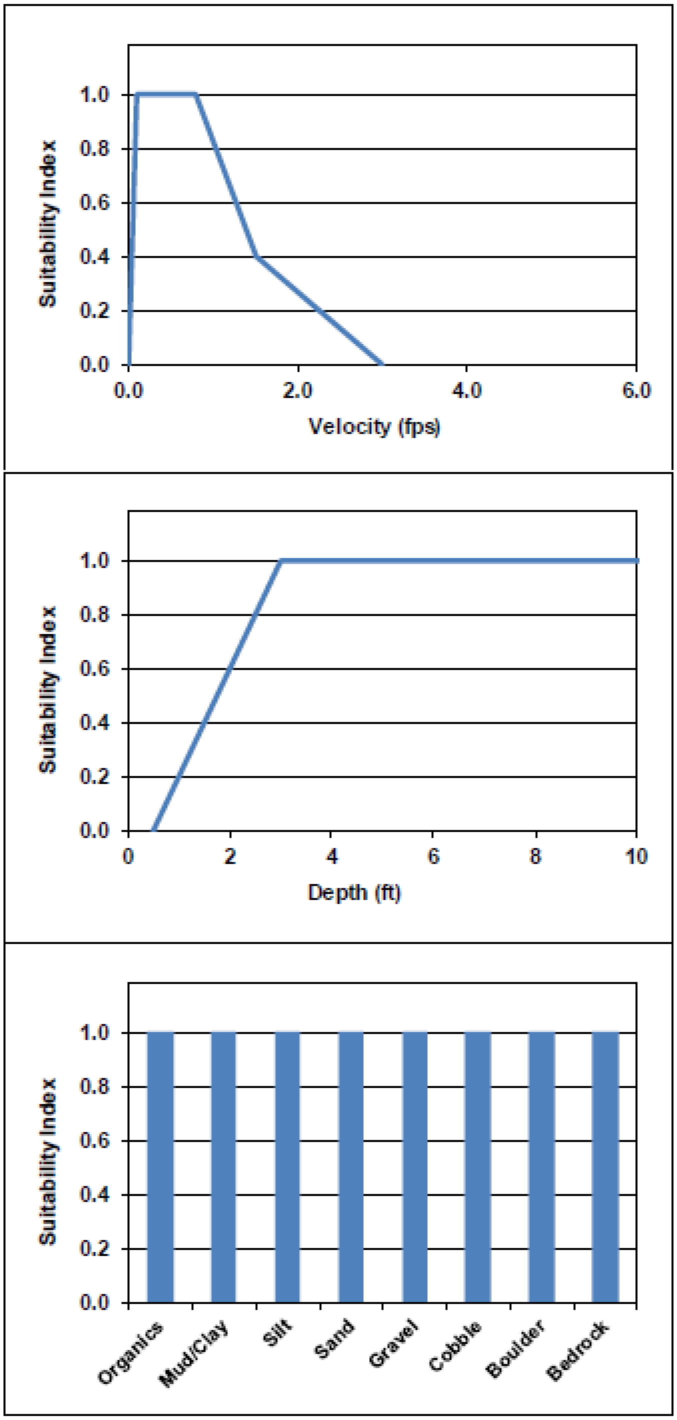
Substrate	SI
Organics	0.10
Mud/Clay	0.00
Silt	0.10
Sand	0.50
Gravel	1.00
Cobble	1.00
Boulder	0.20
Bedrock	0.00

Figure A-6. HSC for fallfish juveniles.

Fallfish Adult

Developed from consultation with NYSDEC
(New York Dept. of Environmental Conservation)

Source:
Gomez and Sullivan, 2007



Velocity (ft/s)	SI
0.00	0.00
0.10	1.00
0.80	1.00
1.50	0.40
3.00	0.00

Depth (ft)	SI
0.00	0.00
0.50	0.00
3.00	1.00
100.00	1.00

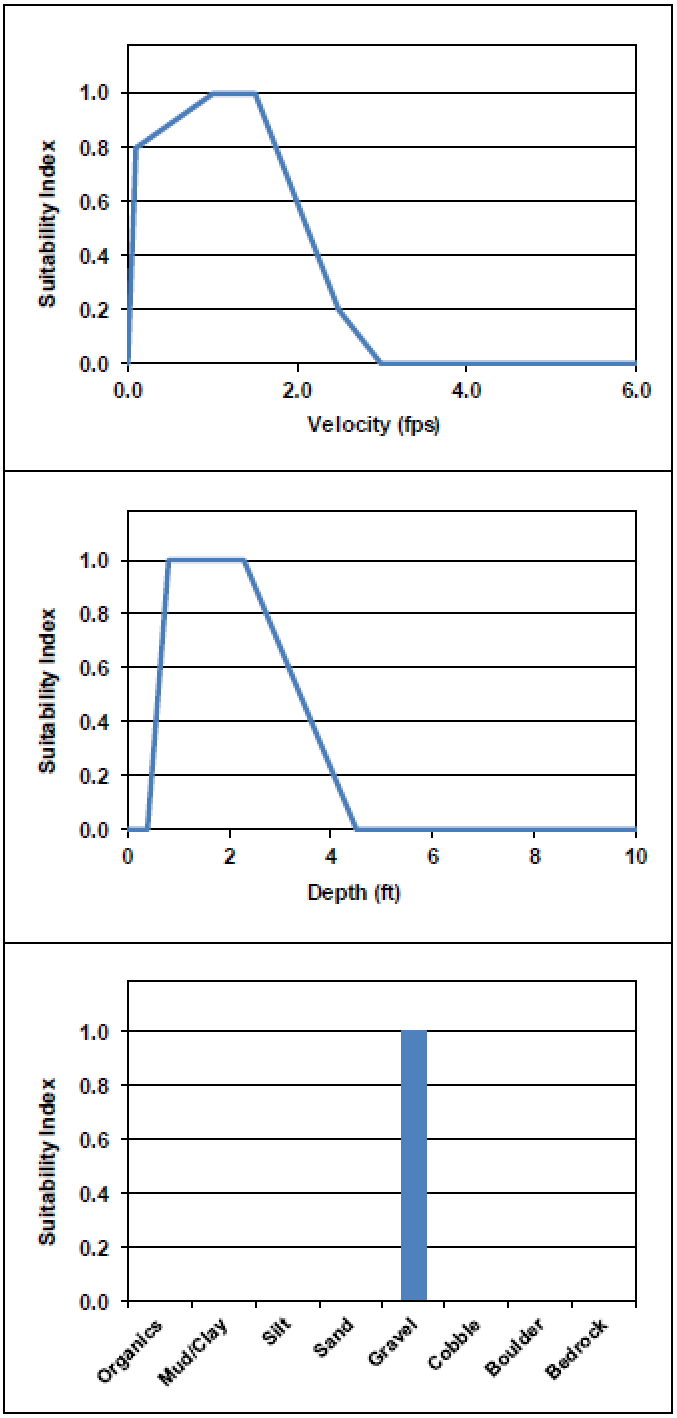
Substrate	SI
Organics	1.00
Mud/Clay	1.00
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	1.00
Bedrock	1.00

Figure A-7. HSC for fallfish adults.

Fallfish Spawning & Incubation

Developed from consultation with NYSDEC
(New York Dept. of Environmental Conservation)

Source:
Gomez and Sullivan, 2007



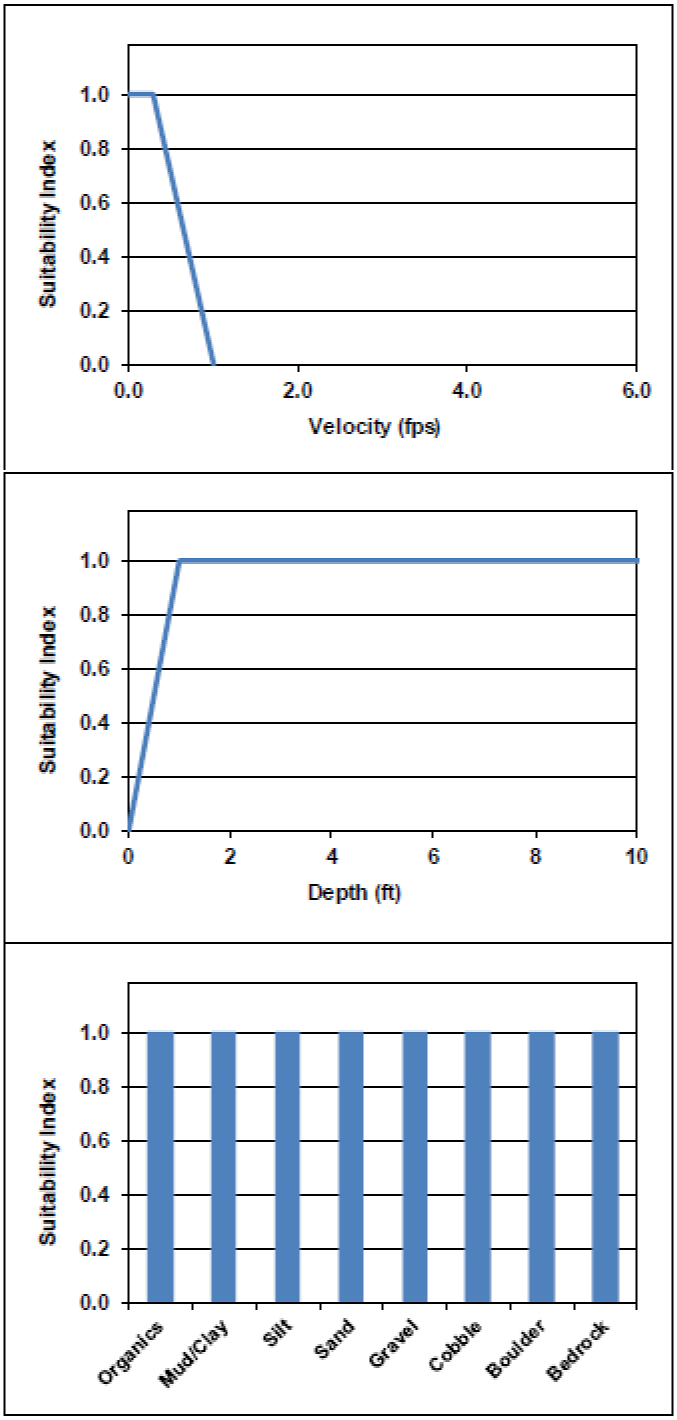
Velocity (ft/s)	SI
0.00	0.00
0.10	0.80
1.00	1.00
1.50	1.00
2.50	0.20
3.00	0.00
100.00	0.00

Depth (ft)	SI
0.00	0.00
0.40	0.00
0.80	1.00
2.30	1.00
4.50	0.00
100.00	0.00

Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.00
Gravel	1.00
Cobble	0.00
Boulder	0.00
Bedrock	0.00

Figure A-8. HSC for fallfish adults.

White Sucker Fry



Source:

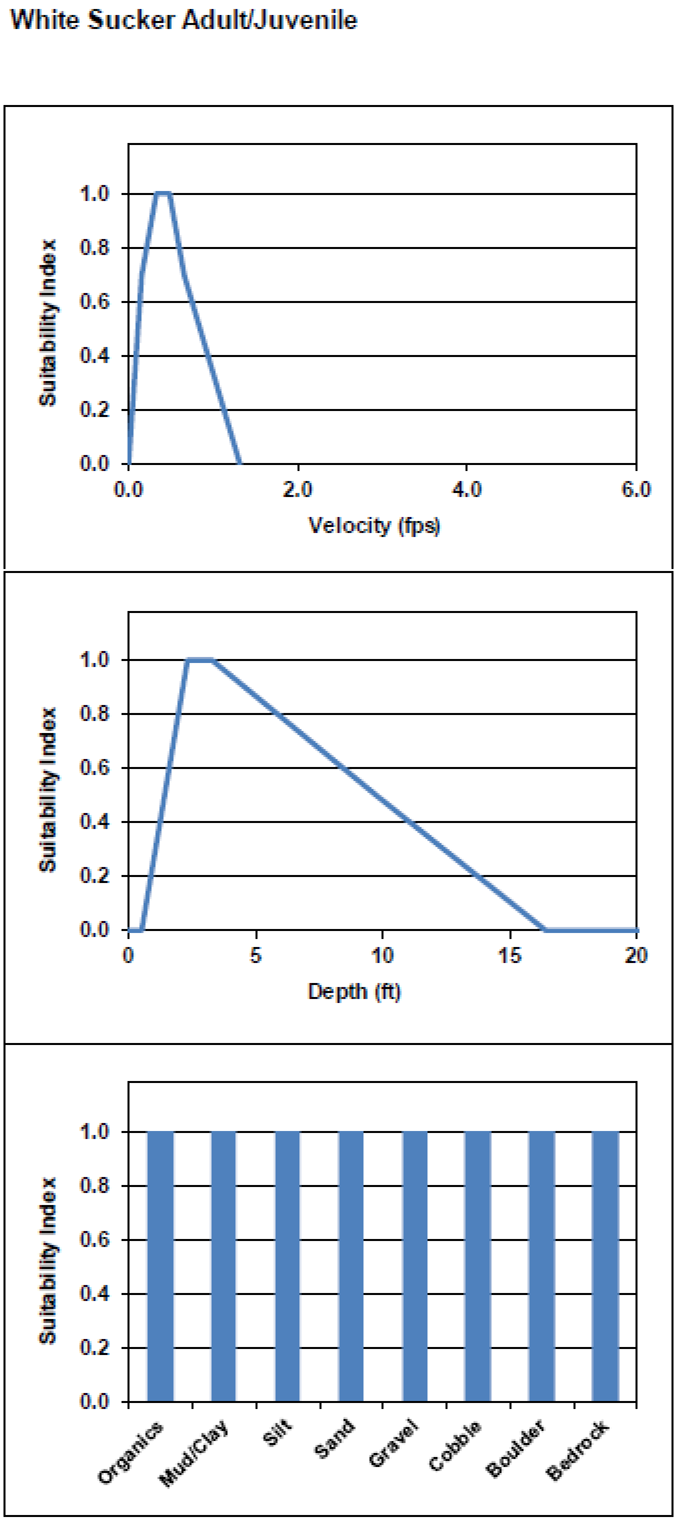
Twomey et al., 1984

Velocity (ft/s)	SI
0.00	1.00
0.30	1.00
1.00	0.00

Depth (ft)	SI
0.00	0.00
1.00	1.00
100.00	1.00

Substrate	SI
Organics	1.00
Mud/Clay	1.00
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	1.00
Bedrock	1.00

Figure A-9. HSC for white sucker fry.



Source:
Twomey et al., 1984

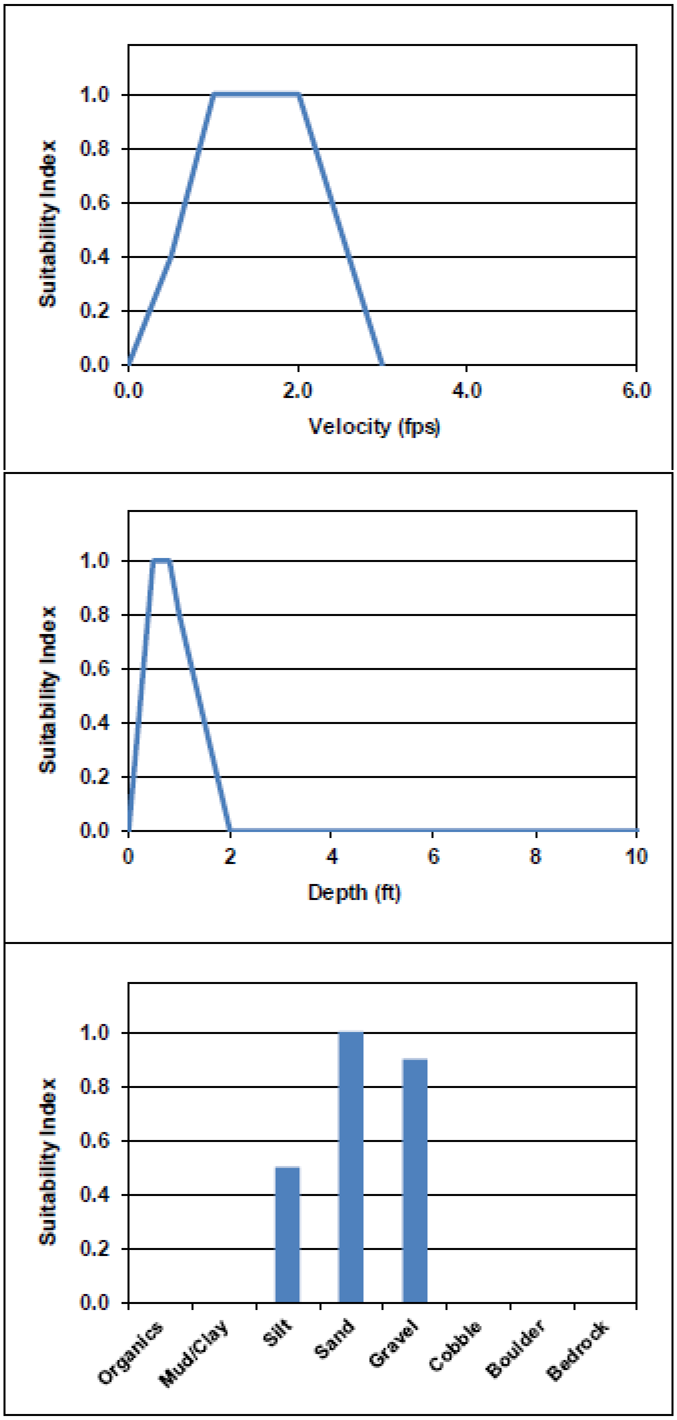
Velocity (ft/s)	SI
0.00	0.00
0.16	0.70
0.33	1.00
0.49	1.00
0.66	0.70
1.31	0.00

Depth (ft)	SI
0.00	0.00
0.50	0.00
2.30	1.00
3.30	1.00
9.80	0.50
16.40	0.00
100.00	0.00

Substrate	SI
Organics	1.00
Mud/Clay	1.00
Silt	1.00
Sand	1.00
Gravel	1.00
Cobble	1.00
Boulder	1.00
Bedrock	1.00

Figure A-10. HSC for white sucker juveniles and adults.

White Sucker Spawning & Incubation



Source:

Twomey et al., 1984

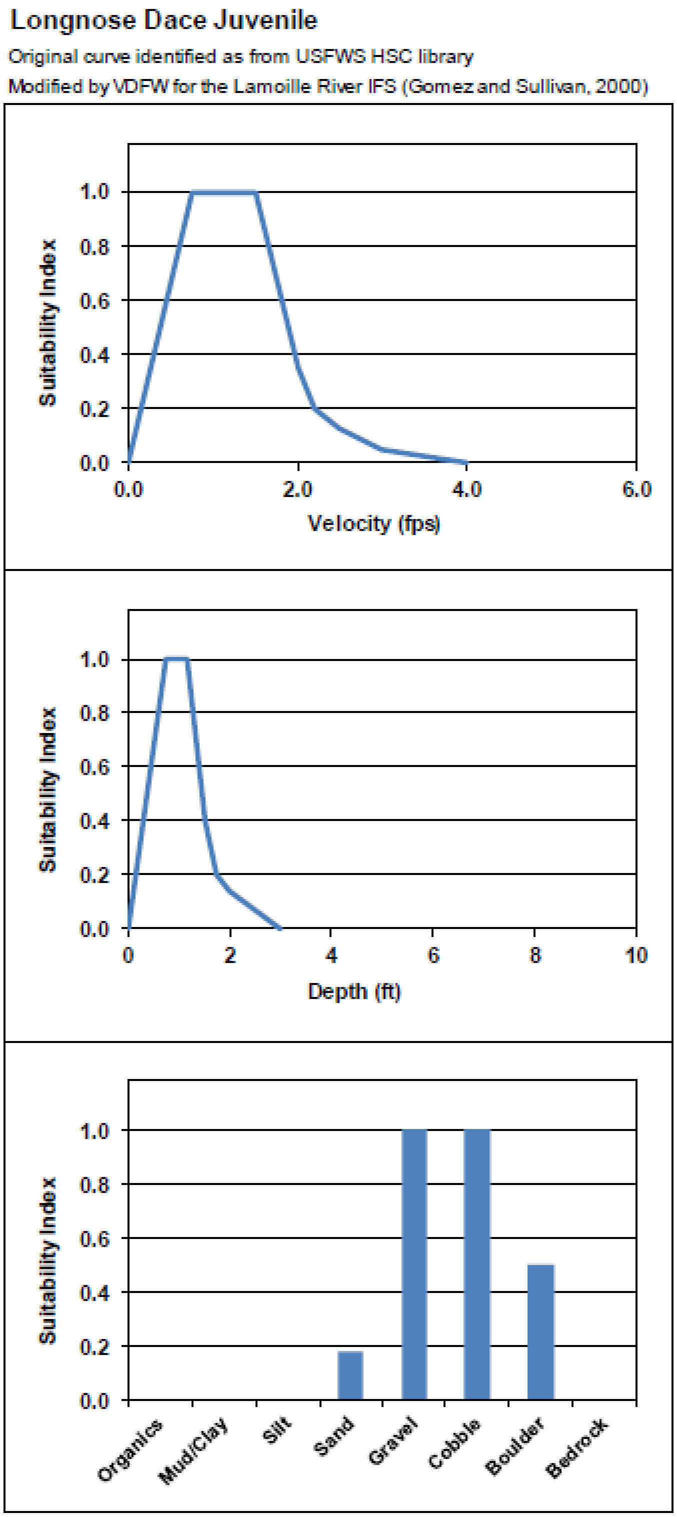
Velocity (ft/s)	SI
0.00	0.00
0.50	0.40
1.00	1.00
2.00	1.00
3.00	0.00

Depth (ft)	SI
0.00	0.00
0.50	1.00
0.80	1.00
1.00	0.80
2.00	0.00
100.00	0.00

Substrate Source:
Gomez and Sullivan, 2007

Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.50
Sand	1.00
Gravel	0.90
Cobble	0.00
Boulder	0.00
Bedrock	0.00

Figure A-11. HSC for white sucker spawning.



Source:
Gomez and Sullivan, 2000

Velocity (ft/s)	SI
0.00	0.00
0.75	1.00
1.50	1.00
2.00	0.35
2.20	0.20
2.50	0.13
3.00	0.05
4.00	0.00

Depth (ft)	SI
0.00	0.00
0.75	1.00
1.15	1.00
1.50	0.40
1.75	0.20
2.00	0.14
3.00	0.00

Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.18
Gravel	1.00
Cobble	1.00
Boulder	0.50
Bedrock	0.00

Figure A-12. HSC for longnose dace juvenile.

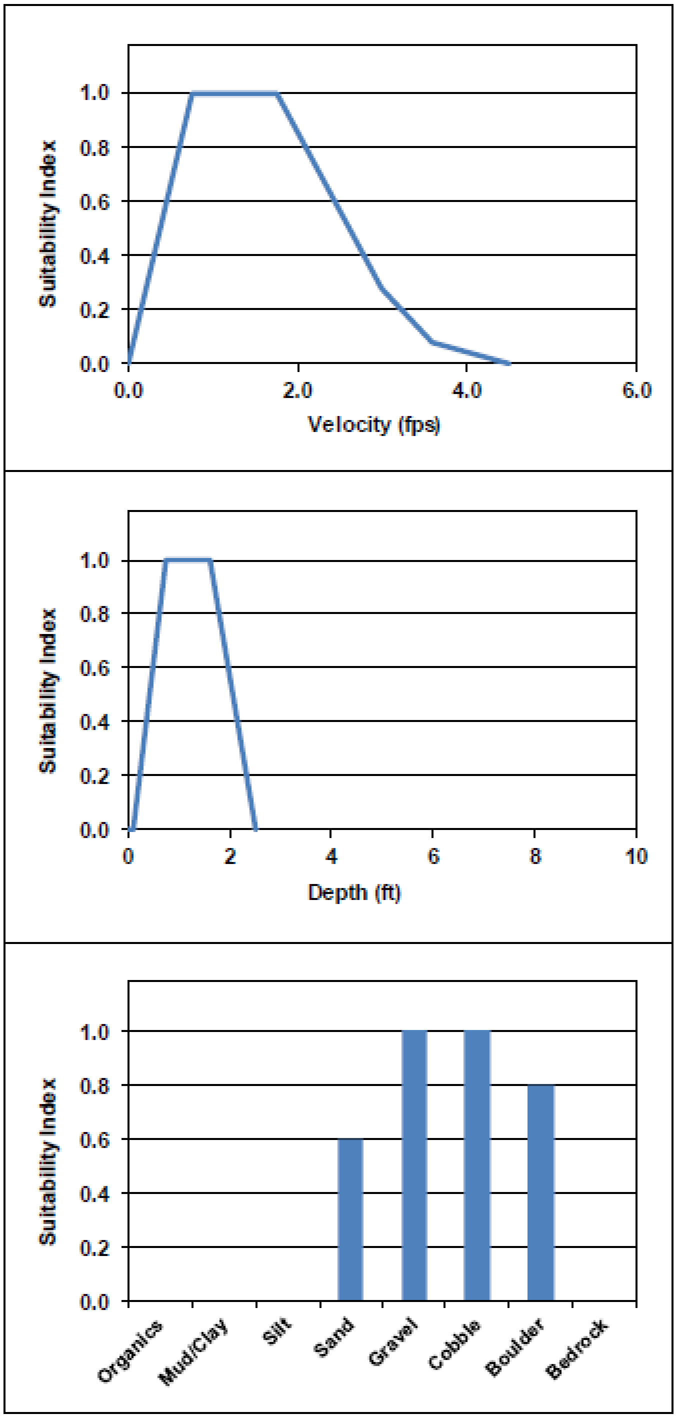
Longnose Dace Adult

Original curve identified as from USGS HSC library

Modified by VDFW for the Lamoille River IFS (Gomez and Sullivan, 2000)

Source:

Gomez and Sullivan, 2000



Velocity (ft/s)	SI
0.00	0.00
0.75	1.00
1.75	1.00
3.00	0.28
3.60	0.08
4.50	0.00

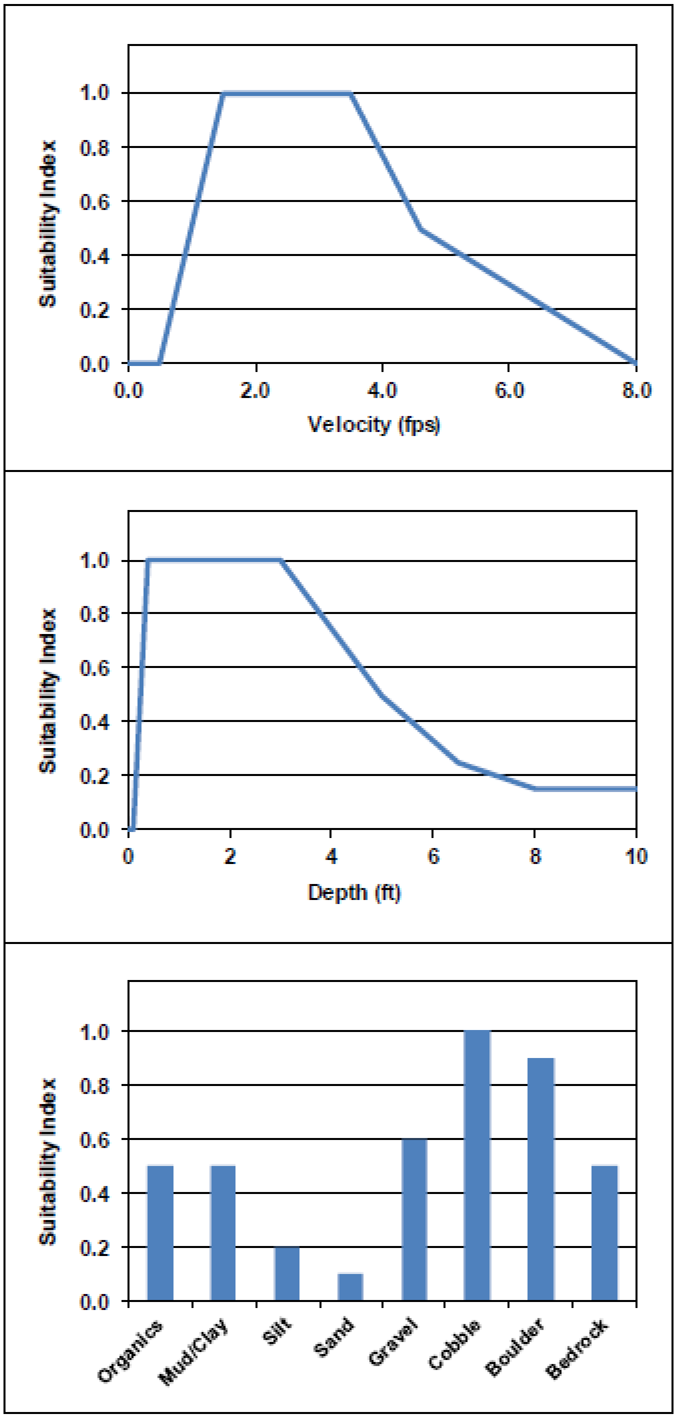
Depth (ft)	SI
0.00	0.00
0.10	0.00
0.75	1.00
1.60	1.00
2.50	0.00

Substrate	SI
Organics	0.00
Mud/Clay	0.00
Silt	0.00
Sand	0.60
Gravel	1.00
Cobble	1.00
Boulder	0.80
Bedrock	0.00

Figure A-13. HSC for longnose dace juvenile.

Macroinvertebrates

Source:
Gomez and Sullivan, 2000



Velocity (ft/s)	SI
0.00	0.00
0.50	0.00
1.50	1.00
3.50	1.00
4.60	0.50
8.00	0.00

Depth (ft)	SI
0.00	0.00
0.10	0.00
0.40	1.00
3.00	1.00
5.00	0.50
6.50	0.25
8.00	0.15
10.00	0.15
100.00	0.00

Substrate	SI
Organics	0.50
Mud/Clay	0.50
Silt	0.20
Sand	0.10
Gravel	0.60
Cobble	1.00
Boulder	0.90
Bedrock	0.50

Figure A-14. HSC for BMI.

Appendix B. 1-D Transect Depth and Velocity Profiles

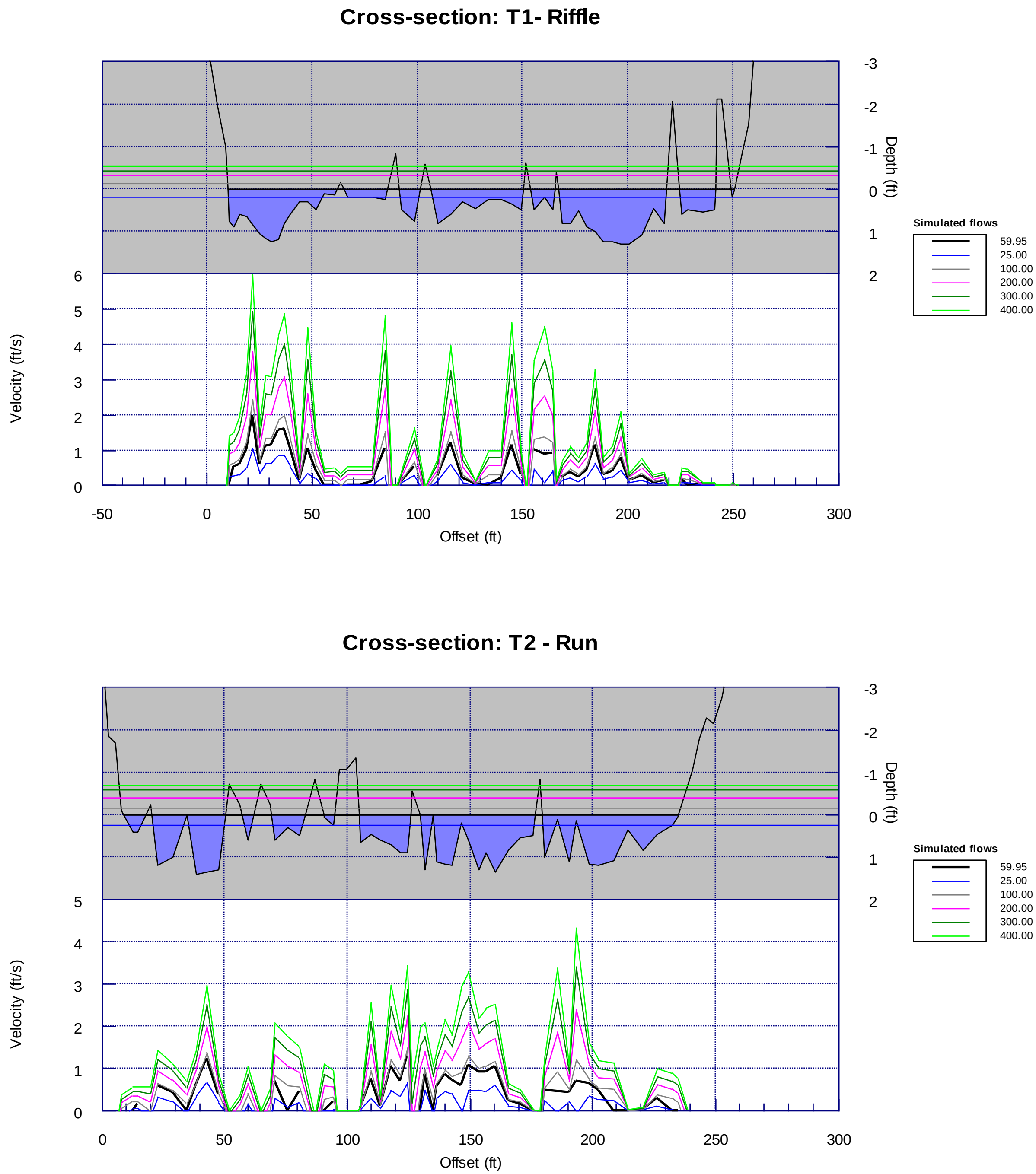
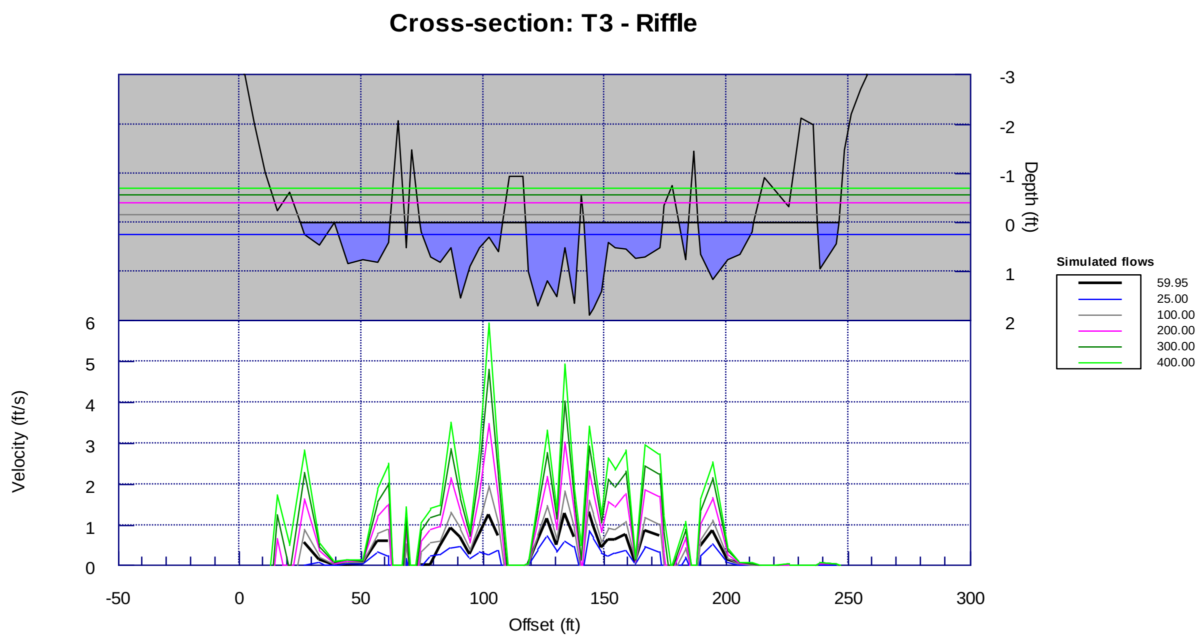


Figure B-1. Depth and velocity profiles for transects 1 (top) and 2 (bottom).



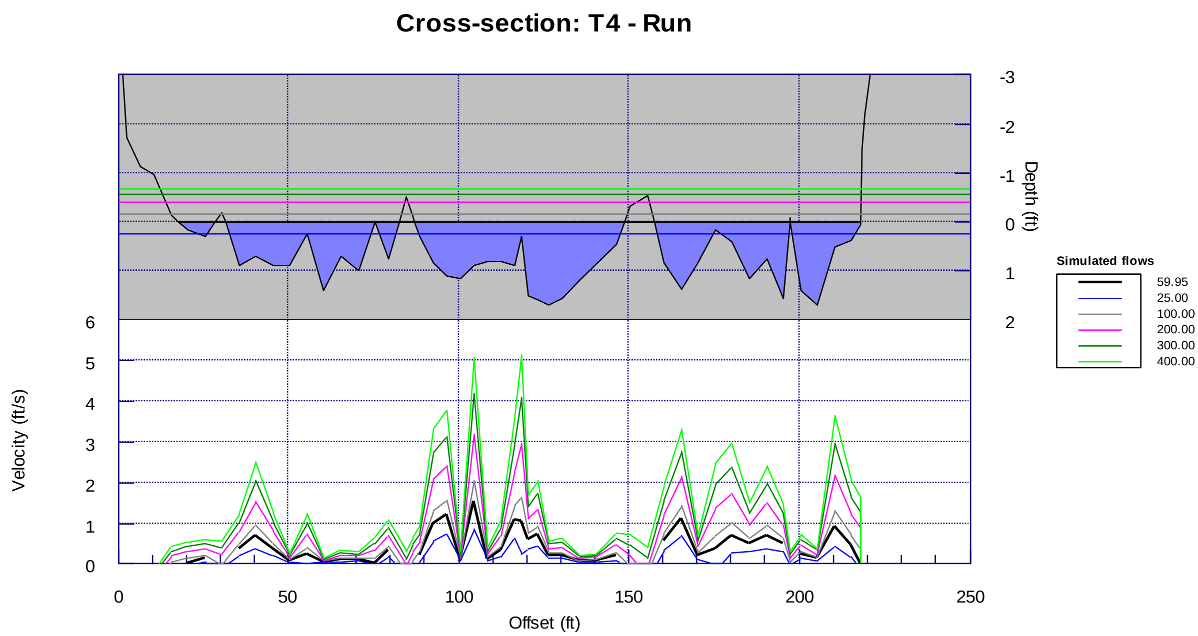
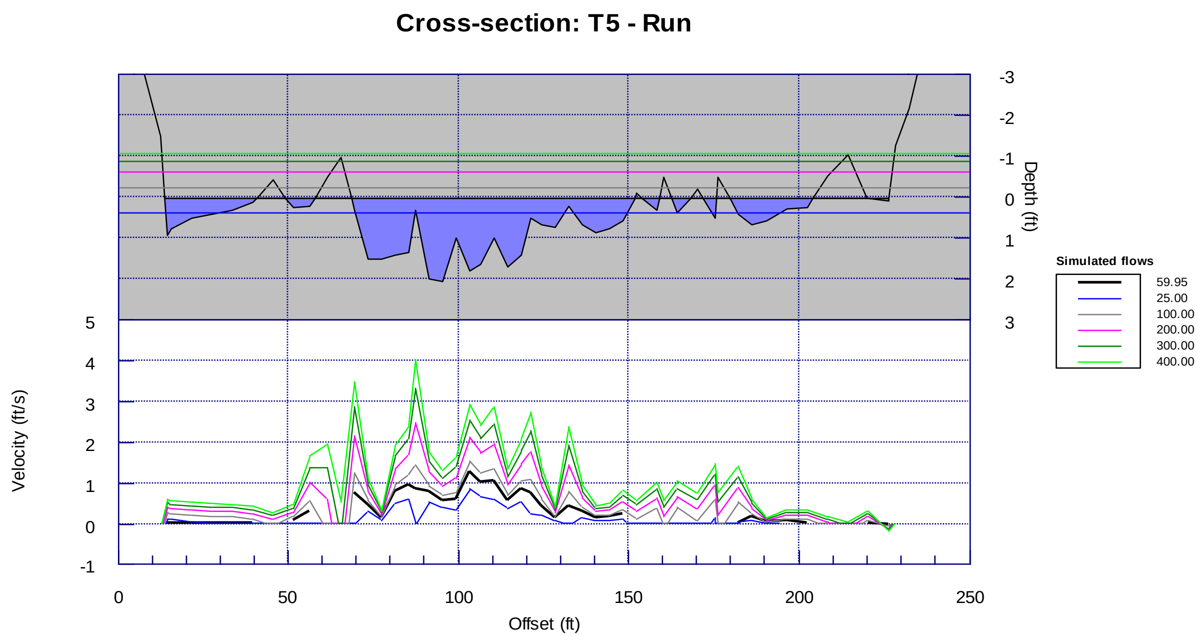


Figure B-2. Depth and velocity profiles for transects 3 (top) and 4 (bottom).



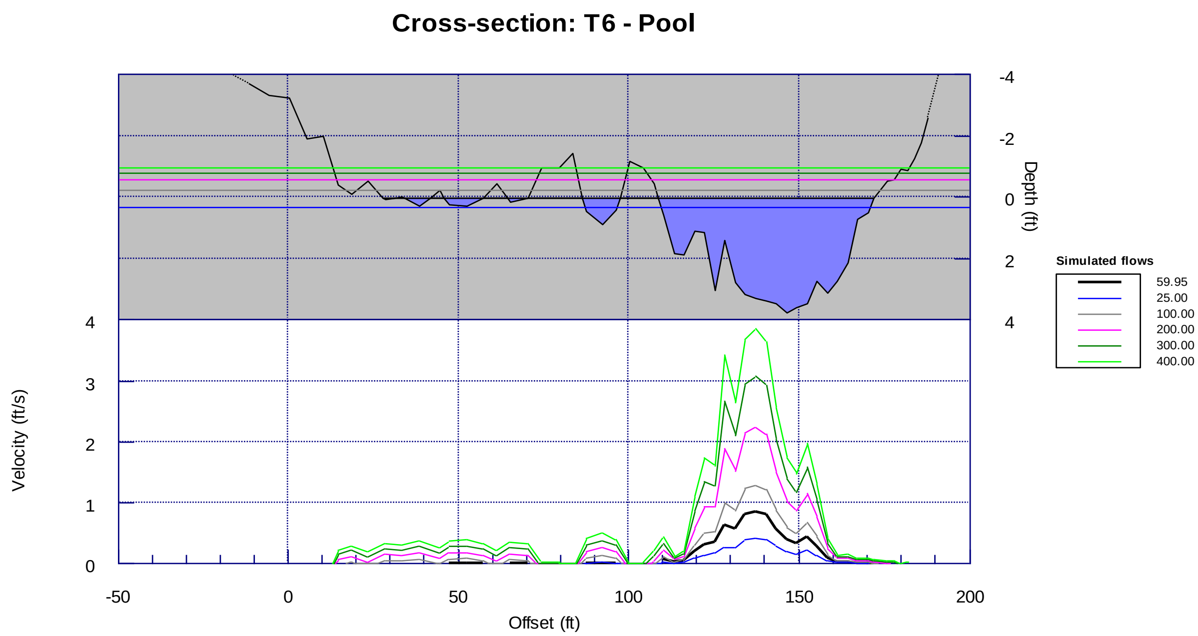
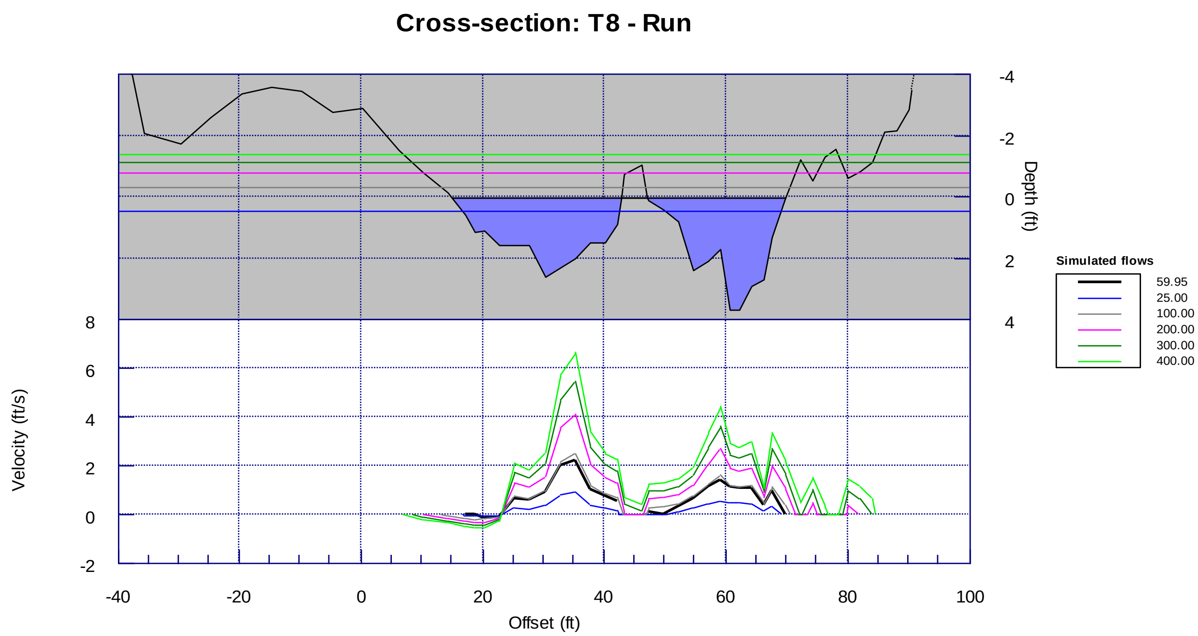


Figure B-3. Depth and velocity profiles for transects 5 (top) and 6 (bottom).



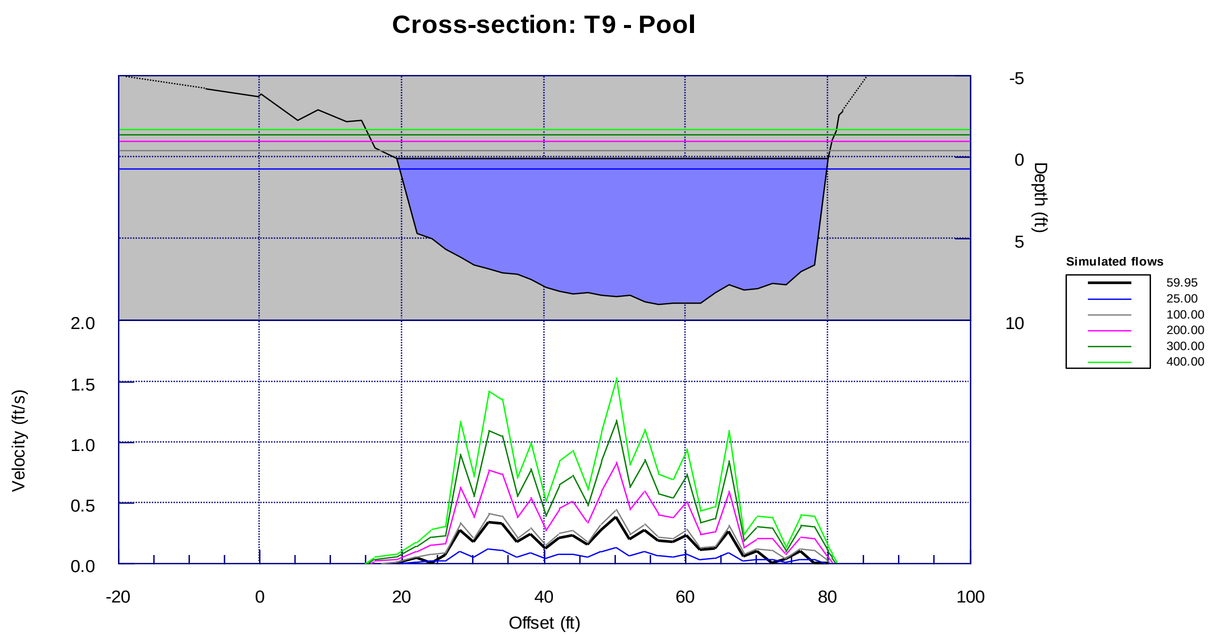
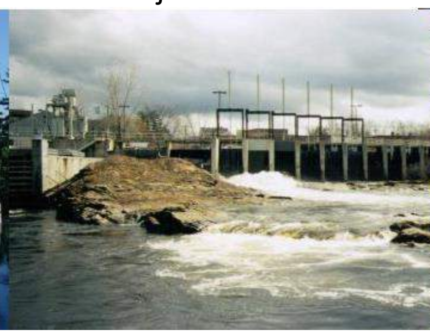
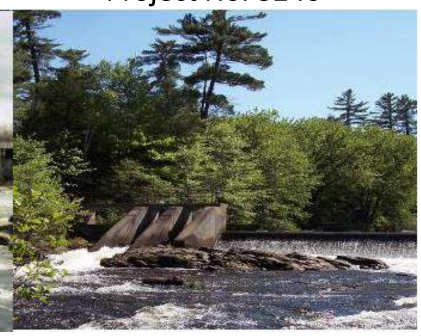


Figure B-4. Depth and velocity profiles for transects 8 (top) and 9 (bottom).

Adult Alosine Downstream Passage Study

Briar Hydro Associates

Penacook Lower Falls	Penacook Upper Falls	Rolfe Canal
Hydroelectric Project	Hydroelectric Project	Hydroelectric Project
Project No. 3342	Project No. 6689	Project No. 3240

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ENVIRONMENTAL CONSULTANTS

February 2022

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1. Introduction and Background

Briar Hydro Associates (Briar Hydro or Licensee) is in the process of relicensing the Rolfe Canal (FERC No. 3240), Penacook Upper Falls (PUF; FERC No. 6689), and Penacook Lower Falls (PLF; FERC No. 3342) Hydroelectric Projects (Project; collectively, Projects) with the Federal Energy Regulatory Commission (FERC or Commission). The Projects are located on the Contoocook River in Boscawen and Concord, New Hampshire. PLF sits at river mile 0 of the Contoocook River, above the confluence with the Merrimack River. The Upper Penacook and Rolfe Canal Projects are located upstream at river miles 1.0 and 2.0, respectively.

The current Project licenses were issued by the Federal Energy Regulatory Commission (FERC or Commission) in accordance with the Commission's delegated authority under the Federal Power Act on November 17, 1982 (PLF) and December 5, 1984 (Rolfe Canal and PUF). By FERC order the original April 17, 2018 license expiration for PLF was extended from October 31, 2022 to November 30, 2024 and matching the expiration for the Rolfe Canal and PUF Projects. Briar Hydro is pursuing a new license for the three Projects through the Commission's Traditional Licensing Process (TLP).

In response to requests provided by the resource agencies as part of the TLP process, Briar Hydro prepared a Preliminary Study Plan (PSP). The intent of the PSP was that the goals, methodology, scope, and schedule would be refined in consultation with interested stakeholders, as necessary. Briar Hydro distributed a copy of the PSP to representatives from the representatives from the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFGD) and the New Hampshire Department of Environmental Services (NHDES) on December 14, 2020. Following receipt and consultation related to comments on the PSP, Briar Hydro prepared a Revised Study Plan (RSP) which was finalized in March 2021 and filed with FERC on July 6, 2021. This report describes the Adult Alosine Downstream Passage Study conducted in support of obtaining a new license for the Project.

2. Goals and Objectives

The goal of this study was to determine the direct and cumulative impact of the Rolfe Canal, PUF, and PLF Projects on the emigration of adult river herring in the Contoocook River. Specifically, this study sought to:

- quantify the movement rates and delay caused by operation of the Projects;
- quantify the relative proportion of adult river herring passing each emigration route at the Projects during various project operations; and
- quantify instantaneous and latent mortality of adult river herring passed via each emigration route.

3. Study Area

The study area for this evaluation encompassed the impoundment, dam/powerhouse structures, bypasses and riverine reaches immediately downstream of the three Projects.

4. Methodology

Radio telemetry was employed to evaluate the downstream passage of adult river herring at Rolfe Canal, PUF, and PLF Projects. Following the release of radio-tagged adult herring upstream of Rolfe Canal, their movements were evaluated using a series of stationary receivers installed at each Project. Additional stationary monitoring locations were installed at bank-side locations downstream of the confluence of the Contoocook and Merrimack Rivers to inform on post-passage movements.

Telemetry Equipment

Downstream passage of radio-tagged adult river herring was recorded via a series of stationary radio telemetry receivers, which included equipment manufactured by both Sigma Eight and Lotek Wireless. All receivers were installed following consideration of the detection requirements for the specific area of coverage, as well as the attributes of the receiver model (e.g., desired range, ability to concurrently scan one or more frequencies, etc.). Each receiver was paired with either an aerial (4 or 6 element Yagi) or underwater antenna (dropper antenna).

Adult river herring were tagged using Sigma-Eight model TX-PSC-I-80D transmitters operating on one of two unique frequencies (149.320 or 149.360 MHz). Each transmitter was coded to emit a unique identifying signal, so that individual fish could be identified by a receiver. Transmitters utilized during this study were programmed to emit a 20 ms coded transmission at a 3.0 second interval.

Monitoring Stations

Radio telemetry antennas and receivers were installed at a number of locations at each of the three Projects. Each monitoring station consisted of a data-logging receiver, one or more antennas, and a power source. Stations were configured to receive transmitter signals from a designated area continuously throughout the study period. During installation of each station, range testing was conducted to configure the antennas and receivers in a manner which maximized detection efficiency at each location. Although each monitoring station was installed in a manner which limited the ability to detect transmitters from unwanted areas, the possibility of such detections did still exist. As a result, behavioral data collected during the study (i.e., duration at a specific location or passage route) was inferred based on the signal strength and the duration and pattern of contacts documented across the entire detection array.

The locations of installed telemetry receivers to evaluate the downstream passage of adult river herring at the three Projects are outlined below and presented visually in Figures 4-1 through 4-3.

Station 01: Station 01 was installed to detect radio-tagged herring as they approached the Rolfe Canal headgate structure. Detections from this location were used to determine when herring arrived at the

Project and was a component of the determination of residence time upstream of the dam and prior to passage. Station 01 consisted of a single antenna and radio-telemetry receiver.

Station 02: Station 02 detected radio-tagged herring as they approached the upstream side of the York Dam. Detections from this location were used in conjunction with subsequent detections at Station 04 to identify individuals which passed downstream of the Rolfe Canal Project via spill flows provided at this location. Station 02 consisted of a single antenna and radio-telemetry receiver.

Station 03: Station 03 was installed to detect radio-tagged herring which approached the Rolfe Canal intake structure. Detections from this location were used in conjunction with subsequent detections at Station 05 to identify individuals which passed downstream via the penstock and turbine unit at Rolfe Canal. Station 03 consisted of a single antenna and radio-telemetry receiver.

Station 04: Station 04 detected radio-tagged herring at a point within the York Dam bypass reach downstream of the Dam and upstream of its confluence with outflow from the tailrace channel. Detections from this location were used to confirm radio-tagged individuals which passed downstream at the York Dam. Station 04 consisted of a single antenna and radio-telemetry receiver.

Station 05: Station 05 detected radio-tagged herring in the Rolfe Canal tailrace. Detections from this location were used to confirm radio-tagged individuals which passed downstream via the turbine unit and were previously detected at Station 03. Station 05 consisted of a single antenna and radio-telemetry receiver.

Station 06: Station 06 detected radio-tagged herring at a point within the historic canal discharge channel. Detections from this location were used to confirm radio-tagged individuals which may have passed downstream via the bypass at the Rolfe Canal intake structure. Station 06 consisted of a single antenna and radio-telemetry receiver.

Station 07: Station 07 was installed to detect radio-tagged herring as they approached and passed a point approximately 100 m upstream of the PUF powerhouse intake. Detections from this location were used to determine when herring arrive at PUF and was a component of the determination of residence time upstream of the dam and prior to passage. Station 07 consisted of a single antenna and radio-telemetry receiver.

Station 08: Station 08 was installed to detect radio-tagged herring as they approached the PUF intake structure. Detections from this location were used in conjunction with subsequent detections at Station 11 to identify individuals which passed downstream via the PUF turbine unit. Station 08 consisted of a single antenna and radio-telemetry receiver.

Station 09: Station 09 consisted of a single receiver and an underwater drop antenna installed to detect radio-tagged herring as they passed downstream of PUF via the downstream bypass.

Station 10: Station 10 consisted of a single receiver and an aerial antenna installed to detect radio-tagged adult herring which passed downstream of PUF via spill flow through the bypass reach.

Station 11: Station 11 detected radio-tagged herring in the PUF tailrace. Detections from this location were used to confirm radio-tagged individuals which had passed downstream via the turbine unit and were last detected at Station 08. Station 11 consisted of a single antenna and radio-telemetry receiver.

Station 12: Station 12 detected radio-tagged herring as they approached and passed a point approximately 150 m upstream of the PLF powerhouse intake. Detections from this location were used to determine when radio-tagged adult river herring arrive at PLF and were used as a component in the determination of residence time upstream of the dam and prior to passage. Station 12 consisted of a single antenna and radio-telemetry receiver.

Station 13: Station 13 detected radio-tagged adult herring as they approached the upstream side of the PLF diversion spillway structure. Detections from this location were used in conjunction with subsequent detections at Station 16 to identify individuals which may have passed downstream at this location. Station 13 consisted of a single antenna and radio-telemetry receiver.

Station 14: Station 14 was installed to detect radio-tagged adult herring as they approached the PLF intake structure. Detections from this location were used in conjunction with subsequent detections at Station 17 to identify individuals which passed downstream via the PLF turbine unit. Station 14 consisted of a single antenna and radio-telemetry receiver.

Station 15: Station 15 consisted of a single receiver and an underwater drop antenna installed to monitor radio-tagged adult herring as they passed downstream of PLF via the downstream bypass.

Station 16: Station 16 detected radio-tagged herring moving through the PLF bypass reach following passage via spill flow at the diversion or auxiliary dam structures. Station 16 consisted of a single antenna and radio-telemetry receiver.

Station 17: Station 17 was installed to detect radio-tagged adult herring in the PLF tailrace. Detections from this location were used to confirm radio-tagged individuals which had passed downstream via the turbine unit and were previously detected at Station 14. Station 17 consisted of a single antenna and radio-telemetry receiver.

Station 18: Station 18 consisted of aerial, cross-river coverage at a point downstream of PLF. Detections from this location was used to assess cumulative passage survival of radio-tagged herring following downstream passage at the Projects. Following receipt of property access permission, Station 18 was established along the Merrimack River at a point approximately 7.0 miles downstream of its confluence with the Contoocook River

Station 19: Station 19 consisted of aerial, cross-river coverage at a point downstream of PLF and served as the second detection location to assess cumulative passage survival of radio-tagged herring following downstream passage at the Projects. Following receipt of permission from Central Rivers Power, Station 19 was installed facing upstream from the gatehouse structure at Garvins Falls (approximately 13.3 miles downstream of the confluence of the Contoocook and Merrimack Rivers).

Test Fish Collection, Tagging and Releases

Adult river herring were collected for tagging at the trap and truck facility associated with the Amoskeag fishway. Fish were dip-netted out of the sorting tank and visually assessed to ascertain their suitability for tagging. Any individuals exhibiting excessive scale loss or other signs of significant stress were not considered for tagging. Individuals deemed acceptable for tagging were quickly measured (total length, nearest mm), and sex was determined (when possible) by gently expressing eggs or milt from running-ripe fish. Radio transmitters were inserted gastrically. To facilitate gastric implantation, transmitters were affixed to a flexible tube with their trailing antenna running through the hollow center. The transmitter and leading edge of the flexible tube was pushed through the mouth and down to the stomach. Once in place, the tube was removed leaving the transmitter antenna trailing from the mouth. Following tagging, fish were immediately transferred to a stocking vehicle filled with aerated Merrimack River water. Salt was added to the transport tank in an effort to reduce osmotic stress of tagged fish.

A total of 100 radio-tagged adult river herring were transported via stocking truck from the Amoskeag fishway and released into the Contoocook River at one of three release locations. A total of 60 individuals were released at a point approximately 2.0 miles upstream of Rolfe Canal, 20 individuals were released immediately downstream of the Rolfe Canal powerhouse, and 20 individuals were released immediately downstream of the PUF powerhouse. Four separate release events were conducted during May 2021, with each event consisting of 25 radio-tagged individuals. For each release date, the tagged adult river herring were distributed among the three release sites as follows: 15 individuals upstream of Rolfe Canal, 5 individuals downstream of Rolfe Canal, and 5 individuals downstream of PUF.

Data Collection

Stationary Telemetry Data

Data were downloaded from receivers weekly during the period from the initial tag and release date through June 30, 2021. Backup copies of all telemetry data were made prior to receiver initialization. Field tests to ensure data integrity and receiver performance included confirmation of file integrity, confirmation that the last record was consistent with the downloaded data (a portable beacon tag was critical to this step), and lastly, to confirm that the receiver was operational upon restart and actively collecting data post download. Within a data file, transmitter detections were stored as a single event (i.e., single data line). Each event included the date and time of detection, frequency, ID code, and signal strength.

Manual Telemetry Data

To provide supplemental detection information to the stationary receiver data set, manual tracking was conducted twice during the monitoring period. Manual tracking events covered the section of the Contoocook from the area immediately upstream of Rolfe Canal to the confluence of the Contoocook and Merrimack Rivers downstream of PLF.

River and Project Operational Data

In addition to the radio telemetry data described above, river and project operations data were collected and reported for the 2021 evaluation period. Inflow at each Project was calculated as the sum of discharge values for the USGS flow gages 0108550 (Contoocook River downstream Hopkinton Dam) and 01086000 (Warner River at Davisville, NH) and multiplied by a proration factor of 1.3264 for Rolfe Canal and 1.3333 for PUF and PLF. Water temperature was recorded using a single Onset temperature logger set to read at a one-hour interval and installed in the vicinity of the turbine intake at PLF.

The Projects were operated under "baseline" conditions for the 2021 study period (i.e., generation online during periods of adequate inflow and turbine functionality and downstream bypass system open). The York Dam gate was open and passed at least 100 cfs for the duration of the study period. Briar Hydro operated the downstream bypass facilities at both the PUF (~25 cfs) and PLF (~25 cfs) for the duration of the study period from May 24 to June 30, 2021.

Briar Hydro provided power output (i.e., kw) for the duration of the monitoring period at all three Projects. Output was converted to turbine generation (cfs) using the following equations:

Rolfe Canal:

- If power output < 1000 KW, then flow (cfs) = power (KW) * 0.365 + 77
- If power output 1000-3561 KW, then flow (cfs) = power (KW) * 0.3676 + 74.31
- If power output 3562-4406 KW, then flow (cfs) = power (KW) * 0.4561 - 240.84
- If power output > 4406 KW, then flow (cfs) = power (KW) * 0.3662 + 155.13

PLF:

- If power output < 2131 KW, then flow (cfs) = power (KW) * 0.3285 + 250
- If power output 2131-3118 KW, then flow (cfs) = power (KW) * 0.3382 + 228.43
- If power output > 3118 KW, then flow (cfs) = power (KW) * 0.378 + 104.24

PUF:

- If power output < 675 KW, then flow (cfs) = power (KW) * 0.4237 + 85
- If power output 675-1442 KW, then flow (cfs) = power (KW) * 0.5474 + 1.442
- If power output 1443-2183 KW, then flow (cfs) = power (KW) * 0.476 + 103.89
- If power output > 2183 KW, then flow (cfs) = power (KW) * 0.4738 + 108.54

Available spill flow was calculated as the difference between the calculated generation flow and prorated inflow for all instances where inflow was greater than generation.

Data Analysis and Reporting

Upstream Residency and Downstream Passage Routes

A complete record of all valid detections for each uniquely coded radio-tagged adult herring was generated, and the pattern and timing of detections in these individual records were reviewed. For each radio-tagged individual released into the Contoocook River upstream of Rolfe Canal, the arrival and passage times and downstream route of passage were determined at Rolfe Canal, PUF, and PLF.

The stationary telemetry dataset collected during the study also permitted the evaluation of travel time for radio-tagged adult herring between any two adjacent monitoring stations both prior to and following downstream passage at a particular project. Passage duration through any defined river reach was calculated as the duration from initial detection at the stationary receiver on the upstream end of the reach until initial detection at the stationary receiver on the downstream end of the reach. For radio-tagged herring which approached Rolfe Canal, PUF or PLF, a 'project residence duration' was defined as the duration of time from initial detection at the dam until successful downstream passage.

Parameter Estimates for Evaluation of Project Survival

Downstream passage survival for adult river herring was estimated using a standard Cormack-Jolly-Seber (CJS) model run for the set of individual encounter histories developed for each radio-tagged fish which was determined to have approached Rolfe Canal, PUF, and PLF. The CJS approach utilized during this study provided estimates for passage survival (*Phi)* of radio-tagged fish through defined reaches at the Projects. This approach relied on a suite of candidate models developed in Program MARK (White and Burnham 1999) and was based on whether survival, recapture (i.e., detection), or both varied or were constant among stations. Models developed during this study included:

- *Phi*(t)*p*(t): survival and recapture may vary between receiver stations;
- *Phi*(t)*p*(.): survival may vary between stations; recapture is constant between stations;
- *Phi*(.)*p*(t): survival is constant between stations; recapture may vary between stations; and
- *Phi*(.)*p*(.): survival and recapture are constant between stations.

Where;

- *Phi* = probability of survival
- *p* = probability of detection
- (t) = parameter varies
- (.) = parameter is constant

To evaluate the fit of the CJS model, goodness of fit testing was conducted for the "starting model" (i.e., the fully parameterized model) using the function RELEASE within Program MARK. Akaike's Information Criterion (AIC) was used to rank the models as to how well they fit the observed mark-recapture data. Lower AIC values denote a more explanatory yet parsimonious fit than higher AIC values. The model with the lowest AIC value was selected for the purposes of generating passage effectiveness estimates.

For all fish determined to have approached the Projects, an encounter history was assembled as the series of sequential detection (1) or no detection (0) records for each individual fish at:

- Release Location (1),
- Station 01/02, Rolfe Canal Approach (0 or 1),
- Station 07, PUF Approach (0 or 1),
- Station 12, PLF Approach (0 or 1),
- Station 18, Downstream Station #1 (0 or 1), and
- Station 19, Downstream Station #2 (0 or 1).

The resulting model permitted the estimation of passage survival for (1) Rolfe Canal, (2) PUF, (3) PLF, and (4) cumulative survival through each of the three Projects.

- Passage survival at the Rolfe Canal Project was estimated as the probability of a radio-tagged adult river herring to be detected approaching PUF following an initial detection at Station 01/02.
- Passage survival at the PUF Project was estimated as the probability of a radio-tagged adult river herring to be detected approaching PLF following an initial detection at Station 07.
- Passage survival at the PLF Project was estimated as the probability of a radio-tagged adult river herring to be detected approaching Station 18 (i.e., the first downstream receiver) following an initial detection at Station 12.
- Cumulative survival for passage survival at all three Projects was estimated as the joint probability of survival at from Rolfe Canal to PUF, PUF to PLF, and PLF to the first downstream receiver.

This approach assumed that the background mortality (i.e., natural mortality such as predation) was negligible for adult river herring in the reaches downstream of each dam and that the observed losses are attributable solely to Project effects. The use of this assumption results in a minimum estimate of total Project survival for adult river herring passing downstream of the three Projects.

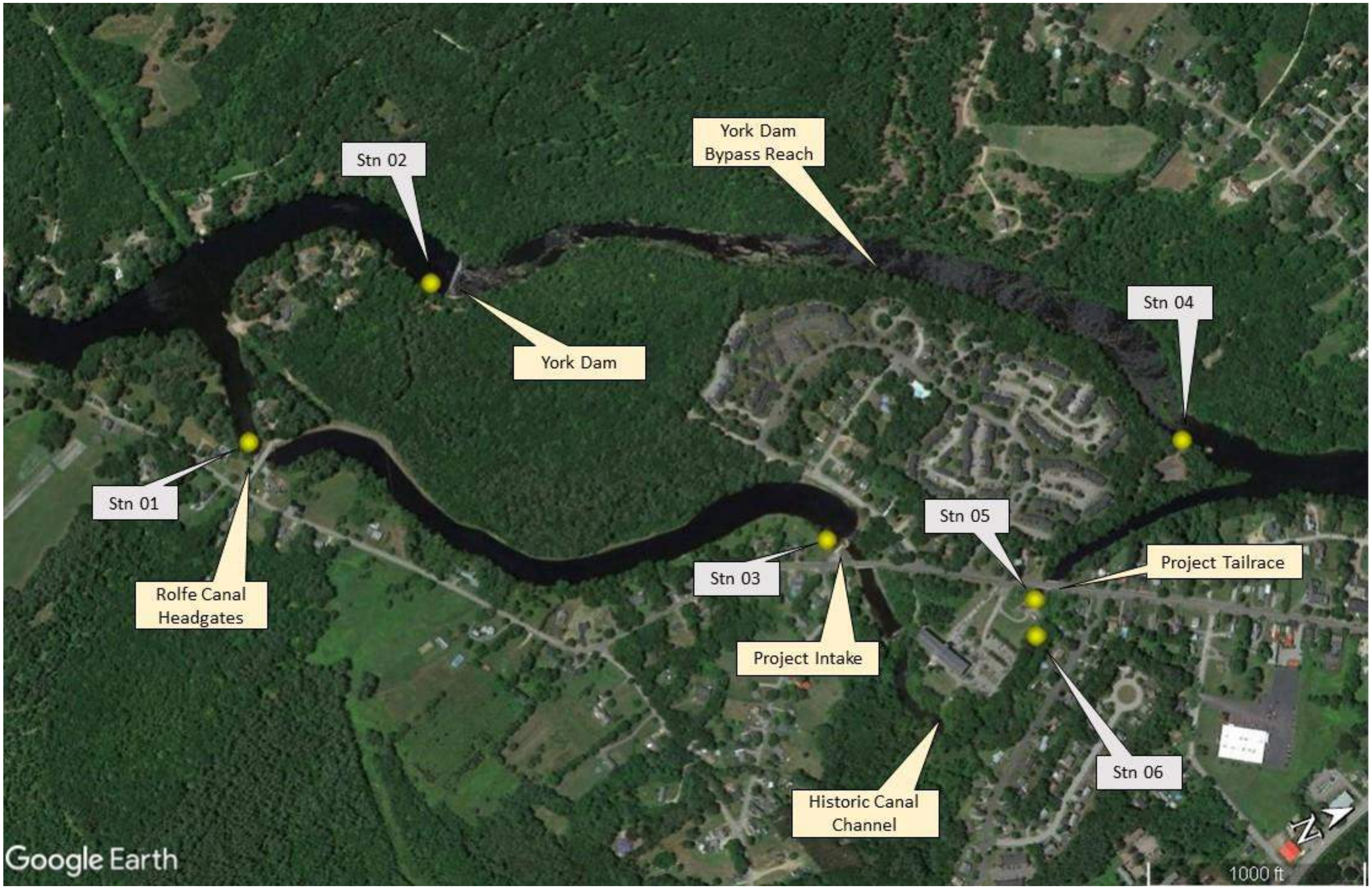


Figure 60–1. Final stationary receiver placement at Rolfe Canal for the adult river herring downstream passage study, May 24 – June 30, 2021.

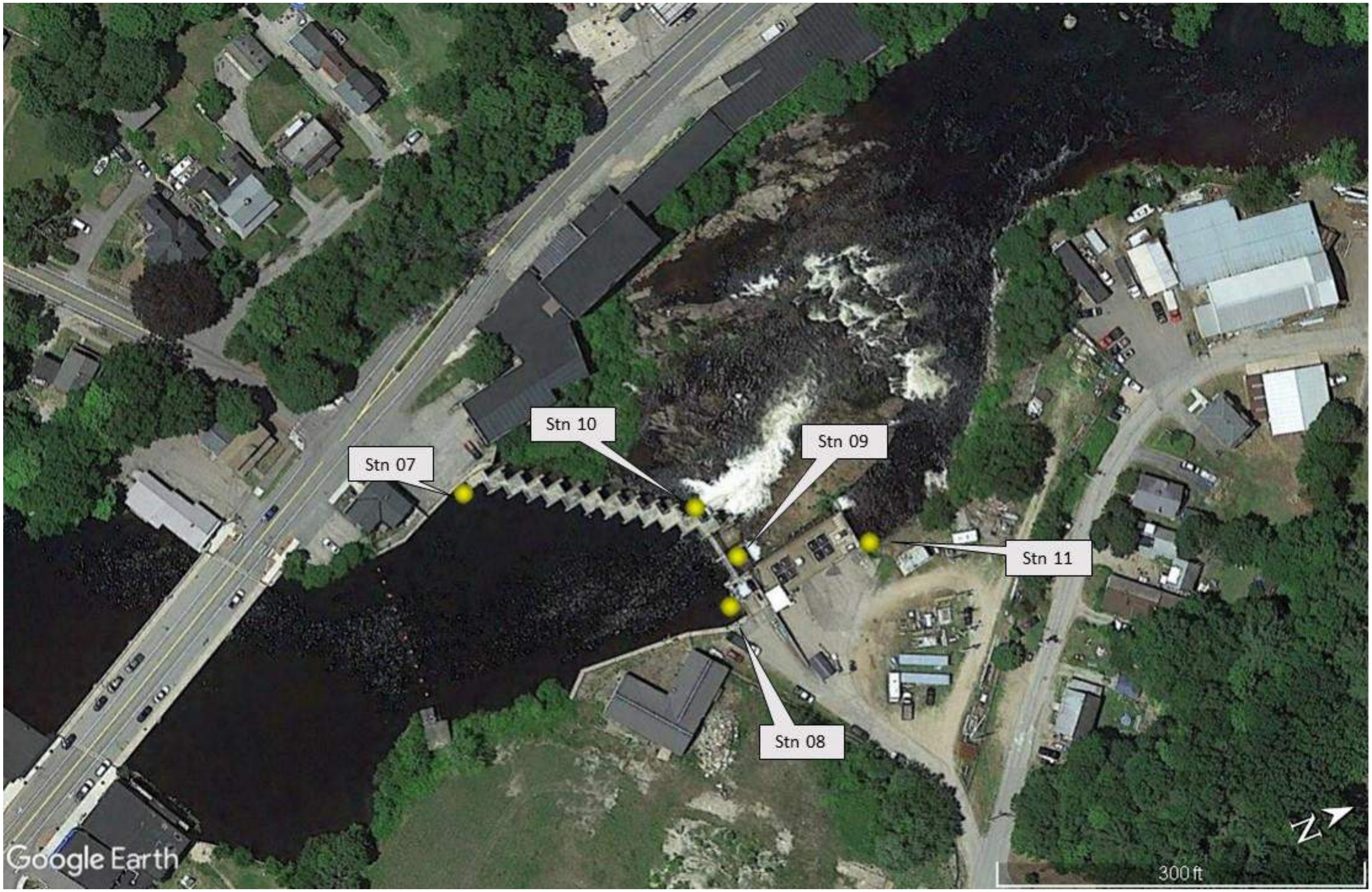


Figure 60–2. Final stationary receiver placement at PUF for the adult river herring downstream passage study, May 24 – June 30, 2021.

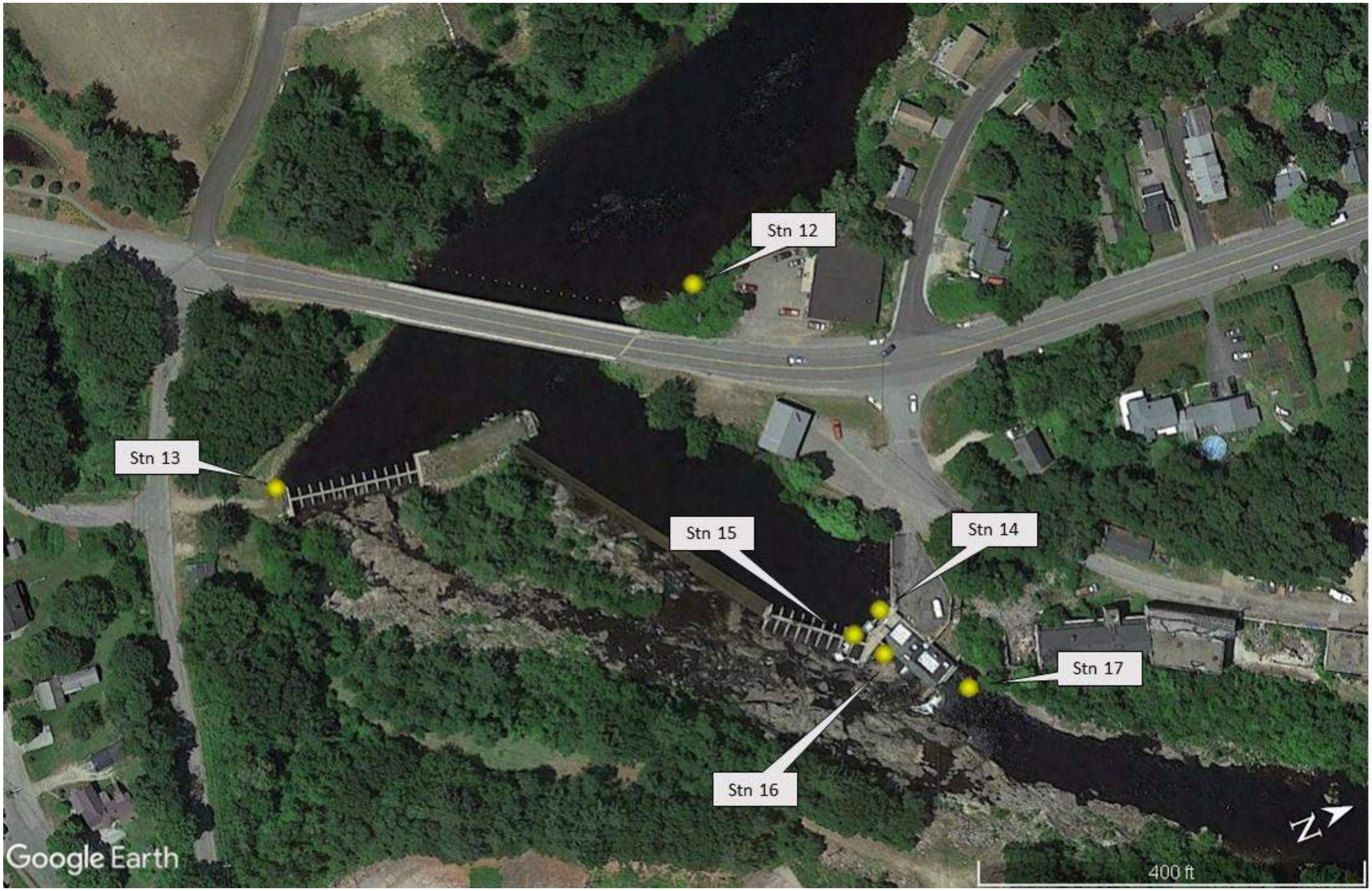


Figure 60–3. Final stationary receiver placement at PLF for the adult river herring downstream passage study, May 24 – June 30, 2021.

5. Results

Contoocook River Conditions

The first group of radio-tagged adult river herring was released into the Contoocook River on May 24, 2021 and monitoring for those individuals continued until June 30, 2021. Figure 5-1 presents the Contoocook River flow (prorated to Rolfe Canal) for the 2021 adult herring study period. Over the course of the 2021 monitoring period, inflow at Rolfe Canal ranged from 151 cfs to 1,432 cfs (P25 = 231 cfs; median = 363 cfs; P75 = 528 cfs).

Hourly temperature readings collected for the duration of the study period from the intake area at PUF are presented in Figure 5-1. River temperature over the course of the full monitoring period ranged between 14-27°C (median = 22°C). Mean daily water temperature on tagging dates (May 24, 25, 26, and 27) ranged from 20-22°C.

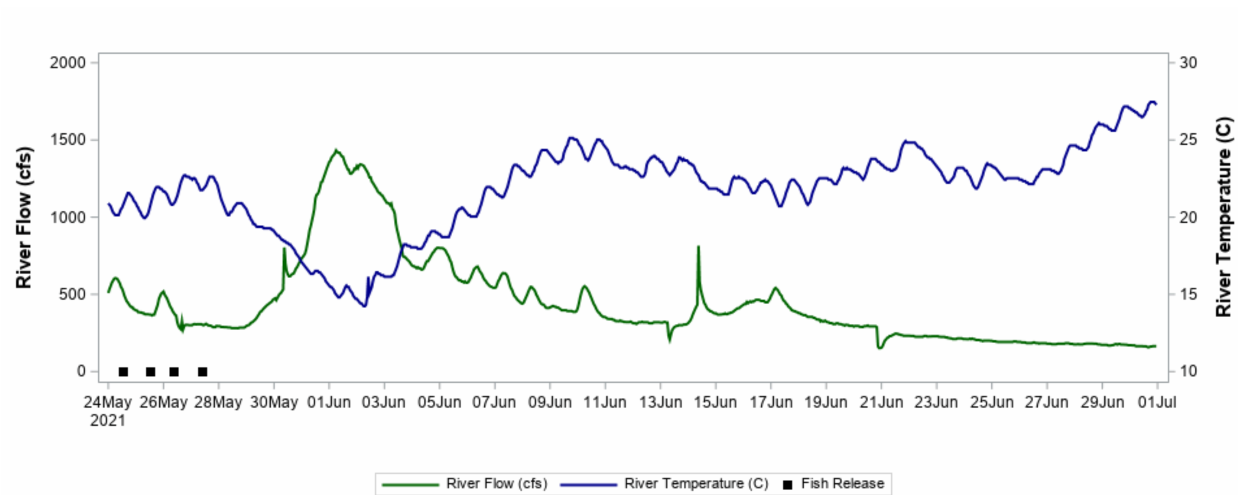


Figure 60–4. Contoocook River flow prorated for Rolfe Canal for the adult river herring downstream passage study period, May 24 – June 30, 2021.

Briar Hydro Project Operations

Rolfe Canal

Total discharge reported for Rolfe Canal during the downstream adult river herring passage study period from May 24 to June 30, 2021 is presented in Figure 5-2. The Rolfe Canal turbine was in operation for most of the study period with the exception of 1700 on May 26 to 0700 on June 2 (due to a mechanical issue associated with a malfunctioning bearing) and from 0500 on June 21 through the end of the monitoring period (due to low water). Flow at York Dam ranged from the existing minimum flow of 100 cfs up to a high of 900 cfs on June 1.

Penacook Upper Falls

Total discharge reported for PUF during the downstream adult river herring passage study (May 24 to June 30, 2021) is presented in Figure 5-3. The PUF turbine was in operation for most of the study period with the exception of 1800 on June 26 to 0700 on May 27 (due to the impact on flow at PUF associated with the concurrent unit shutdown at Rolfe Canal) and from 1600 on June 20 through the end of the monitoring period (due to low water). Briar Hydro operated the downstream bypass facility at PUF for the duration of the river herring study period, passing approximately 25 cfs. Spill flow at PUF ranged from zero up to a high of 490 cfs on June 14.

Penacook Lower Falls

Total discharge reported for PLF during the downstream adult river herring passage study (May 24 to June 30, 2021) is presented in Figure 5-4. The PLF turbine was in operation for the duration of the study period until June 21 when it was taken offline due to low water. Briar Hydro opened the downstream bypass facility at PLF prior to the first herring release on May 24 and operated it for the duration of the study period, passing approximately 25 cfs. Spill flow at PLF ranged from zero up to a high of 267 cfs on June 14.

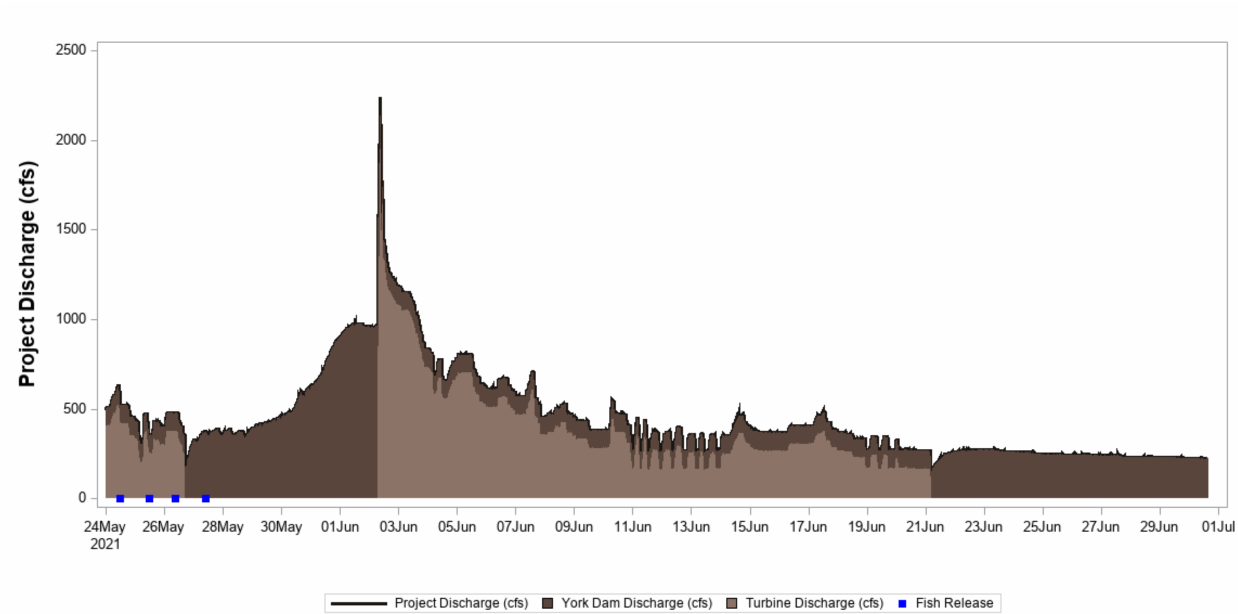


Figure 60–5. Distribution of Rolfe Canal discharge during the adult river herring downstream passage study period, May 24 – June 30, 2021.

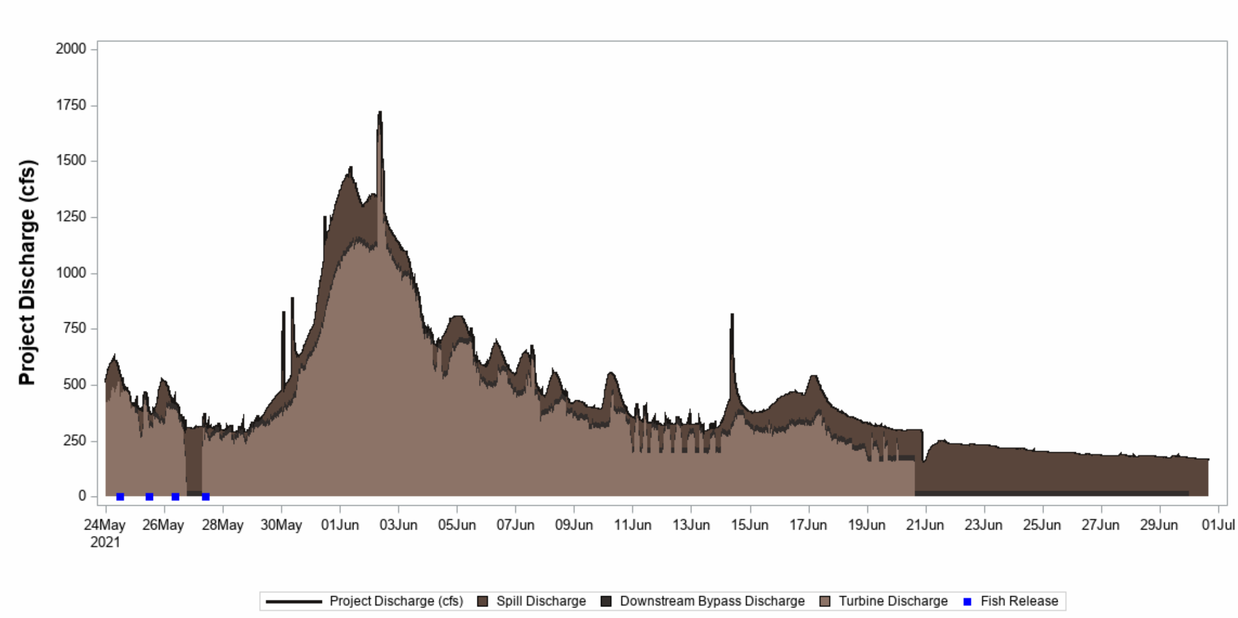


Figure 60–6. Distribution of PUF discharge during the adult river herring downstream passage study period, May 24 – June 30, 2021.

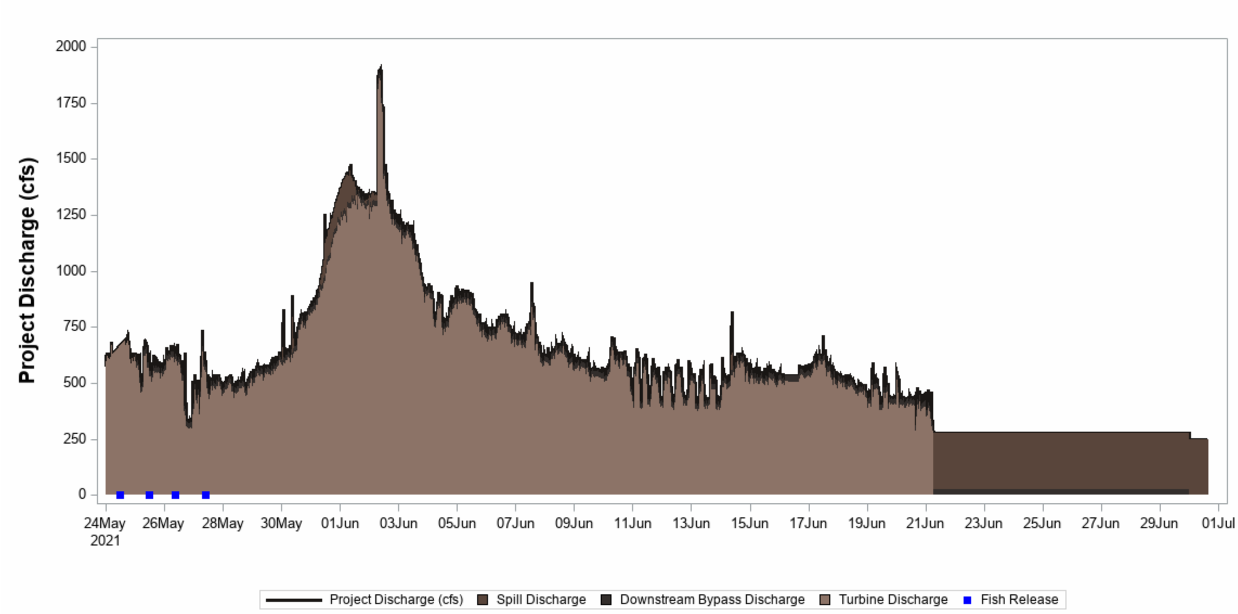


Figure 60–7. Distribution of PLF discharge during the adult river herring downstream passage study period, May 24 – June 30, 2021.

Monitoring Station Functionality

Radio-tagged adult river herring were released into the Contoocook River beginning on May 24, 2021, and the study plan called for continuous monitoring at project locations through the month of June. Normandeau conducted weekly checks and downloads of all stationary receivers during that period. Station coverage was determined by a combination of portable beacon transmitter detections and observations reported by field personnel conducting the receiver checks and data downloads. All 19 of the stationary monitors operated with no issues for the duration of the study period (Figure 5-5).

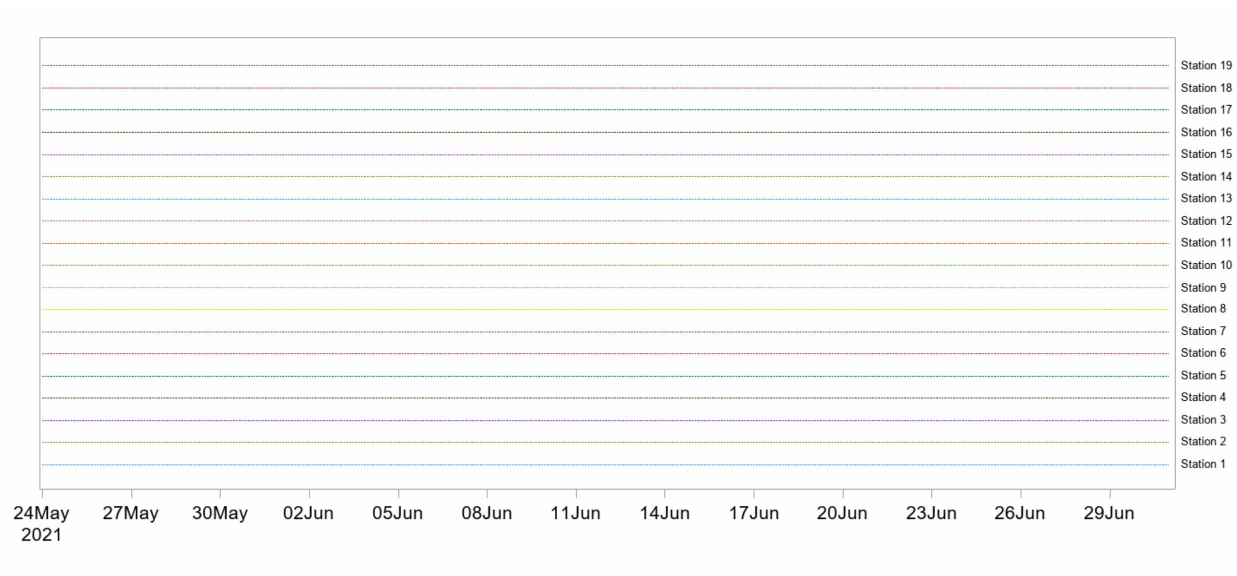


Figure 60–8. Monitoring station operational coverage for receiver stations at Rolfe Canal, PUF, and PLF during the adult river herring downstream passage study period, May 24 – June 30, 2021.

Test Fish Collection, Tagging and Release

A total of 100 adult river herring were radio-tagged following collection at the Amoskeag upstream fishway lift during 2021 (Table 5-1). Radio-tagged adult herring were released approximately 2.0 miles upstream of Rolfe Canal (n = 60), in the tailrace channel of Rolfe Canal (n=20), and in the tailrace channel of PUF (n=20). Tagging and release events took place on four dates: May 24, 25, 26, and 27, 2021. River herring radio-tagged during 2021 ranged in total length from 264-623 mm with the average total length at 291 mm. A full listing of adult river herring tagged during the 2021 telemetry evaluation is provided in Appendix A.

Project Arrival

Releases of radio-tagged adult river herring were initiated upstream of Rolfe Canal, PUF, and PLF on May 24, 2021. Figure 5-5 presents the distribution of arrival dates for radio-tagged individuals at each of the three Projects. Radio-tagged adult herring were initially detected at Rolfe Canal from the date of the initial release (May 24) until June 17 with the majority approaching Rolfe Canal between May 24 and 28. Approach timing at Rolfe Canal was determined based on the initial detection for each fish at Station 01 (i.e., the power canal headgate structure) or 02 (upstream of York Dam). Of the 58 radio-tagged herring which approached Rolfe Canal, 48% individuals were detected at both Stations 01 and 02, 9% were detected only at Station 01, and 43% were detected only at Station 02. The majority of individuals approaching Rolfe Canal from the first two release groups (May 24 and 25) were more likely to first approach the entrance to the power canal (Station 01) then move back upstream and descend down the bypass reach towards York Dam (26 of 29 individuals). The majority of radio-tagged adult herring released on May 26 and 27 were initially detected at the York Dam receiver (Station 02; 24 of 29 individuals), likely in response to the predominant flow in that direction due to the turbine outage at the Rolfe Canal powerhouse at that time.

Approach timing at PUF and PLF was determined based on the initial detection for each fish at Stations 07 and 12, respectively. Radio-tagged adult herring released in the Rolfe Canal or PUF tailraces were initially detected at the next downstream Project relatively quickly: between May 24 and 28 for herring released in the Rolfe Canal tailrace to arrive at PUF and May 24 and 27 for herring released in the PUF tailrace to arrive at PLF (Figure 5-5). The distribution of approach dates for adult herring originally released upstream of Rolfe Canal peaked between May 27-28 at PUF and May 29-31 at PLF.

Upstream Residence Duration

Outmigrating adult river herring encountering Rolfe Canal can (1) pass through the gatehouse and enter the power canal where they can (a) pass downstream through the turbine or (b) move back upstream, (2) approach York Dam where they can (a) pass downstream by way of spill through the bypass reach, or (b) move back upstream, or (3) spend a period of time in both locations prior to eventual downstream passage. When all individuals are considered the median upstream residence duration (i.e., the duration of time from initial detection upstream of Rolfe Canal until downstream passage) was 22.3 hours (P25 = 7.4 hours; P75 = 64.6 hours; Table 5-2). When evaluated by behavior, the median upstream residence duration was shorter for individuals which either directly approached only the Rolfe Canal powerhouse (n = 5; median = 13.4 hours) or York Dam (n = 25; median = 6.7 hours) versus those which spent a portion of time upstream of both the powerhouse and York Dam (n = 28; median = 65.9 hours). Table 5-3 provides a summary of the calculated upstream residence duration values for radio-tagged adult herring at Rolfe Canal based on their initial date of detection. For dates with multiple arrivals, the median upstream residence duration was longer for dates early in the study period versus later. As noted earlier, radio-tagged herring from the May 27 and 28 release groups had a higher likelihood to approach only York Dam rather than both the powerhouse intake area and York Dam, likely leading to a shorter upstream residence duration. For all adult river herring approaching Rolfe Canal, 53% passed downstream within 24 hours of initial arrival and 84% within 72 hours of initial arrival.

Following their initial detection at PUF, the median upstream residence duration for radio-tagged adult herring was 32.2 hours (P25 = 14.9 hours; P75 = 60.3 hours; Table 5-4). The median duration did not differ greatly between herring originating upstream of Rolfe Canal (34.0 hours) or released directly into the Rolfe

Canal tailrace (median = 29.6 hours). Table 5-5 summarizes upstream residence duration by the eventual route of passage at PUF. The median values for upstream residence duration among passage routes utilized during the 2021 study were 20.0 hours for fish passing on spill, 31.9 hours for fish passing through the downstream bypass, and 58.3 hours for fish passing downstream through the PUF turbine unit. Upstream residence duration summarized by approach date at PUF is presented in Table 5-6. For all adult river herring approaching PUF, 35% passed downstream within 24 hours of initial arrival and 85% within 72 hours of initial arrival.

Following arrival at PLF, the median upstream residence duration for radio-tagged adult herring was 85.0 hours (P25 = 31.8 hours; P75 = 124.3 hours; Table 5-7). The median duration appeared to differ for herring originating upstream of Rolfe Canal (39.6 hours) versus those released directly into the Rolfe Canal tailrace (median = 105.1 hours) or the PUF tailrace (135.6 hours). Table 5-8 summarizes upstream residence duration for adult river herring by their eventual route of downstream passage at PLF. The median values for upstream residence duration between passage routes utilized during the 2021 study were 64.9 hours for fish passing through the downstream bypass and 97.5 hours for fish passing downstream through the PLF turbine unit. Upstream residence duration summarized by approach date at PLF is presented in Table 5-9. For all adult river herring approaching PLF, 20% passed downstream within 24 hours of initial arrival and 45% within 72 hours of initial arrival.

Downstream Passage

A total of 60 radio-tagged adult river herring were released upstream of Rolfe Canal during the spring of 2021. Of that total, 58 (97%) were determined to have approached Rolfe Canal and were available for the evaluation of downstream passage route (Table 5-10). The majority (86%) of radio-tagged adult herring passed downstream via York Dam. Of the fifty individuals which passed downstream of Rolfe Canal via spill at York Dam, 48 of those passage events occurred during the turbine outage which occurred from 1700 on May 26 to 0700 on June 2.

Table 5-11 summarizes downstream passage route utilization for adult river herring which approached PUF. A total of 80 radio-tagged adult river herring were released at points upstream of PUF during the spring of 2021. Of that total, 72 (90%) were determined to have approached the Project and were available for the evaluation of downstream passage route. The majority (60%) of radio-tagged adult herring passed downstream of PUF using the downstream bypass. Approximately 23% of radio-tagged herring passed downstream via the PUF turbine and an additional 17% passed downstream during periods of spill.

Of the 100 radio-tagged adult river herring released at locations upstream of PLF, 87% were determined to have approached the Project and were available for the evaluation of downstream passage route (Table 5-12). Downstream passage of adult river herring at PLF occurred via the Project turbine (52% of all events) and downstream bypass (44% of all events). A limited number of individuals (n = 4) were detected on the approach at PLF but were determined to have not successfully passed downstream during the study period. These individuals may have been predated, succumbed to injuries during previous passage at Rolfe Canal and/or PUF, or shed their transmitter.

Radio-tagged adult river herring were observed passing downstream of Rolfe Canal between May 25 and June 17 with the peak number of events occurring on May 27 and 28 (Figure 5-7). At PUF, downstream passage of adult river herring was recorded between May 24 and June 8 when individuals from all upstream release locations were considered. The first downstream passage event at PLF was recorded on May 30. Downstream passage of radio-tagged adult river herring at PLF peaked on May 31 and June 1 and the final event was observed on June 13, 2021. Figure 5-8 presents the timing distribution of downstream passage events for radio-tagged adult river herring at the Projects. The majority of individuals passed downstream during the morning, mid-afternoon and evening hours.

River Transit

Project Reach Transit

Radio-tagged adult river herring were released at one of three locations within the Project areas (upstream of Rolfe Canal, downstream of Rolfe Canal, or downstream of PUF). Table 5-13 summarizes the overall duration of time from release until passage downstream at the lowermost Project (PLF). The median duration of time for radio-tagged adult herring released upstream of Rolfe Canal to pass downstream of all three Projects was 157.5 hours (6.6 days; P25 = 5.5 days; P75 = 7.9 days). The overall transit duration through the full set of Projects did not appear to differ among release locations. Radio-tagged adult river herring released in the tailrace at Rolfe Canal (median = 6.7 days) and in the tailrace at PUF (median = 6.1 days) were comparable to that observed for fish released upstream of Rolfe Canal.

Downstream Reach Transit

Two monitoring stations were installed downstream of PLF for the purpose of detecting radio-tagged adult river herring following outmigration from the Contoocook River during spring 2021. Those receivers were located approximately 7.0 (Station 18) and 13.3 (Monitoring Station 19) miles downstream of the confluence of the Contoocook and Merrimack Rivers. Quartile transit times for adult river herring (1) following downstream passage at PLF to Station 18, (2) from Station 18 to Station 19, and (3) for the full downstream river section are presented in Table 5-14. The median transit time durations for all tagged adult river herring moving downstream of PLF were 8.8, 5.6, and 20.9 hours for the three downstream reaches, respectively. Median values and quartile ranges were comparable for each downstream reach when compared among the three release locations (upstream of Rolfe Canal, Rolfe Canal tailrace, and PUF tailrace.

Table 60–1. Summary of release and biological information (total length and sex) for adult river herring radio-tagged and released into the Contoocook River (May 2021)

River Herring	Release Location			
	US Rolfe Canal	US PUF	US PLF	All
Release Dates (May)	24, 25, 25, 27	24, 25, 25, 27	24, 25, 25, 27	24, 25, 25, 27

Number Released	60	20	20	100
% Male	45%	40%	55%	46%
% Female	55%	60%	45%	54%
Min. Total Length (mm)	264	276	264	264
Max. Total Length (mm)	326	324	317	326
Mean Total Length (mm)	291	292	291	291

Table 60–2. Minimum, maximum and quartile values for Rolfe Canal upstream residence duration (by project behavior) during the adult river herring downstream passage study period, May 24 – June 30, 2021

River Herring – Upstream Residence Duration (hrs)					
Rolfe Approach	Minimum	P25	P50 (Median)	P75	Maximum
Powerhouse & York Dam	20.3	36.0	65.9	140.4	508.6
Powerhouse	9.5	11.8	13.4	16.2	18.4
York Dam	0.1	2.3	6.7	15.6	40.2
All	**0.1**	**7.4**	**22.3**	**64.6**	**508.6**

Table 60–3. Minimum, maximum and quartile values for Rolfe Canal upstream residence duration (by approach date) during the adult river herring downstream passage study period, May 24 – June 30, 2021

River Herring - Upstream Residence Duration (hrs)				
Approach Date	n	P25	P50 (Median)	P75
24-May	6	69.5	108.8	165.6
25-May	11	38.6	53.6	68.5
26-May	15	22.2	35.0	132.9
27-May	12	2.3	7.7	17.5
28-May	7	1.6	6.3	15.6
29-May	2	0.1	3.4	6.7
30-May	1	2.5	2.5	2.5
2-Jun	1	13.4	13.4	13.4
4-Jun	1	20.3	20.3	20.3
6-Jun	1	16.2	16.2	16.2
17-Jun	1	11.8	11.8	11.8
All	**58**	**7.4**	**22.3**	**64.6**

Table 60–4. Minimum, maximum and quartile values for PUF upstream residence duration (by release location) during the adult river herring downstream passage study period, May 24 – June 30, 2021

River Herring - Upstream Residence Duration (hrs)

Release Location	Minimum	P25	P50 (Median)	P75	Maximum
Upstream Rolfe Canal	0.5	16.4	34.0	62.1	126.9
Rolfe Canal Tailrace	1.7	12.4	29.6	51.6	114.9
All	**0.5**	**14.9**	**32.2**	**60.3**	**126.9**

Table 60–5. Minimum, maximum and quartile values for PUF upstream residence duration (by passage route) during the adult river herring downstream passage study period, May 24 – June 30, 2021

River Herring - Upstream Residence Duration (hrs)					
Passage Route	**Minimum**	**P25**	**P50 (Median)**	**P75**	**Maximum**
Downstream Bypass	0.5	12.8	31.9	56.3	114.9
Spill	0.9	7.7	20.0	30.9	92.5
Turbine	14.6	33.9	58.3	78.3	126.9
All	**0.5**	**14.9**	**32.2**	**60.3**	**126.9**

Table 60–6. Minimum, maximum and quartile values for PUF upstream residence duration (by approach date) during the adult river herring downstream passage study period, May 24 – June 30, 2021

River Herring - Upstream Residence Duration (hrs)				
Approach Date	**n**	**P25**	**P50 (Median)**	**P75**
24-May	1	1.7	1.7	1.7
25-May	6	12.8	30.9	37.4
26-May	8	13.3	20.0	30.2
27-May	21	5.3	39.7	65.6
28-May	19	31.9	52.2	70.5
29-May	7	16.5	41.1	58.8
30-May	3	10.3	23.0	26.7
31-May	5	8.2	17.6	33.9
2-Jun	1	6.6	6.6	6.6
7-Jun	1	24.2	24.2	24.2
All	**72**	**14.9**	**32.2**	**60.3**

Table 60–7. Minimum, maximum and quartile values for PLF upstream residence duration (by release location) during the adult river herring downstream passage study period, May 24 – June 30, 2021

River Herring - Upstream Residence Duration (hrs)					
Release Location	**Minimum**	**P25**	**P50 (Median)**	**P75**	**Maximum**
Upstream Rolfe Canal	0.3	16.6	39.6	93.5	253.7
Rolfe Canal Tailrace	23.3	42.9	105.1	124.3	252.6
PUF Tailrace	94.1	114.7	135.6	169.4	193.0
All	**0.3**	**31.8**	**85.0**	**124.3**	**253.7**

Table 60–8. Minimum, maximum and quartile values for PLF upstream residence duration (by passage route) during the adult river herring downstream passage study period, May 24 – June 30, 2021

River Herring - Upstream Residence Duration (hrs)					
Passage Route	Minimum	P25	P50 (Median)	P75	Maximum
Downstream Bypass	0.3	34.0	64.9	111.4	169.3
Turbine	0.3	30.7	97.5	137.1	253.7
All	**0.3**	**31.8**	**85.0**	**124.3**	**253.7**

Table 60–9. Minimum, maximum and quartile values for PLF upstream residence duration (by approach date) during the adult river herring downstream passage study period, May 24 – June 30, 2021

River Herring - Upstream Residence Duration (hrs)				
Approach Date	n	P25	P50 (Median)	P75
24-May	4	162.2	171.3	185.4
25-May	8	130.5	152.4	170.1
26-May	6	112.5	115.3	116.3
27-May	19	97.5	116.1	143.8
28-May	1	77.8	77.8	77.8
29-May	11	39.2	53.8	73.5
30-May	14	23.3	35.4	51.8
31-May	9	1.2	10.0	30.7
1-Jun	6	0.8	6.0	42.9
2-Jun	3	1.0	17.9	27.5
3-Jun	1	0.3	0.3	0.3
8-Jun	1	97.3	97.3	97.3
All	**83**	**31.8**	**85.0**	**124.3**

Table 60–10. Downstream passage route selection for radio-tagged adult river herring released upstream of Rolfe Canal during the spring downstream passage study period, May 24 – June 30, 2021

River Herring - Rolfe Canal Downstream Passage Route					
Release Date	Release Location	No. Released	No. Detected	Turbine	York Dam
24-May	US Rolfe	15	15	2	13
25-May	US Rolfe	15	14	2	12
26-May	US Rolfe	15	15	4	11
27-May	US Rolfe	15	14	0	14
All		**60**	**58**	**8**	**50**

% of Total Detected	14%	86%

Table 60–11. Downstream passage route selection for radio-tagged adult river herring released upstream of PUF during the spring downstream passage study period, May 24 – June 30, 2021

River Herring - PUF Downstream Passage Route						
Release Date	Release Location	No. Released	No. Detected	Turbine	Downstream Bypass	Spill
24-May	US Rolfe	15	14	4	9	1
	DS Rolfe	5	5	0	5	0
25-May	US Rolfe	15	14	4	8	2
	DS Rolfe	5	5	1	1	3
26-May	US Rolfe	15	10	2	7	1
	DS Rolfe	5	5	0	2	3
27-May	US Rolfe	15	14	4	8	2
	DS Rolfe	5	5	2	3	0
All		**80**	**72**	**17**	**43**	**12**
% of Total Detected				**23%**	**60%**	**17%**

Table 60–12. Downstream passage route selection for radio-tagged adult river herring released upstream of PLF during the spring downstream passage study period, May 24 – June 30, 2021

River Herring - PLF Downstream Passage Route						
Release Date	Release Location	No. Released	No. Detected	Turbine	Downstream Bypass	No Pass
24-May	US Rolfe	15	13	6	6	1
	DS Rolfe	5	5	2	2	1
	DS PUF	5	5	3	2	0
25-May	US Rolfe	15	10	3	7	0
	DS Rolfe	5	5	2	3	0
	DS PUF	5	9	7	2	0
26-May	US Rolfe	15	7	2	5	0
	DS Rolfe	5	5	2	2	1
	DS PUF	5	7	4	3	0
27-May	US Rolfe	15	12	8	4	0
	DS Rolfe	5	4	3	1	0
	DS PUF	5	5	3	1	1
All		**100**	**87**	**45**	**38**	**4**
% of Total Detected				**52%**	**44%**	**4%**

Table 60–13. Quartile values for the project reach transit duration (by release location) observed for radio-tagged adult river herring released during the spring downstream passage study period, May 24 – June 30, 2021

River Herring - Project Reach Transit (hrs)			
Release Location	P25	P50 (Median)	P75
Upstream Rolfe Canal	131.3	157.5	189.8
Rolfe Canal Tailrace	136.3	160.3	176.7
PUF Tailrace	124.8	145.5	176.2
All	**130.6**	**160.2**	**180.5**

Table 60–14. Quartile values for the downstream transit duration (by release location) observed for radio-tagged adult river herring released during the spring downstream passage study period, May 24 – June 30, 2021

River Herring - Downstream Transit (hrs)				
River Reach	Release Location	P25	P50 (Median)	P75
PLF to Station 18	Upstream Rolfe Canal	4.9	8.4	15.4
	Rolfe Canal Tailrace	6.2	12.9	16.7
	PUF Tailrace	5.4	7.8	10.7
	All	*4.9*	*8.8*	*15.4*
Station 18 to Station 19	Upstream Rolfe Canal	3.9	4.7	16.1
	Rolfe Canal Tailrace	4.0	5.6	15.6
	PUF Tailrace	3.8	17.5	19.6
	All	*3.8*	*5.6*	*17.3*
PLF to Station 19	Upstream Rolfe Canal	13.7	20.2	22.0
	Rolfe Canal Tailrace	17.9	20.9	25.3
	PUF Tailrace	18.8	21.9	27.6
	All	*15.1*	*20.9*	*22.1*

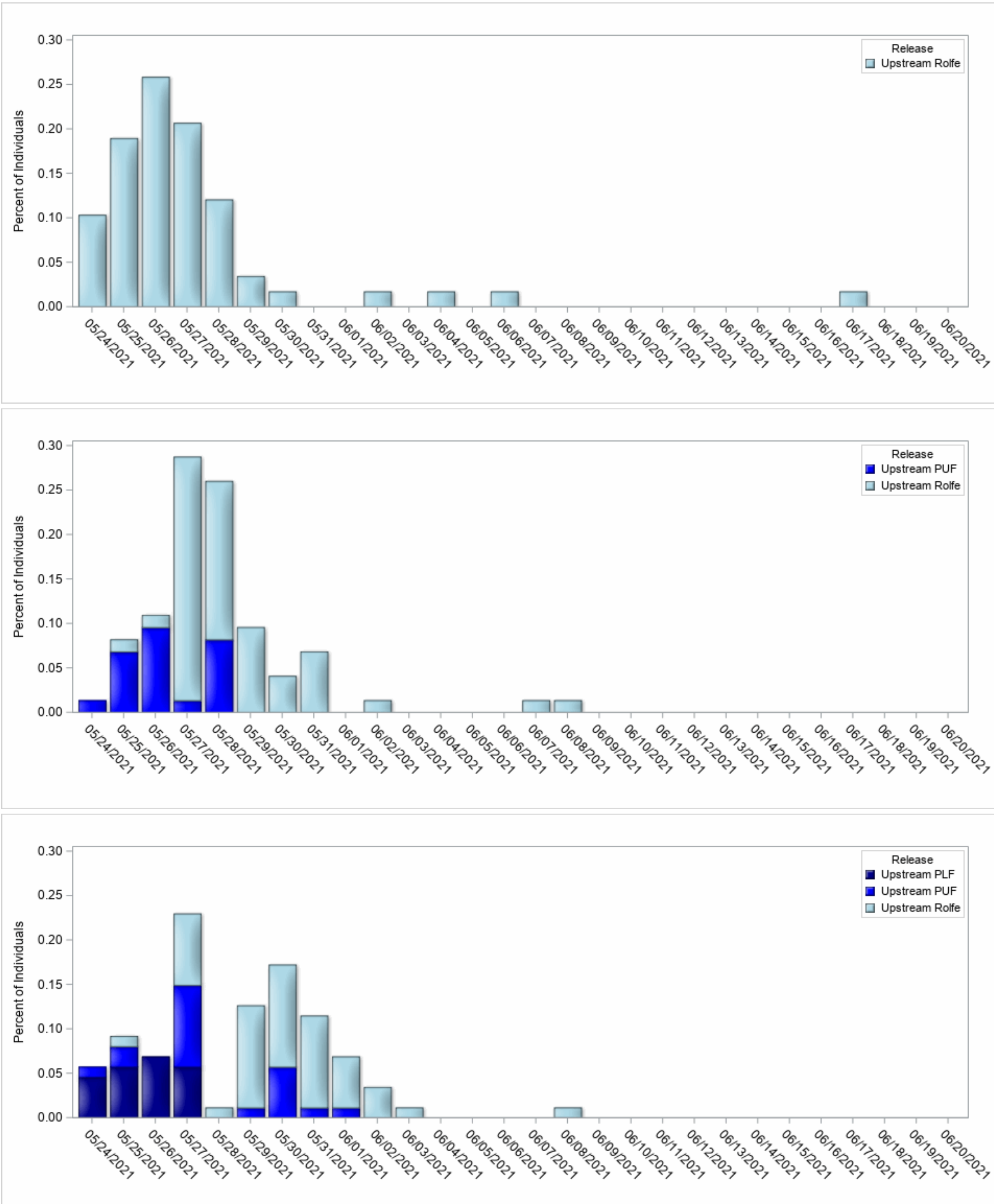
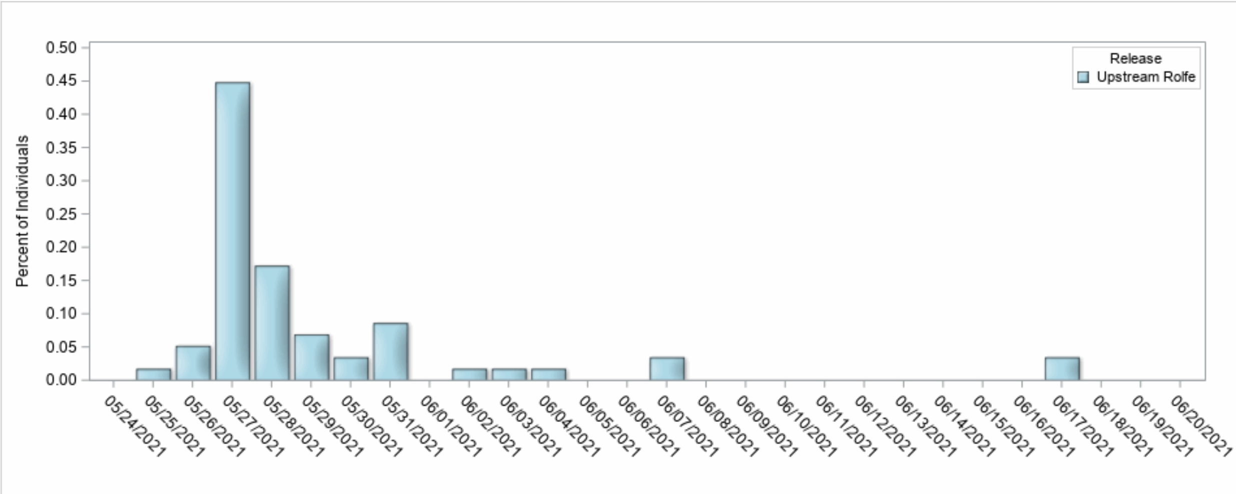


Figure 60–9. Approach date (by release location) for radio-tagged adult river herring at Rolfe Canal (upper), PUF (middle), and PLF (lower) during the downstream passage study period, May 24 – June 30, 2021.


Release
Upstream Rolfe
Percent of Individuals
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
05/24/2021
05/25/2021
05/26/2021
05/27/2021
05/28/2021
05/29/2021
05/30/2021
05/31/2021
06/01/2021
06/02/2021
06/03/2021
06/04/2021
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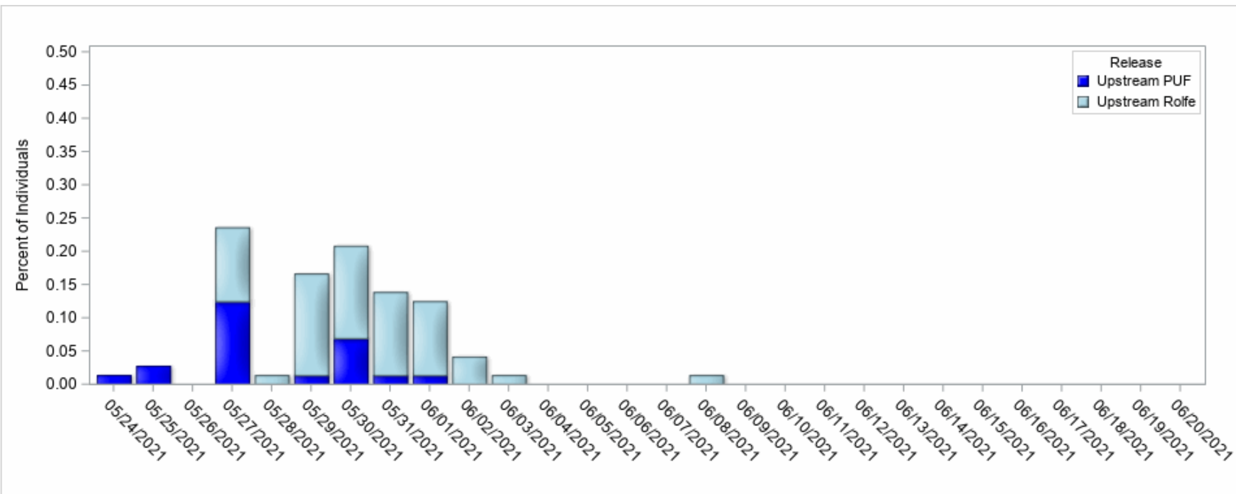
06/19/2021
06/20/2021


Release
Upstream PUF
Upstream Rolfe
Percent of Individuals
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
05/24/2021
05/25/2021
05/26/2021
05/27/2021
05/28/2021
05/29/2021
05/30/2021
05/31/2021
06/01/2021
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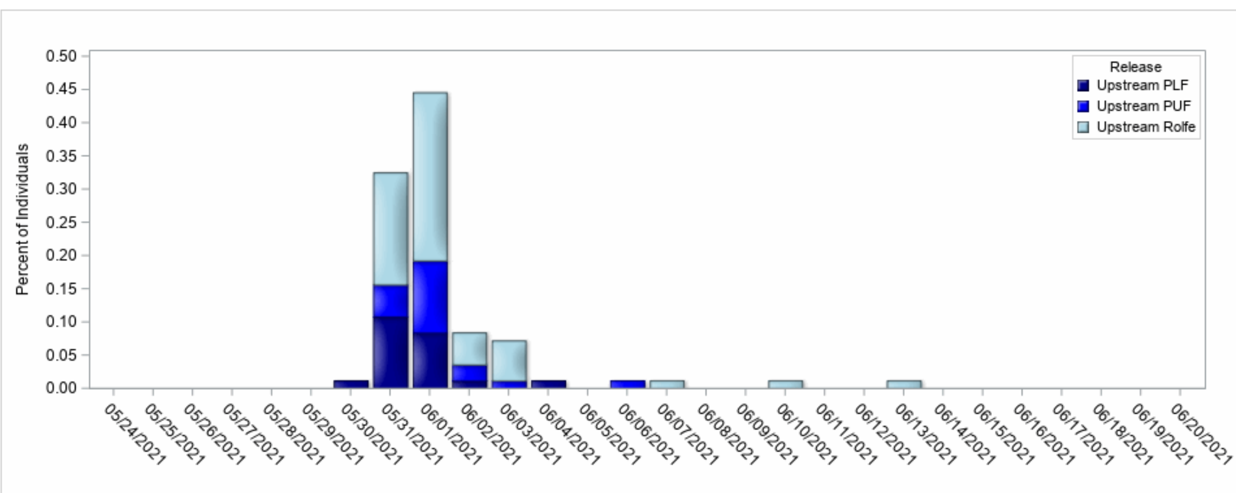
06/19/2021
06/20/2021


Release
Upstream PLF
Upstream PUF
Upstream Rolfe
Percent of Individuals
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
05/24/2021
05/25/2021
05/26/2021
05/27/2021
05/28/2021
05/29/2021
05/30/2021
05/31/2021
06/01/2021
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06/14/2021
06/15/2021
06/16/2021
06/17/2021
06/18/2021
06/19/2021
06/20/2021

Figure 60–10. Downstream passage date (by release location) for radio-tagged adult river herring at Rolfe Canal (upper), PUF (middle), and PLF (lower) during the downstream passage study period, May 24 – June 30, 2021.

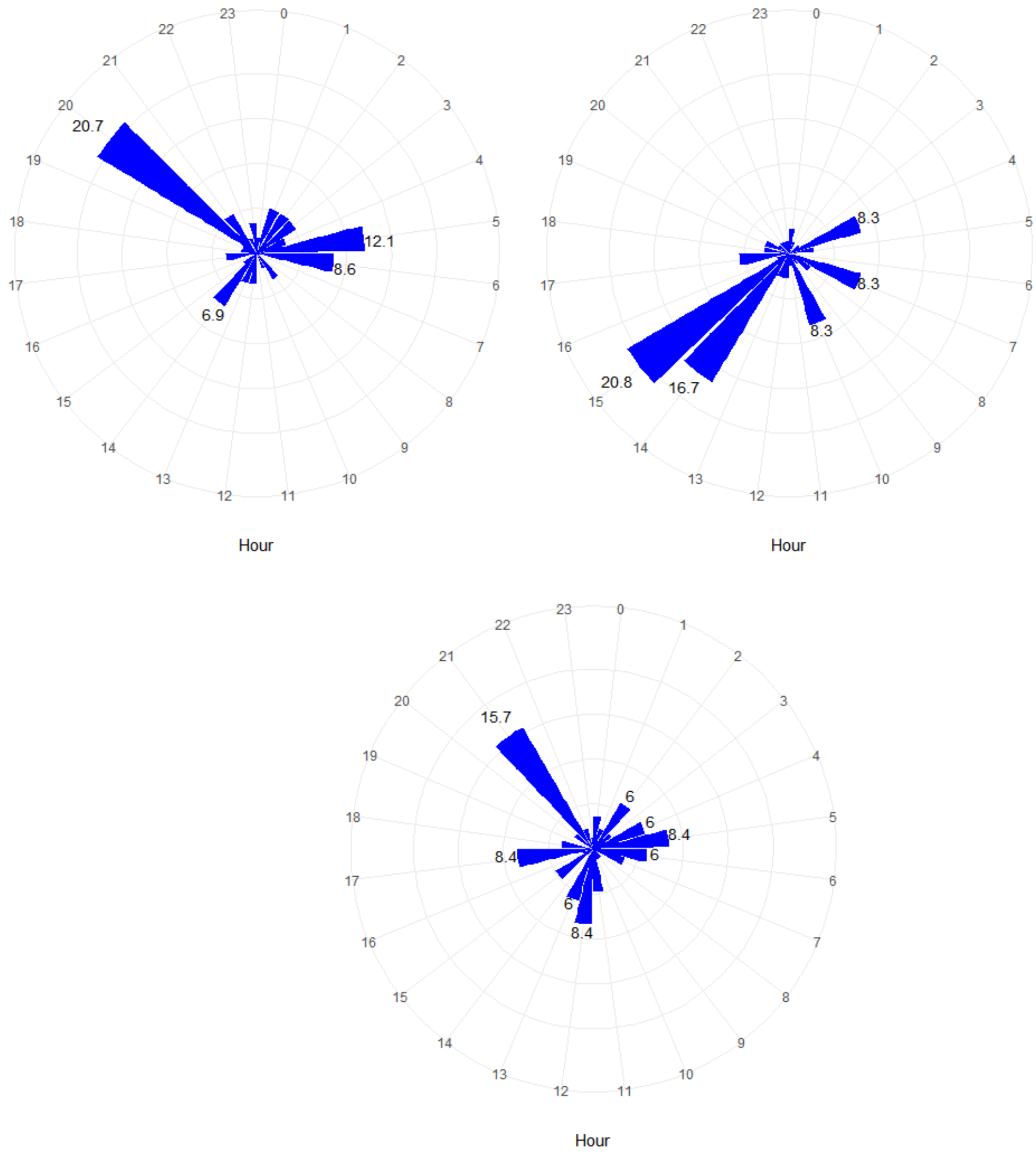


Figure 60–11. Downstream passage timing for radio-tagged adult river herring at Rolfe Canal (upper left), PUF (upper right), and PLF (lower) during the downstream passage study period, May 24 – June 30, 2021.

Passage Survival

The CJS model *Phi(t)p(.)* provided the best fit for the observed mark-recapture data associated with downstream movements of all radio-tagged adult river herring approaching and passing at Rolfe Canal, PUF, and PLF during the 2021 study period (Table 5-15). The detection efficiency for telemetry receivers recording passage of adult herring at locations incorporated into the CJS model was 1.0. The reach-specific survival estimates for the Project reach are presented in Table 5-16. Project-specific estimates of passage survival were 91.4% (95% CI = 80.9-96.4%) for Rolfe Canal, 91.8% (95% CI = 82.9-96.3%) for PUF, and 75.9% (95% CI = 65.8-83.7%) for PLF. Downstream passage success for adult river herring at the full set of Projects was calculated as the joint probability of the three reach-specific survival estimates which encompassed the riverine section from arrival at Rolfe Canal downstream to a point approximately 7.0 miles below the confluence of the Contoocook and Merrimack Rivers. This resulted in a cumulative estimated downstream passage survival for adult river herring of 63.6% (95% CI = 52.9-73.4%).

Radio-tagged adult river herring approached and passed downstream at Rolfe Canal, PUF, and PLF via a variety or passage routes (Section 5.7). Individual CJS models were run for the subset of individuals utilizing each passage route at the three Projects (Table 5-17). Survival rates for adult river herring passing downstream through project turbines ranged from 50.0% to 82.4%. Survival rates for adult herring passing downstream via spill or through a downstream bypass ranged from 89.5% to 100%.

Table 60–15. CJS model selection criteria for survival of radio-tagged adult river herring released during the spring downstream passage study period, May 24 – June 30, 2021

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
Phi(t) p(.)	229.60	0.00	0.50	1.00	5	7.26
Phi(t) p(t)	229.60	0.00	0.50	1.00	5	7.26
Phi(.) p(t)	241.08	11.48	0.00	0.00	1	26.91
Phi(.) p(.)	243.11	13.50	0.00	0.00	2	26.91

Table 60–16. Reach-specific survival probability estimates (*phi)*, standard errors, and 95% confidence intervals for for radio-tagged adult river herring released during the spring downstream passage study period, May 24 – June 30, 2021

River Reach	*Phi*	SE	95% CI	
Release to Rolfe Canal	0.967	0.023	0.876	0.992
Rolfe Canal to PUF	0.914	0.037	0.809	0.964
PUF to PLF	0.918	0.032	0.829	0.963
PLF to Station 18	0.759	0.046	0.658	0.837

Table 60–17. Project and passage route-specific survival probability estimates (*phi)* and 95% confidence intervals for radio-tagged adult river herring released during the spring downstream passage study period, May 24 – June 30, 2021

Project	Route	n	*Phi*	95% CI	
Rolfe Canal	Turbine	8	0.500	0.200	0.800
	York Dam (spill)	50	0.980	0.871	0.997
PUF	Turbine	17	0.824	0.573	0.942
	Downstream Bypass	43	0.953	0.832	0.988
	Spill	12	1.000	-	-
PLF	Turbine	45	0.711	0.564	0.824
	Downstream Bypass	38	0.895	0.751	0.960

Manual Tracking

Downstream passage timing, route selection, and survival of adult river herring at Rolfe Canal, PUF, and PLF were informed using the stationary telemetry data collected at the nineteen receiver locations detailed in Section 4.2. Based on those data downstream passage occurred from the date of initial release until June 17, 2021 when the final passage event was recorded at Rolfe Canal. However, per the revised study plan, limited manual tracking information was collected for adult river herring from the Rolfe Canal Project downstream to the confluence of the Contoocook and Merrimack Rivers. A tracking event conducted on June 7, 2021 identified a total of seven adult river herring from the targeted reach. Transmitter locations for each of the fish observed during manual tracking were in full agreement with the final disposition of those individuals as determined from the overall data set collected by the stationary receivers. This included one stationary tag in the PUF forebay, one stationary tag in the PUF tailrace, two stationary tags in the PLF forebay, and three stationary tags in the PLF tailrace.

6. Summary

An evaluation of downstream passage success for adult river herring was conducted in support of the FERC relicensing of the Rolfe Canal, PUF, and PLF Projects. Passage effectiveness was evaluated using radio-telemetry during the 2021 spring passage season (May-June). Contoocook River inflow ranged between 151 to 1,432 cfs, less than the station capacity at each of the three Projects. Project turbines at Rolfe Canal and PUF were off for portions of the study period. Briar Hydro operated the downstream bypasses at both PUF and PLF and provided at least 100 cfs of flow at York Dam to meet minimum flow requirements for the downstream bypass reach.

A total of 100 adult river herring were radio-tagged and released on one of four dates during late May (May 24, 25, 26, and 27). Of that total, 60 were tagged and released upstream of Rolfe Canal, 20 were tagged and released in the Rolfe Canal tailrace, and 20 were tagged and released in the PUF tailrace. Outmigration of radio-tagged adult river herring was observed over a range of dates from May 24 to June 17 with peaks in downstream passage activity occurring May 27-28 at Rolfe Canal, May 27-30 at PUF, and

May 31 – June 1 at PLF. The median duration of time for radio-tagged herring released upstream of Rolfe Canal to move from the release location and pass downstream of all three projects was 6.6 days. When examined among projects, the median upstream residence duration for adult herring originating at the release location upstream of all three Projects was 22.3 hours at Rolfe Canal, 34.0 hours at PUF, and 39.6 hours at PLF. The majority of downstream passage at Rolfe Canal occurred during an outage period and fish passed downstream via York Dam and the bypass reach. At PUF the majority of adult herring utilized the downstream bypass or passed on spill (77% of all fish) with the remainder entrained at the turbine. Downstream passage at PLF was documented for adult herring through the turbine and downstream bypass in a near even proportion. Project-specific estimates of passage survival were 91.4% at Rolfe Canal, 91.8% at PUF, and 75.9% at PLF. Cumulative estimated downstream passage survival for adult river herring passing all three projects was estimated at 63.6%. These estimates of downstream passage survival for adult river herring at the Briar Projects includes any background mortality (i.e., natural mortality) for the species in the downstream reach, along with any tagging-related mortalities or tag regurgitations. As a result, these estimates should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult river herring at these locations.

7. Variances from Approved Study Plan

This study was conducted following the methodology described in the RSP which was finalized in March 2021 and filed with FERC on July 6, 2021

8. Appendices

Appendix A. Adult River Herring – Tagging Information.

Frequency	ID	Total Length (mm)	Sex	Release Date	Release Location
149.320	122	304	M	5/24/2021	PUF Tailrace
149.320	123	292	M	5/24/2021	PUF Tailrace
149.320	124	279	F	5/24/2021	PUF Tailrace
149.360	111	297	F	5/24/2021	PUF Tailrace
149.360	112	293	M	5/24/2021	PUF Tailrace
149.320	120	296	F	5/24/2021	Rolfe Tailrace
149.320	121	294	M	5/24/2021	Rolfe Tailrace
149.360	108	302	F	5/24/2021	Rolfe Tailrace
149.360	109	288	M	5/24/2021	Rolfe Tailrace
149.360	110	295	F	5/24/2021	Rolfe Tailrace
149.320	113	264	M	5/24/2021	US Rolfe Canal
149.320	114	285	F	5/24/2021	US Rolfe Canal
149.320	115	289	M	5/24/2021	US Rolfe Canal
149.320	116	276	M	5/24/2021	US Rolfe Canal
149.320	117	287	M	5/24/2021	US Rolfe Canal
149.320	118	318	M	5/24/2021	US Rolfe Canal
149.320	119	326	F	5/24/2021	US Rolfe Canal
149.360	100	297	M	5/24/2021	US Rolfe Canal
149.360	101	312	F	5/24/2021	US Rolfe Canal
149.360	102	297	F	5/24/2021	US Rolfe Canal
149.360	103	290	M	5/24/2021	US Rolfe Canal
149.360	104	293	F	5/24/2021	US Rolfe Canal
149.360	105	292	M	5/24/2021	US Rolfe Canal
149.360	106	295	M	5/24/2021	US Rolfe Canal
149.360	107	295	F	5/24/2021	US Rolfe Canal
149.320	136	291	M	5/25/2021	PUF Tailrace
149.320	137	284	F	5/25/2021	PUF Tailrace
149.360	147	291	M	5/25/2021	PUF Tailrace
149.360	148	311	F	5/25/2021	PUF Tailrace
149.360	149	314	F	5/25/2021	PUF Tailrace
149.320	133	283	F	5/25/2021	Rolfe Tailrace
149.320	134	290	M	5/25/2021	Rolfe Tailrace
149.320	135	313	F	5/25/2021	Rolfe Tailrace
149.360	145	276	F	5/25/2021	Rolfe Tailrace
149.360	146	324	F	5/25/2021	Rolfe Tailrace
149.320	125	270	F	5/25/2021	US Rolfe Canal

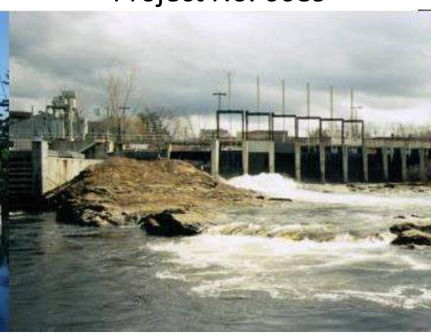
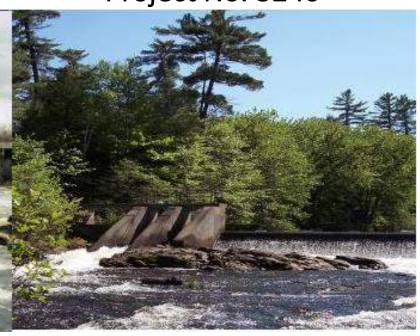
Frequency	ID	Total Length (mm)	Sex	Release Date	Release Location
149.320	126	287	M	5/25/2021	US Rolfe Canal
149.320	127	317	F	5/25/2021	US Rolfe Canal
149.320	128	292	M	5/25/2021	US Rolfe Canal
149.320	129	281	M	5/25/2021	US Rolfe Canal
149.320	130	288	M	5/25/2021	US Rolfe Canal
149.320	131	282	M	5/25/2021	US Rolfe Canal
149.320	132	303	F	5/25/2021	US Rolfe Canal
149.360	138	276	M	5/25/2021	US Rolfe Canal
149.360	139	280	M	5/25/2021	US Rolfe Canal
149.360	140	315	F	5/25/2021	US Rolfe Canal
149.360	141	273	M	5/25/2021	US Rolfe Canal
149.360	142	297	F	5/25/2021	US Rolfe Canal
149.360	143	300	F	5/25/2021	US Rolfe Canal
149.360	144	279	M	5/25/2021	US Rolfe Canal
149.320	172	283	M	5/26/2021	PUF Tailrace
149.320	173	287	M	5/26/2021	PUF Tailrace
149.320	174	264	M	5/26/2021	PUF Tailrace
149.360	161	290	F	5/26/2021	PUF Tailrace
149.360	162	317	F	5/26/2021	PUF Tailrace
149.320	170	281	F	5/26/2021	Rolfe Tailrace
149.320	171	282	F	5/26/2021	Rolfe Tailrace
149.360	158	295	M	5/26/2021	Rolfe Tailrace
149.360	159	285	M	5/26/2021	Rolfe Tailrace
149.360	160	287	M	5/26/2021	Rolfe Tailrace
149.320	163	288	F	5/26/2021	US Rolfe Canal
149.320	164	297	F	5/26/2021	US Rolfe Canal
149.320	165	295	F	5/26/2021	US Rolfe Canal
149.320	166	292	F	5/26/2021	US Rolfe Canal
149.320	167	292	F	5/26/2021	US Rolfe Canal
149.320	168	266	F	5/26/2021	US Rolfe Canal
149.320	169	307	M	5/26/2021	US Rolfe Canal
149.360	150	286	F	5/26/2021	US Rolfe Canal
149.360	151	288	M	5/26/2021	US Rolfe Canal
149.360	152	305	M	5/26/2021	US Rolfe Canal
149.360	153	293	F	5/26/2021	US Rolfe Canal
149.360	154	304	F	5/26/2021	US Rolfe Canal
149.360	155	290	F	5/26/2021	US Rolfe Canal
149.360	156	271	M	5/26/2021	US Rolfe Canal
149.360	157	283	F	5/26/2021	US Rolfe Canal
149.320	186	304	M	5/27/2021	PUF Tailrace
149.320	187	283	M	5/27/2021	PUF Tailrace

Frequency	ID	Total Length (mm)	Sex	Release Date	Release Location
149.360	197	271	M	5/27/2021	PUF Tailrace
149.360	198	291	F	5/27/2021	PUF Tailrace
149.360	199	286	F	5/27/2021	PUF Tailrace
149.320	183	287	F	5/27/2021	Rolfe Tailrace
149.320	184	276	M	5/27/2021	Rolfe Tailrace
149.320	185	293	M	5/27/2021	Rolfe Tailrace
149.360	195	295	F	5/27/2021	Rolfe Tailrace
149.360	196	287	F	5/27/2021	Rolfe Tailrace
149.320	175	285	F	5/27/2021	US Rolfe Canal
149.320	176	295	F	5/27/2021	US Rolfe Canal
149.320	177	283	F	5/27/2021	US Rolfe Canal
149.320	178	271	M	5/27/2021	US Rolfe Canal
149.320	179	286	M	5/27/2021	US Rolfe Canal
149.320	180	295	F	5/27/2021	US Rolfe Canal
149.320	181	304	F	5/27/2021	US Rolfe Canal
149.320	182	291	F	5/27/2021	US Rolfe Canal
149.360	188	298	F	5/27/2021	US Rolfe Canal
149.360	189	290	F	5/27/2021	US Rolfe Canal
149.360	190	290	M	5/27/2021	US Rolfe Canal
149.360	191	277	M	5/27/2021	US Rolfe Canal
149.360	192	278	M	5/27/2021	US Rolfe Canal
149.360	193	291	F	5/27/2021	US Rolfe Canal
149.360	194	309	F	5/27/2021	US Rolfe Canal

American Eel Downstream Passage Study

Briar Hydro Associates

Penacook Lower Falls	Penacook Upper Falls	Rolfe Canal
Hydroelectric Project	Hydroelectric Project	Hydroelectric Project
Project No. 3342	Project No. 6689	Project No. 3240

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February 2022

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• Introduction and Background

Briar Hydro Associates (Briar Hydro or Licensee) is in the process of relicensing the Rolfe Canal (FERC No. 3240), Penacook Upper Falls (PUF; FERC No. 6689), and Penacook Lower Falls (PLF; FERC No. 3342) Hydroelectric Projects (Project; collectively, Projects) with the Federal Energy Regulatory Commission (FERC or Commission). The Projects are located on the Contoocook River in Boscawen and Concord, New Hampshire. PLF sits at river mile 0 of the Contoocook River, above the confluence with the Merrimack River. The Upper Penacook and Rolfe Canal Projects are located upstream at river miles 1.0 and 2.0, respectively.

The current Project licenses were issued by the Federal Energy Regulatory Commission (FERC or Commission) in accordance with the Commission's delegated authority under the Federal Power Act on November 17, 1982 (PLF) and December 5, 1984 (Rolfe Canal and PUF). By FERC order the original April 17, 2018 license expiration for PLF was extended from October 31, 2022 to November 30, 2024 and matching the expiration for the Rolfe Canal and PUF Projects. Briar Hydro is pursuing a new license for the three Projects through the Commission's Traditional Licensing Process (TLP).

In response to requests provided by the resource agencies as part of the TLP process, Briar Hydro prepared a Preliminary Study Plan (PSP). The intent of the PSP was that the goals, methodology, scope, and schedule would be refined in consultation with interested stakeholders, as necessary. Briar Hydro distributed a copy of the PSP to representatives from the representatives from the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFGD) and the New Hampshire Department of Environmental Services (NHDES) on December 14, 2020. Following receipt and consultation related to comments on the PSP, Briar Hydro prepared a Revised Study Plan (RSP) which was finalized in March 2021 and filed with FERC on July 6, 2021. This report describes the American Eel Downstream Passage Study conducted in support of obtaining a new license for the Project.

61 Goals and Objectives

The goal of this study was to determine the direct and cumulative impact of the Rolfe Canal, PUF, and PLF Projects on the emigration of silver eels in the Contoocook River. Specifically this study sought to:

- quantify the movement rates and delay caused by operation of the Projects;
- quantify the relative proportion of eels passing each emigration route at the Projects during various project operations; and
- quantify instantaneous and latent mortality of eels passed via each emigration route.

62 Study Area

The study area for this evaluation encompassed the impoundment, dam/powerhouse structures, bypasses and riverine reaches immediately downstream of the three Projects.

63 Methodology

Radio telemetry was employed to evaluate the downstream passage of adult silver-phase American eels at Rolfe Canal, PUF, and PLF Projects. Following the release of radio-tagged adult eels upstream of Rolfe Canal, their movements were evaluated using a series of stationary receivers installed at each Project. Additional stationary monitoring locations were installed at bank-side locations downstream of the confluence of the Contoocook and Merrimack Rivers to inform on post-passage movements.

63.1 Telemetry Equipment

Downstream passage of radio-tagged adult eels was recorded via a series of stationary radio telemetry receivers, which included equipment manufactured by both Sigma Eight and Lotek Wireless. All receivers were installed following consideration of the detection requirements for the specific area of coverage, as well as the attributes of the receiver model (e.g., desired range, ability to concurrently scan one or more frequencies, etc.). Each receiver was paired with either an aerial antenna (4 or 6 element Yagi) or an underwater drop antenna.

Adult eels were tagged using Sigma-Eight model TX-PSC-I-450 transmitters operating on one of three unique frequencies (149.440, 149.480 or 149.760 MHz). Each transmitter was coded to emit a unique identifying signal, so that individual fish could be identified by a receiver. Transmitters utilized during this study were programmed to emit a 20 ms coded transmission at a 3.0 second interval.

63.2 Monitoring Stations

Radio telemetry antennas and receivers were installed at a number of locations at each of the three Projects. Each monitoring station consisted of a data-logging receiver, one or more antennas, and a power source. Stations were configured to receive transmitter signals from a designated area continuously throughout the study period. During installation of each station, range testing was conducted to configure the antennas and receivers in a manner which maximized detection efficiency at each location. Although each monitoring station was installed in a manner which limited the ability to detect transmitters from unwanted areas, the possibility of such detections did still exist. As a result, behavioral data collected during the study (i.e., duration at a specific location or passage route) was inferred based on the signal strength and the duration and pattern of contacts documented across the entire detection array.

The locations of installed telemetry receivers to evaluate the downstream passage of adult eels at the three Projects are outlined below and presented visually in Figures 4-1 through 4-3.

Station 01: Station 01 was installed to detect radio-tagged eels as they approached the Rolfe Canal headgate structure. Detections from this location were used to determine when eels arrived at the Project and was a component of the determination of residence time upstream of the dam and prior to passage. Station 01 consisted of a single antenna and radio-telemetry receiver.

Station 02: Station 02 detected radio-tagged eels as they approached the upstream side of the York Dam. Detections from this location were used in conjunction with subsequent detections at Station 04 to identify individuals which passed downstream of the Rolfe Canal Project via spill flows provided at this location. Station 02 consisted of a single antenna and radio-telemetry receiver.

Station 03: Station 03 was installed to detect radio-tagged eels which approached the Rolfe Canal intake structure. Detections from this location were used in conjunction with subsequent detections at Station 05 to identify individuals which passed downstream via the penstock and turbine unit at Rolfe Canal. Station 03 consisted of a single antenna and radio-telemetry receiver.

Station 04: Station 04 detected radio-tagged eels at a point within the York Dam bypass reach downstream of the Dam and upstream of its confluence with outflow from the tailrace channel. Detections from this location were used to confirm radio-tagged individuals which passed downstream at the York Dam. Station 04 consisted of a single antenna and radio-telemetry receiver.

Station 05: Station 05 detected radio-tagged eels in the Rolfe Canal tailrace. Detections from this location were used to confirm radio-tagged individuals which passed downstream via the turbine unit and were previously detected at Station 03. Station 05 consisted of a single antenna and radio-telemetry receiver.

Station 06: Station 06 detected radio-tagged eels at a point within the historic canal discharge channel. Detections from this location were used to confirm radio-tagged individuals which may have passed downstream via the bypass at the Rolfe Canal intake structure. Station 06 consisted of a single antenna and radio-telemetry receiver.

Station 07: Station 07 was installed to detect radio-tagged eels as they approached and passed a point approximately 100 m upstream of the PUF powerhouse intake. Detections from this location were used to determine when eels arrived at PUF and was a component of the determination of residence time upstream of the dam and prior to passage. Station 07 consisted of a single antenna and radio-telemetry receiver.

Station 08: Station 08 was installed to detect radio-tagged eels as they approached the PUF intake structure. Detections from this location were used in conjunction with subsequent detections at Station 11 to identify individuals which passed downstream via the PUF turbine unit. Station 08 consisted of a single antenna and radio-telemetry receiver.

Station 10: Station 10 consisted of a single receiver and an aerial antenna installed to detect radio-tagged adult eels which passed downstream of PUF via spill flow through the bypass reach.

Station 11: Station 11 detected radio-tagged eels in the PUF tailrace. Detections from this location were used to confirm radio-tagged individuals which had passed downstream via the turbine unit and were last detected at Station 08. Station 11 consisted of a single antenna and radio-telemetry receiver.

Station 12: Station 12 detected radio-tagged eels as they approached and passed a point approximately 150 m upstream of the PLF powerhouse intake. Detections from this location were used to determine when radio-tagged adult eels arrived at PLF and were used as a component in the determination of residence time upstream of the dam and prior to passage. Station 12 consisted of a single antenna and radio-telemetry receiver.

Station 13: Station 13 detected radio-tagged adult eels as they approached the upstream side of the PLF diversion spillway structure. Detections from this location were used in conjunction with subsequent detections at Station 16 to identify individuals which may have passed downstream at this location. Station 13 consisted of a single antenna and radio-telemetry receiver.

Station 14: Station 14 was installed to detect radio-tagged adult eels as they approached the PLF intake structure. Detections from this location were used in conjunction with subsequent detections at Station 17 to identify individuals which passed downstream via the PLF turbine unit. Station 14 consisted of a single antenna and radio-telemetry receiver.

Station 16: Station 16 detected radio-tagged eels moving through the PLF bypass reach following passage via spill flow at the diversion or auxiliary dam structures. Station 16 consisted of a single antenna and radio-telemetry receiver.

Station 17: Station 17 was installed to detect radio-tagged adult eels in the PLF tailrace. Detections from this location were used to confirm radio-tagged individuals which had passed downstream via the turbine unit and were previously detected at Station 14. Station 17 consisted of a single antenna and radio-telemetry receiver.

Station 18: Station 18 consisted of aerial, cross-river coverage at a point downstream of PLF. Detections from this location was used to assess cumulative passage survival of radio-tagged eels following downstream passage at the Projects. Following receipt of property access permission, Station 18 was established along the Merrimack River at a point approximately 7.0 miles downstream of its confluence with the Contoocook River

Station 19: Station 19 consisted of aerial, cross-river coverage at a point downstream of PLF and served as the second detection location to assess cumulative passage survival of radio-tagged eels following downstream passage at the Projects. Following receipt of permission from Central Rivers Power, Station 19 was installed facing upstream from the gatehouse structure at Garvins Falls (approximately 13.3 miles downstream of the confluence of the Contoocook and Merrimack Rivers).

63.3 Test Fish Acquisition, Tagging and Releases

Adult silver-phase American eels for evaluation of passage at Rolfe Canal, PUF and PLF were obtained from a commercial trapping operation on the St. Croix River, Maine. Upon notification from the vendor on test specimen availability, eels were trucked from the St. Croix River to a temporary tank facility established at Garvins Falls Dam on the Merrimack River[7]. Transported eels were held for at least 24 hours prior to any tagging. In advance of tagging, eels were visually examined; healthy eels suitable for tagging

[7] Central Rivers Power willingly provided a location for Normandeau staff to house and tag adult eels during this study.

were anesthetized in a clove oil and ethanol solution. Eels were held and visually monitored in the anesthesia bath until sufficiently sedated. Once sedated, eels were removed from the bath and placed in a specially designed restraining holder. The total length and eye diameter (horizontal and vertical; nearest 0.1 mm) was measured. A previously described correlation between eye size, body length, and gonad development was used to confirm whether individuals were mature and could be considered as active outmigrants (Pankhurst, 1982). Silver-phase American eels typically have an eye index between 6.0 and 13.5, with a bronze coloration along the lateral line that separates the dark, silver back from the white belly. Although eels collected from the St. Croix had a high probability of being silver based on the weir methodology used to collect them, eye measurements were recorded regardless.

For tagging, an incision was made off-center on the ventral surface of the individual. A hollow needle was inserted into the incision and pushed through the body wall just off the ventral mid-line and at a point posterior to the incision. The antenna was fed through the needle and gently pulled so that the transmitter entered the body cavity. The needle was then be pulled through the body wall and removed from the antenna. The transmitter was positioned by pulling the antenna so that it lay directly under the incision. The incision was closed with two or three interrupted sutures. A small amount of an antibacterial ointment was applied to the incision site to prevent infection. Following tagging, each individual was transferred to a second holding tank supplied with ambient river water for an additional 24-hour observation/recovery period.

A total of 105 radio-tagged adult American eels were transported via stocking truck from Garvins Falls Dam and released into the Contoocook River at one of three release locations. A total of 63 individuals were released at a point approximately 10.0 miles upstream of Rolfe Canal, 21 individuals were released immediately downstream of the Rolfe Canal powerhouse, and 21 individuals were released immediately downstream of the PUF powerhouse. Three separate release events were conducted during the October 2021, with each event consisting of 35 live, radio-tagged individuals. Tagged eels were distributed among the three release sites as follows; 21 individuals upstream of Rolfe Canal, 7 individuals downstream of Rolfe Canal, and 7 individuals downstream of PUF. Releases were conducted during the evening hours.

63.4 Data Collection

63.4.1 Stationary Telemetry Data

Data were downloaded from receivers weekly during the period from the initial tag and release date through November 31, 2021. Backup copies of all telemetry data were made prior to receiver initialization. Field tests to ensure data integrity and receiver performance included confirmation of file integrity, confirmation that the last record was consistent with the downloaded data (a portable beacon tag was critical to this step), and lastly, to confirm that the receiver was operational upon restart and actively collecting data post download. Within a data file, transmitter detections were stored as a single event (i.e., single data line). Each event included the date and time of detection, frequency, ID code, and signal strength.

63.4.2 Manual Telemetry Data

To provide supplemental detection information to the stationary receiver data set, manual tracking was conducted twice during the monitoring period. Manual tracking events covered the section of the Contoocook from the area immediately upstream of Rolfe Canal to the confluence of the Contoocook and Merrimack Rivers downstream of PLF.

63.4.3 River and Project Operational Data

In addition to the radio telemetry data described above, river and project operations data were collected and reported for the 2021 evaluation period. Inflow at each Project was calculated as the sum of discharge values for the USGS flow gages 0108550 (Contoocook River downstream Hopkinton Dam) and 01086000 (Warner River at Davisville, NH) and multiplied by a proration factor of 1.3264 for Rolfe Canal and 1.3333 for PUF and PLF. Water temperature was recorded using a single Onset temperature logger set to read at a one-hour interval and installed in the vicinity of the turbine intake at PLF.

The Projects were operated under "baseline" conditions for the fall 2021 study period. Briar Hydro followed their current downstream passage operational strategy for eels and conducted nightly shutdowns for a three-night period following a quarter inch of rain. The York Dam gate was open and passed at least 100 cfs for the duration of the study period. Per their current operations plan Briar Hydro did not operate the downstream bypass facilities at PUF or PLF during the fall season eel outmigration study.

Briar Hydro provided power output (i.e., kw) for the duration of the monitoring period at all three Projects. Output was converted to turbine generation (cfs) using the following equations:

Rolfe Canal:

- If power output < 1000 KW, then flow (cfs) = power (KW) * 0.365 + 77
- If power output 1000-3561 KW, then flow (cfs) = power (KW) * 0.3676 + 74.31
- If power output 3562-4406 KW, then flow (cfs) = power (KW) * 0.4561 - 240.84
- If power output > 4406 KW, then flow (cfs) = power (KW) * 0.3662 + 155.13

PLF:

- If power output < 2131 KW, then flow (cfs) = power (KW) * 0.3285 + 250
- If power output 2131-3118 KW, then flow (cfs) = power (KW) * 0.3382 + 228.43
- If power output > 3118 KW, then flow (cfs) = power (KW) * 0.378 + 104.24

PUF:

- If power output < 675 KW, then flow (cfs) = power (KW) * 0.4237 + 85
- If power output 675-1442 KW, then flow (cfs) = power (KW) * 0.5474 + 1.442
- If power output 1443-2183 KW, then flow (cfs) = power (KW) * 0.476 + 103.89
- If power output > 2183 KW, then flow (cfs) = power (KW) * 0.4738 + 108.54

Available spill flow was calculated as the difference between the calculated generation flow and prorated inflow for all instances where inflow was greater than generation.

63.4.4 Downstream Drift Assessment

In addition to the 105 radio-tagged eels released upstream of the Projects, a total of nine freshly dead adult American eels were radio-tagged and released downstream of PLF during the 2021 study period. Three individuals were released on each of the three release dates for live radio-tagged eels. The downstream progression of these individuals was recorded by stationary receivers 18 and 19.

63.5 Data Analysis and Reporting

63.5.1 Upstream Residency and Downstream Passage Routes

A complete record of all valid detections for each uniquely coded radio-tagged adult eel was generated, and the pattern and timing of detections in these individual records were reviewed. For each radio-tagged individual released into the Contoocook River upstream of Rolfe Canal, the arrival and passage times and downstream route of passage were determined at Rolfe Canal, PUF, and PLF.

The stationary telemetry dataset collected during the study also permitted the evaluation of travel time for radio-tagged adult eels between any two adjacent monitoring stations both prior to and following downstream passage at a particular project. Passage duration through any defined river reach was calculated as the duration from initial detection at the stationary receiver on the upstream end of the reach until initial detection at the stationary receiver on the downstream end of the reach. For radio-tagged eels which approached Rolfe Canal, PUF or PLF, a 'project residence duration' was defined as the duration of time from initial detection at the dam until successful downstream passage.

63.5.2 Parameter Estimates for Evaluation of Project Survival

Downstream passage survival for adult eels was estimated using a standard Cormack-Jolly-Seber (CJS) model run for the set of individual encounter histories developed for each radio-tagged fish which was determined to have approached Rolfe Canal, PUF, and PLF. The CJS approach utilized during this study provided estimates for passage survival (*Phi)* of radio-tagged fish through defined reaches at the Projects. This approach relied on a suite of candidate models developed in Program MARK (White and Burnham 1999) and was based on whether survival, recapture (i.e., detection), or both varied or were constant among stations. Models developed during this study included:

- *Phi*(t)*p*(t): survival and recapture may vary between receiver stations;

- *Phi*(t)*p*(.): survival may vary between stations; recapture is constant between stations;
- *Phi*(.)*p*(t): survival is constant between stations; recapture may vary between stations; and
- *Phi*(.)*p*(.): survival and recapture are constant between stations.

Where;

- *Phi* = probability of survival
- *p* = probability of detection
- (t) = parameter varies
- (.) = parameter is constant

To evaluate the fit of the CJS model, goodness of fit testing was conducted for the "starting model" (i.e., the fully parameterized model) using the function RELEASE within Program MARK. Akaike's Information Criterion (AIC) was used to rank the models as to how well they fit the observed mark-recapture data. Lower AIC values denote a more explanatory yet parsimonious fit than higher AIC values. The model with the lowest AIC value was selected for the purposes of generating passage effectiveness estimates.

For all fish determined to have approached the Projects, an encounter history was assembled as the series of sequential detection (1) or no detection (0) records for each individual fish at:

- Release Location (1),
- Station 01/02, Rolfe Canal Approach (0 or 1),
- Station 08, PUF Approach (0 or 1),
- Station 12, PLF Approach (0 or 1),
- Station 18, Downstream Station #1 (0 or 1), and
- Station 19, Downstream Station #2 (0 or 1).

The resulting model permitted the estimation of passage survival for (1) Rolfe Canal, (2) PUF, (3) PLF, and (4) cumulative survival through each of the three Projects.

- Passage survival at the Rolfe Canal Project was estimated as the probability of a radio-tagged adult eels to be detected approaching PUF following an initial detection at Station 01/02.
- Passage survival at the PUF Project was estimated as the probability of a radio-tagged adult eels to be detected approaching PLF following an initial detection at Station 08.
- Passage survival at the PLF Project was estimated as the probability of a radio-tagged adult eels to be detected approaching Station 18 (i.e., the first downstream receiver) following an initial detection at Station 12.
- Cumulative survival for passage survival at all three Projects was estimated as the joint probability of survival at from Rolfe Canal to PUF, PUF to PLF, and PLF to the first downstream receiver.

This approach assumed that the background mortality (i.e., natural mortality such as predation) was negligible for adult eels in the reaches downstream of each dam and that the observed losses are attributable solely to Project effects. The use of this assumption results in a minimum estimate of total Project survival for adult eels passing downstream of the three Projects.

In addition to the base model to assess downstream passage survival for adult American eels at Rolfe Canal, PUF, and PLF individually and cumulatively, additional models were prepared which evaluated downstream passage success for eels by:

- Downstream passage route;
- Operational condition (i.e., normal generation or precipitation-triggered station shutdown; and
- Average “travel time” for freshly dead eels released in the PLF tailrace to reach Station 18 (i.e., test eels whose travel time from PLF to Garvins Falls Dam was in excess of the average drift duration were manually adjusted to reflect mortality passing through the Projects).

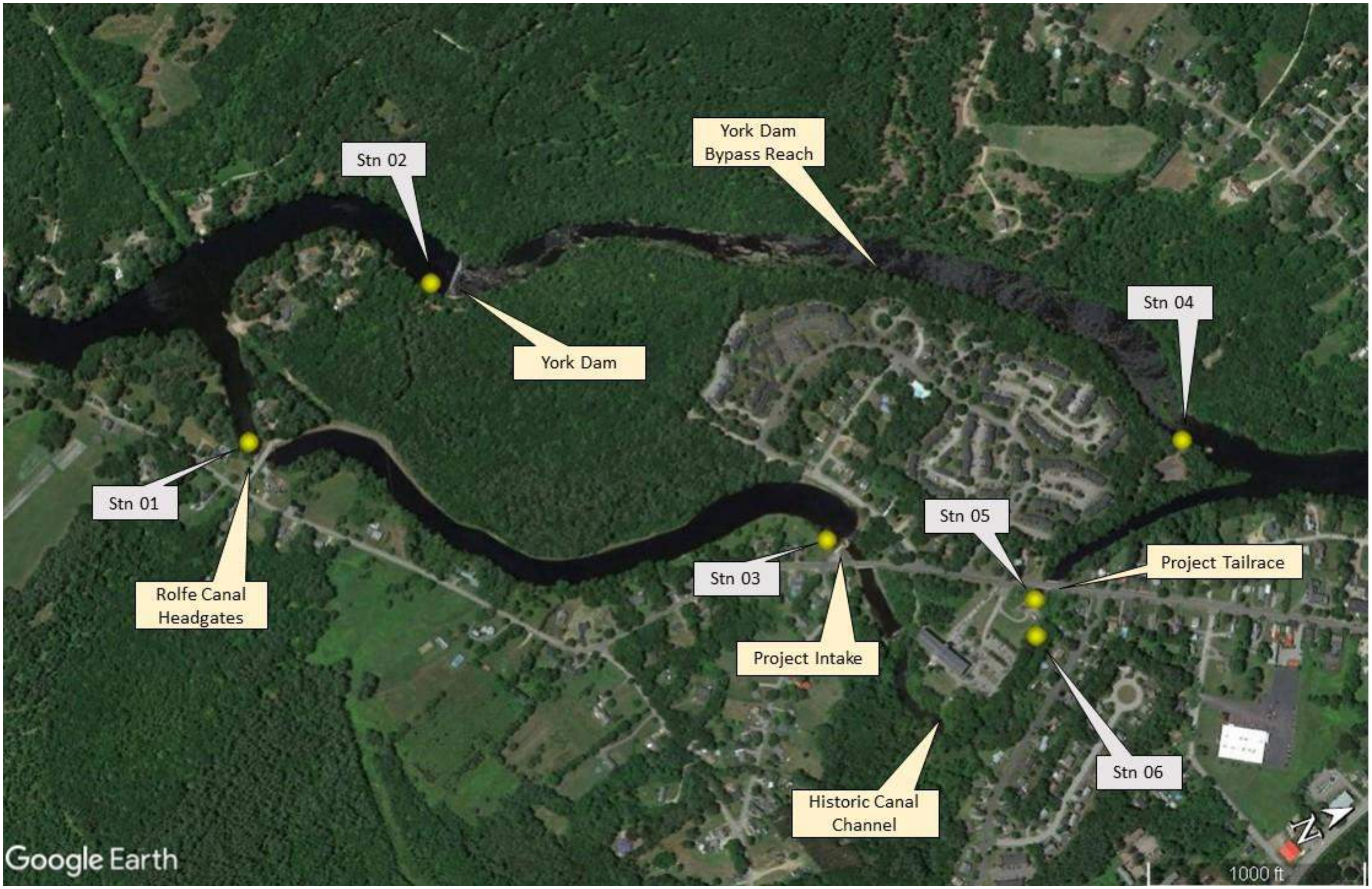


Figure 60–12. Final stationary receiver placement at Rolfe Canal for the adult silver eel downstream passage study, October 12 – November 30, 2021.

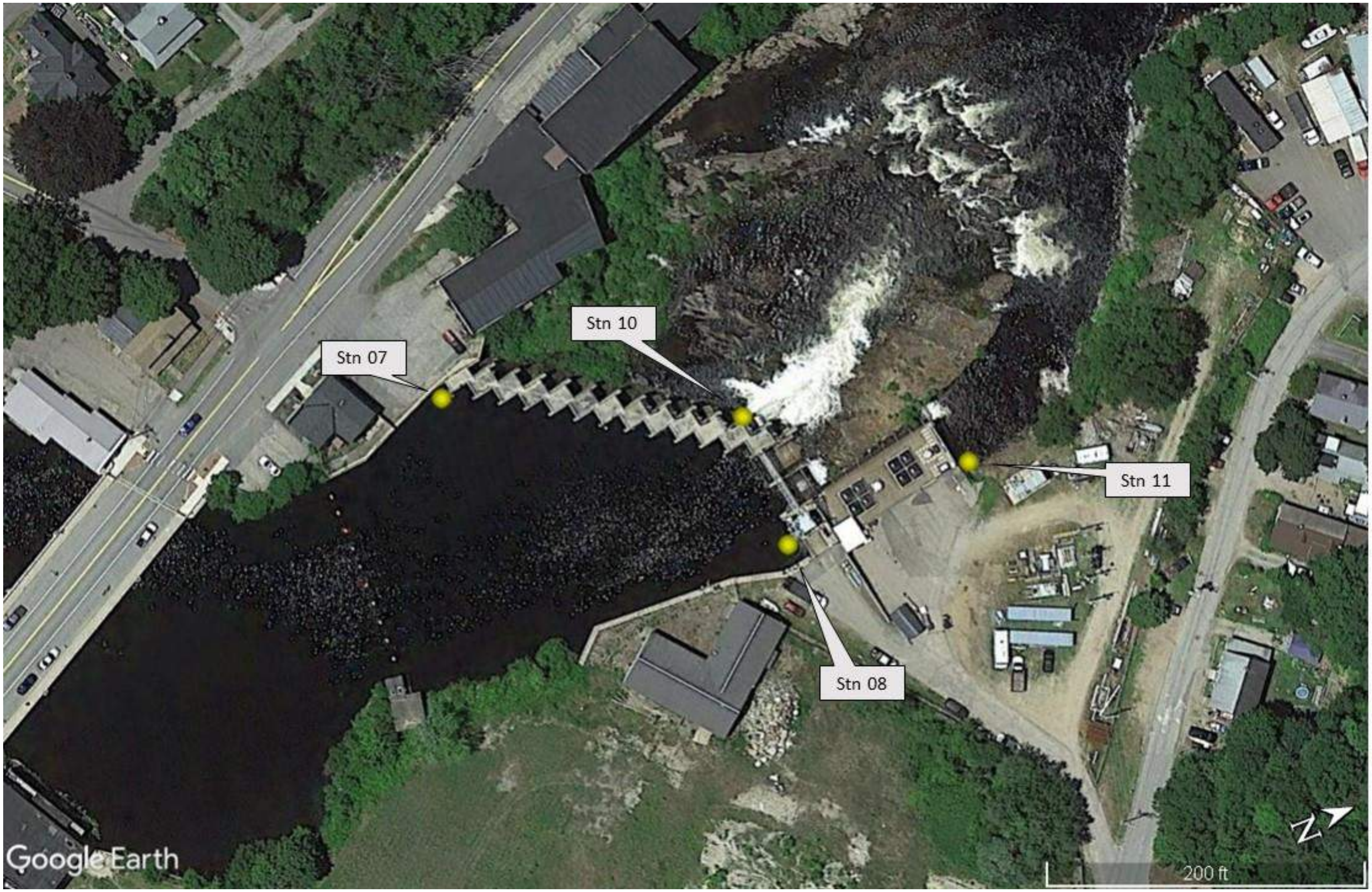


Figure 60–13. Final stationary receiver placement at PUF for the adult silver eel downstream passage study, October 12 – November 30, 2021.

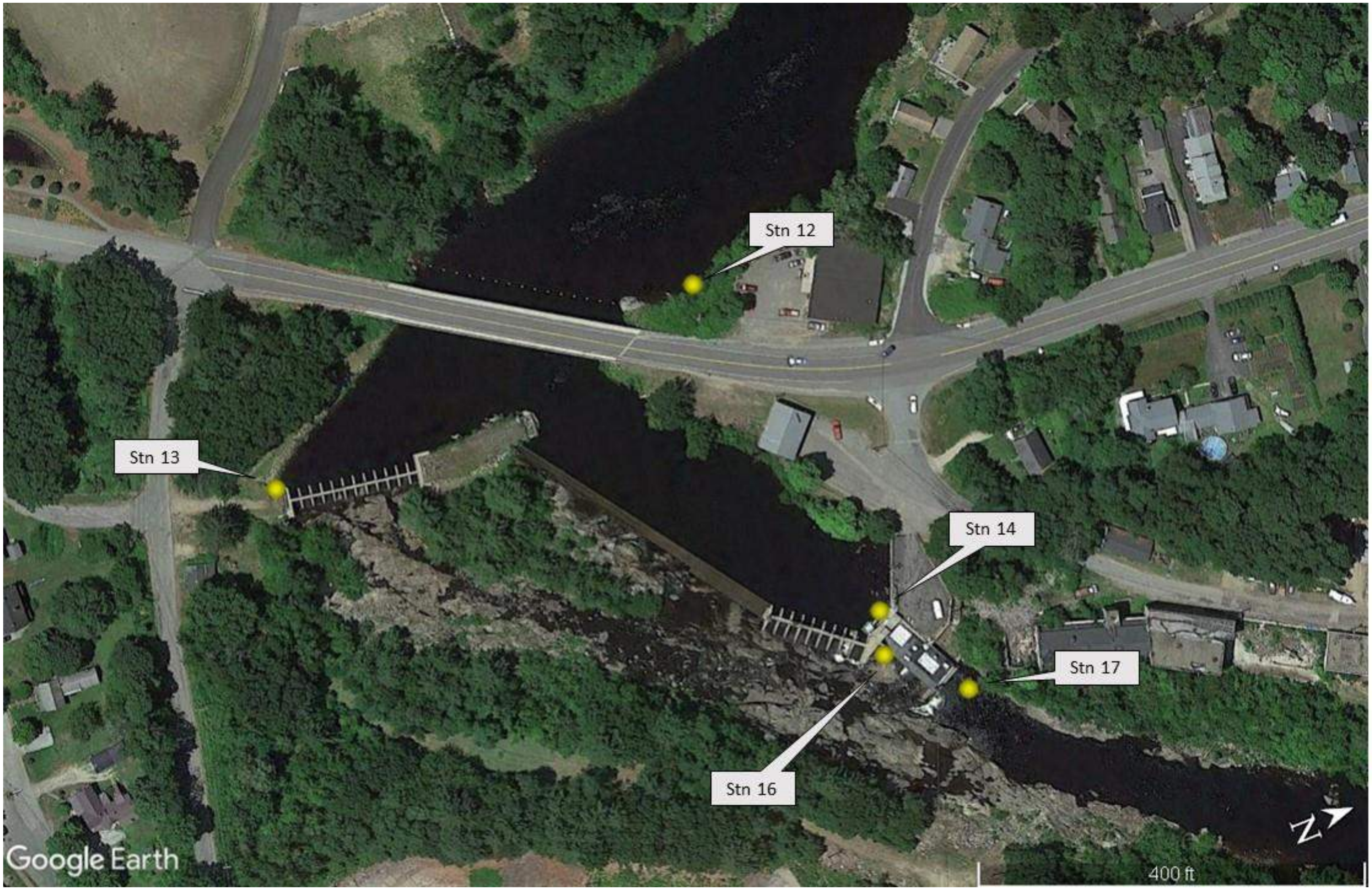


Figure 60–14. Final stationary receiver placement at PLF for the adult silver eel downstream passage study, October 12 – November 30, 2021.

64 Results

64.1 Contoocook River Conditions

The first group of radio-tagged adult eels was released into the Contoocook River on the evening of October 12, 2021 and monitoring for all individuals continued until November 30, 2021. Figure 5-1 presents the Contoocook River flow (prorated to Rolfe Canal) for the 2021 adult eel study period. Over the course of the 2021 fall monitoring period, inflow at Rolfe Canal ranged from 673 cfs to 5,581 cfs (P25 = 918 cfs; median = 1,669 cfs; P75 = 2,354 cfs).

Hourly temperature readings collected for the duration of the study period from the intake area at PUF are presented in Figure 5-1. River temperature over the course of the full monitoring period ranged between 2-17°C (median = 8°C). Mean daily water temperature on release dates (October 12, 20, and 26) were 16, 15, and 12°C, respectively.

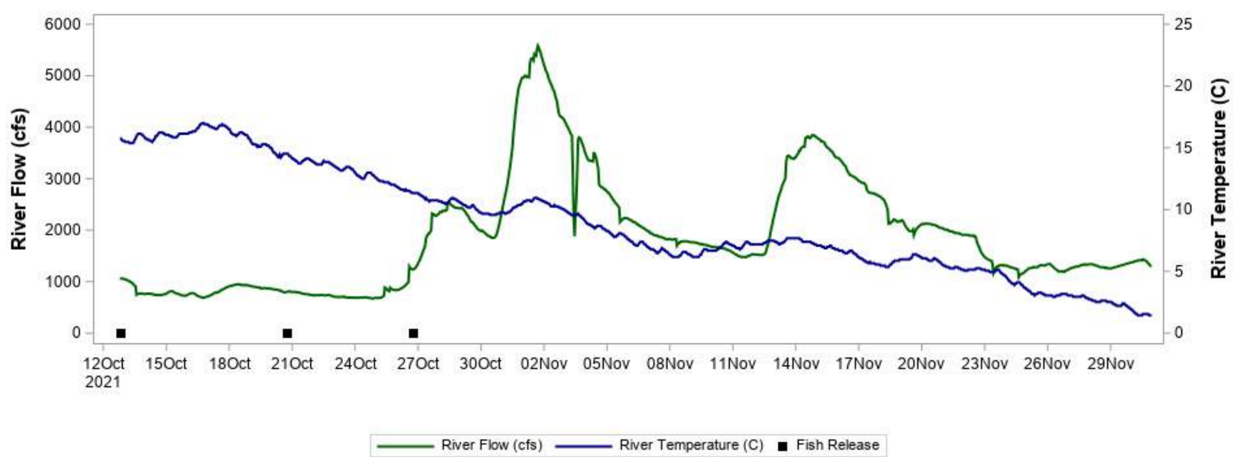


Figure 60–15. Contoocook River flow prorated for Rolfe Canal for the adult eel downstream passage study period, October 12 – November 30, 2021.

64.2 Briar Hydro Project Operations

64.2.1 Rolfe Canal

Total discharge reported for Rolfe Canal during the downstream adult eel passage study period from October 12 to November 30, 2021 is presented in Figure 5-2. The Rolfe Canal turbine was in operation for most of the study period with the exception of precipitation triggered nighttime outages on the nights of October 17-18, 18-19, 19-20, 25-26, 26-27, 27-28, 28-29, and 30-31, October 31-November 1, November 1-2, and 2-3. Nighttime shutdowns were terminated on November 4 when river temperature reached 10°C. Flow at York Dam ranged from the existing minimum flow of 100 cfs up to a high of 2,567 cfs on November 2.

64.2.2 Penacook Upper Falls

Total discharge reported for PUF during the downstream adult eel passage study (October 12 to November 30, 2021) is presented in Figure 5-3. The PUF turbine was in operation for most of the study period with the exception of precipitation triggered nighttime outages on the nights of October 17-18, 18-19, 19-20, 25-26, 26-27, 27-28, 28-29, and 30-31, October 31-November 1, November 1-2, and 2-3. Nighttime shutdowns were terminated on November 4 when river temperature reached 10°C. The PUF downstream bypass facility was closed for the duration of the adult eel study period. Spill flow at PUF ranged from zero up to a high of 5,530 cfs on November 1.

64.2.3 Penacook Lower Falls

Total discharge reported for PLF during the downstream adult eel study (October 12 to November 30, 2021) is presented in Figure 5-4. The PLF turbine was in operation for most of the study period with the exception of precipitation triggered nighttime outages on the nights of October 17-18, 18-19, 19-20, 25-26, 26-27, 27-28, 28-29, and 30-31, October 31-November 1, November 1-2, and 2-3. Nighttime shutdowns were terminated on November 4 when river temperature reached 10°C. The PLF downstream bypass facility was closed for the duration of the adult eel study period. Spill flow at PLF ranged from zero up to a high of 5,365 cfs on November 1.

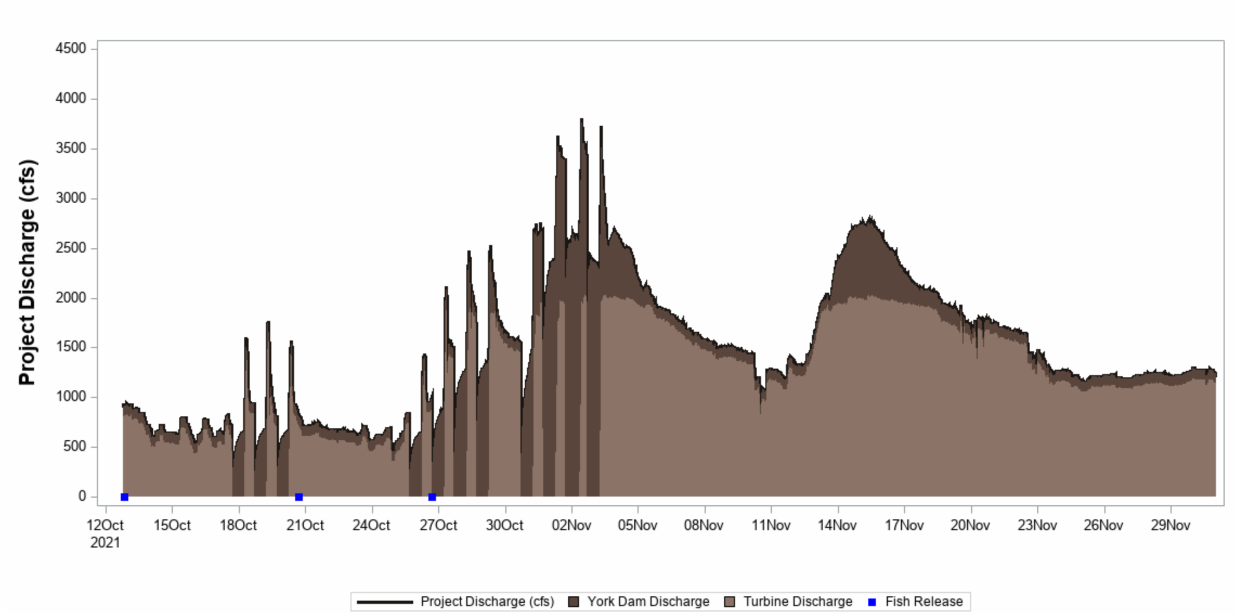


Figure 60–16. Distribution of Rolfe Canal discharge during the adult eel downstream passage study period, October 12 – November 30, 2021.

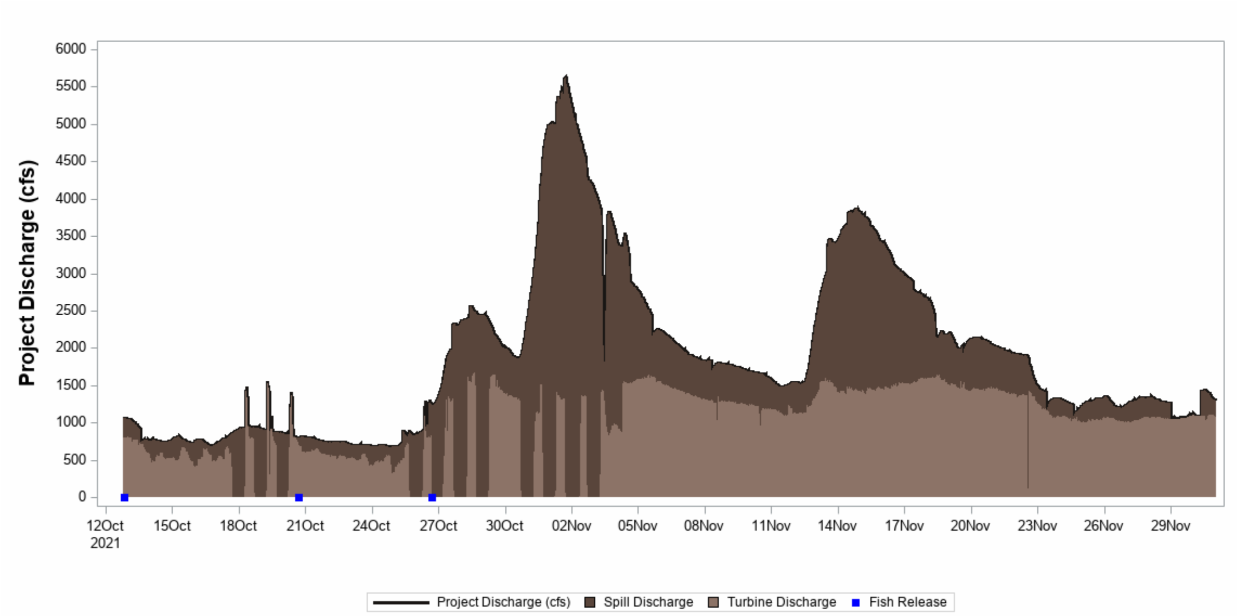


Figure 60–17. Distribution of PUF discharge during the adult eel downstream passage study period, October 12 – November 30, 2021.

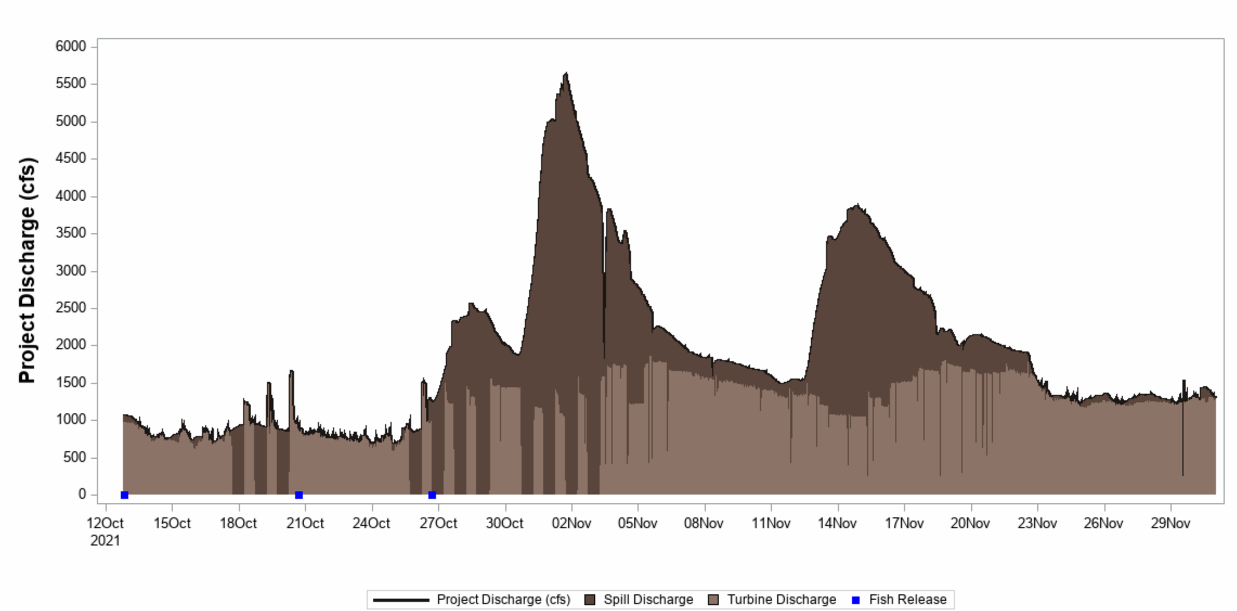


Figure 60–18. Distribution of PLF discharge during the adult eel downstream passage study period, October 12 – November 30, 2021.

64.3 Monitoring Station Functionality

Radio-tagged silver-phase eels were released into the Contoocook River beginning on the evening of October 12, 2021, and the study plan called for continuous monitoring at project locations through the month of November. Normandeau conducted weekly checks and downloads of all stationary receivers during that period. Station coverage was determined by a combination of portable beacon transmitter detections and observations reported by field personnel conducting the receiver checks and data downloads. Each of the 17 stationary monitors operated with no issues for the duration of the study period (Figure 5-5).

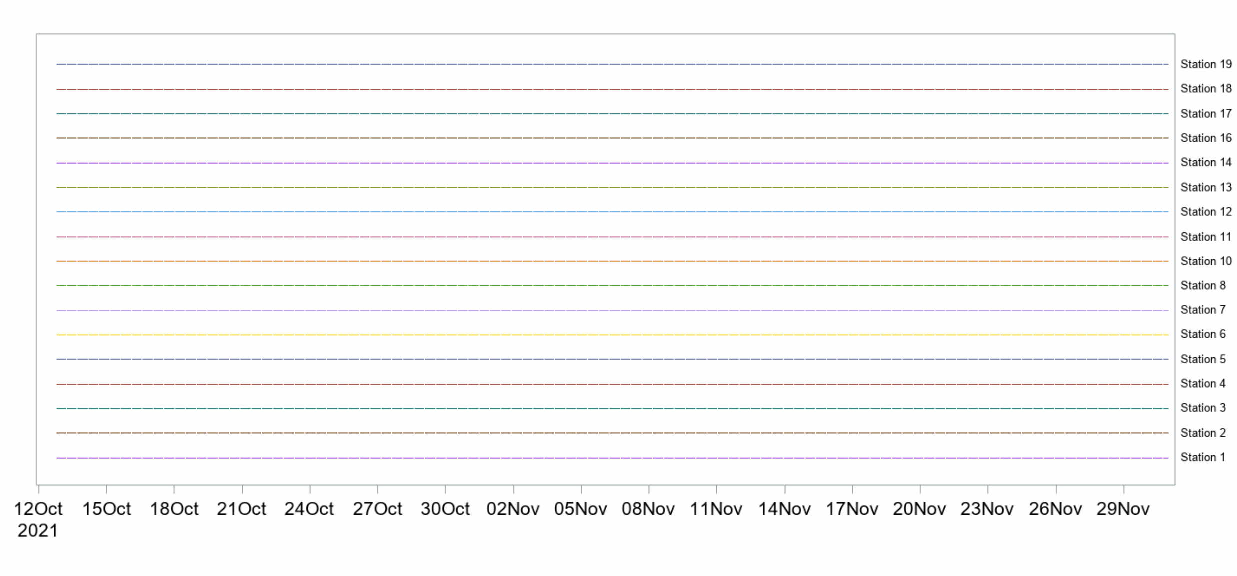


Figure 60–19. Monitoring station operational coverage for receiver stations at Rolfe Canal, PUF, and PLF during the adult eel downstream passage study period, October 12 – November 30, 2021.

64.4 Downstream Drift Assessment

A total of nine freshly dead, radio-tagged American eels were released into the tailrace from the back deck of the PLF powerhouse during the fall 2021 passage study. Freshly-dead eels were released intact and were assumed representative of an individual which suffered a strike or shear related malady causing mortality during passage. Three individuals were released in the tailrace on each date where a group of radio-tagged eels were released upstream of the Projects. Table 5-1 provides a summary of the release schedule and date-time of first detection for the drift eels to arrive at monitoring stations downstream of the Projects (i.e., Stations 18 and 19).

Of the nine freshly dead, radio-tagged eels released at PLF, three were eventually detected at Station 19 (located at Garvins Falls Dam, 13.3 miles downstream of the confluence of the Contoocook and Merrimack Rivers). The duration to drift from the PUF tailrace downstream to Garvins Falls ranged between 2.4 and 12.8 days. The remaining six eels did not drift as far downstream as Station 18, located approximately 7.0 miles downstream of the confluence of the Contoocook and Merrimack Rivers. Five of the remaining seven freshly dead eels were detected during manual tracking at locations nearer to PLF than the first downstream receiver (Station 18). Drift eels were detected in the vicinity of the confluence of the

Contoocook and Merrimack Rivers (n = 2) and at points 1.3, 3.8, and 5.5 miles downstream of the confluence.

Table 60–18. Summary of the downstream drift distance and duration for freshly dead, radio-tagged silver eels released in the PUF tailrace during the adult eel downstream passage study period, October 12 – November 30, 2021

Release Date	PLF Discharge (cfs)	ID Frequency	Total Length (mm)	Station 18 Arrival		Station 19 Arrival		Drift Duration	
				Date	Time	Date	Time	Hours	Days
12-Oct	1027	160 149.760	872	-	-	-	-	-	-
		161 149.760	777	-	-	-	-	-	-
		162 149.760	817	14-Oct	22:34:56	15-Oct	3:19:21	57.1	2.4
20-Oct	860	163 149.760	910	-	-	-	-	-	-
		164 149.760	685	23-Oct	21:06:13	2-Nov	13:27:36	307.6	12.8
		165 149.760	675	-	-	-	-	-	-
26-Oct	Offline*	166 149.760	873	-	-	-	-	-	-
		167 149.760	651	28-Oct	23:00:33	31-Oct	23:02:54	125.4	5.2
		168 149.760	708	-	-	-	-	-	-

*Released into area of spillway flow adjacent to powerhouse tailrace (due to station shutdown)

64.5 Eel Tagging and Releases

Eels were tagged and released upstream of the three Projects over three dates starting on October 12 and ending on October 26 (Table 5-2). A total of 105 live silver-phase American eels were radio-tagged and released upstream of Rolfe Canal, PUF, and PLF. Live radio-tagged eels were released approximately 10.0 miles upstream of Rolfe Canal (n = 63), in the tailrace channel of Rolfe Canal (n=21), and in the tailrace channel of PUF (n=21). Eels tagged and released at all locations upstream of the Projects ranged in length from 552 to 986 mm. Eye index values recorded for all upstream test eels (6.9-13.3) were within the reported range (6.0-13.5) for outmigrating eels. A listing of tagging and biocharacteristics information for eels released during 2021 is provided in Appendix A.

64.6 Project Arrival

Releases of radio-tagged adult eels were initiated upstream of Rolfe Canal, PUF, and PLF on October 12, 2021. The subset of radio-tagged eels released upstream of Rolfe Canal were placed in the Contoocook River at a point upstream of the Rolfe Canal Project impoundment. These individuals were initially detected at either Station 01 or 02 as they arrived at Rolfe Canal. The median duration of time for radio-tagged individuals to move through the Rolfe Canal impoundment and arrive at the Dam was 46.9 hours (P25 = 9.9 hours; P75 = 106.9 hours; Table 5-3). When examined by release date the duration of time for tagged eels to move through the Rolfe Canal impoundment appeared shorter for the October 12 and 26th release groups.

Figure 5-5 presents the distribution of arrival dates for radio-tagged individuals at each of the three Projects. Radio-tagged silver-phase eels were initially detected at Rolfe Canal starting on the date after the initial release until October 31 with the majority approaching Rolfe Canal the two dates after the first release (October 13-14) and between October 25-28. Approach timing at Rolfe Canal was determined based on the initial detection for each eel at Station 01 (i.e., the power canal headgate structure) or 02 (upstream of York Dam). Of the 63 radio-tagged adult eels which approached Rolfe Canal, 10% individuals were detected at both Stations 01 and 02, 33% were detected only at Station 01, and 57% were detected only at Station 02. The majority of individuals approaching Rolfe Canal from the first release group (i.e., October 12) were more likely to either pass downstream of Station 01 and approach the intakes (57% of eels) or approach the intakes prior to moving over to the region immediately upstream or York Dam (i.e., Station 02; 19% of eels). Eels from the second release group (i.e., October 20) had a slightly higher likelihood of initial detection upstream of York Dam (57%) than an initial detection in the vicinity of the intakes (43%). The majority of radio-tagged adult eels released on October 26 were initially detected at the York Dam receiver (Station 02; 19 of 21 individuals.

Approach timing at PUF and PLF was determined based on the initial detection for each eel at Stations 07 and 12, respectively. Radio-tagged silver-phase eels released upstream of Rolfe Canal or in the Rolfe Canal tailrace were initially detected at PUF on October 13 and October 12, respectively. Eels from both release locations continued to arrive at PUF through November 2 with arrivals peaking between October 26 and 28. A similar pattern was observed at PLF for eels released upstream of Rolfe Canal or in the Rolfe Canal or PUF tailraces. Initial detection of eels from each release location occurred within 1-2 days of release and individuals were detected arriving at PLF through November 1 with a peak in arrival of radio-tagged eels between October 25 and October 28, 2021.

64.7 Upstream Residence Duration

Outmigrating adult eels encountering Rolfe Canal can (1) pass through the gatehouse and enter the power canal where they can (a) pass downstream through the turbine or (b) move back upstream, (2) approach York Dam where they can (a) pass downstream by way of spill through the bypass reach, or (b) move back upstream, or (3) spend a period of time in both locations prior to eventual downstream passage. When all individuals are considered the median upstream residence duration (i.e., the duration of time from initial detection upstream of Rolfe Canal until downstream passage) was 0.3 hours (P25 = 0.1 hours; P75 = 0.8 hours; Table 5-4). When evaluated by behavior, the median upstream residence duration was shorter for individuals which either directly approached only the Rolfe Canal powerhouse (n = 21; median = 0.7 hours) or York Dam (n = 36; median = 0.1 hours) versus those which spent a portion of time upstream of both the powerhouse and York Dam (n = 6; median = 87.7 hours). Table 5-5 provides a summary of the calculated upstream residence duration values for radio-tagged adult eels at Rolfe Canal based on their initial date of detection. For dates with multiple arrivals, the median upstream residence duration appeared longer for dates earlier in the study period. River flow increased during the period from the onset of the study in early October through early November, likely facilitating shorter periods of residence upstream of the dam for eels arriving later in the period. For all adult eels approaching Rolfe Canal, 89% passed downstream within 24 hours of initial arrival and 90% within 72 hours of initial arrival.

Following their initial detection at PUF, the median upstream residence duration for radio-tagged eels was 0.3 hours (P25 = 0.1 hours; P75 = 1.6 hours; Table 5-6). The median duration did not differ greatly between adult eels originating upstream of Rolfe Canal (0.2 hours) or released directly into the Rolfe Canal tailrace (median = 0.4 hours). Table 5-7 summarizes upstream residence duration by the eventual route of passage at PUF. Similar to the observation between release locations there did not appear to be a difference between the median duration of residence upstream of PUF prior to downstream passage for adult eels which moved downstream through the turbine (0.2 hours; P25 = 0.1 hours; P75 = 1.6 hours) or made use of spill (0.3 hours; P25 = 0.1 hours; P75 = 1.4 hours). Upstream residence duration summarized by approach date at PUF is presented in Table 5-8. For all adult eels approaching PUF, 88% passed downstream within 24 hours of initial arrival and 91% within 72 hours of initial arrival.

Following arrival at PLF, the median upstream residence duration for radio-tagged adult eels was 1.0 hour (P25 = 0.4 hours; P75 = 8.8 hours; Table 5-9). The median duration of upstream residence appeared similar for adult eels among the three release locations ranging from a high of 2.1 hours for radio-tagged eels released into the tailrace at Rolfe Canal to a low of 1.0 hours for radio-tagged eels released immediately upstream of PLF in the tailrace at PUF. Table 5-10 summarizes upstream residence duration for adult eels by their eventual route of downstream passage at PLF. The median values for upstream residence duration between passage routes utilized during the 2021 study were 1.0 hours (P25 = 0.4; P75 = 4.5 hours) for eels passing PLF via spill and 1.2 hours (P25 = 0.3; P75 = 21.3 hours) for eels passing downstream through the PLF turbine unit. Upstream residence duration summarized by approach date at PLF is presented in Table 5-11. For all adult radio-tagged adult eels which approached PLF, 85% passed downstream within 24 hours of initial arrival and 97% within 72 hours of initial arrival.

64.8 Downstream Passage

A total of 63 radio-tagged adult silver eels were released upstream of Rolfe Canal during October, 2021. Of that total, all 63 were determined to have approached Rolfe Canal and were available for the evaluation of downstream passage route (Table 5-12). The majority (68%) of radio-tagged eels passed downstream via York Dam. Of the 43 individuals which passed downstream of Rolfe Canal via spill at York Dam, 40 of those passage events occurred during precipitation-triggered shut down events between October 18 and 31.

Table 5-13 summarizes downstream passage route utilization for adult American eels which approached PUF. A total of 84 radio-tagged adult eels were released at points upstream of PUF during October 2021. Of that total, 81 (96%) were determined to have approached the Project and were available for the evaluation of downstream passage route. The majority (75%) of radio-tagged silver-phase eels passed downstream of PUF via spill. Approximately 22% of radio-tagged eels passed downstream of PUF using the turbine unit. Of the 61 radio-tagged eels which passed downstream at PUF via spill, 56 of those passage events occurred during precipitation-triggered shut down events between October 18 and November 1.

Of the 105 radio-tagged adult eels released at locations upstream of PLF, 90% were determined to have approached the Project and were available for the evaluation of downstream passage route (Table 5-14). Downstream passage of adult eels at PLF occurred via the Project turbine (33% of all events) and spill (61% of all events). A limited number of individuals (n = 6) were detected on the approach at PLF but were determined to have not successfully passed downstream during the study period. These individuals may succumb to injuries during previous passage at Rolfe Canal and/or PUF. Of the 57 radio-tagged eels which passed downstream at PLF via spill, 56 of those passage events occurred during precipitation-triggered shut down events between October 25 and November 1.

Radio-tagged adult American eels were observed passing downstream of Rolfe Canal between October 13 and 31 with the majority of downstream passage events occurring on or after October 21 (Figure 5-7). At PUF, downstream passage of adult eels was recorded between October 12 and November 1 when individuals from all upstream release locations were considered. The first downstream passage event at PLF was recorded on October 12. Downstream passage of radio-tagged adult eels at PLF peaked during a three-day period from October 26 to October 28 and the final event was observed on November 2, 2021. Figure 5-8 presents the timing distribution of downstream passage events for radio-tagged adult eels at the Projects. Downstream passage events for eels at the three Projects occurred primarily during the nighttime hours (defined as 1800 to 0600 hours). Observations of downstream passage outside of the nighttime hours occurred for 3% of eels at Rolfe Canal, 2% of eels at PUF, and 9% of eels at PLF.

64.9 River Transit

64.9.1 Project Reach Transit

Radio-tagged adult eels were released at one of three locations within the Project areas (upstream of Rolfe Canal, downstream of Rolfe Canal, or downstream of PUF). Table 5-15 summarizes the overall duration of time from release until passage downstream at the lowermost Project (PLF). The median duration of time for radio-tagged eels released upstream of Rolfe Canal to pass downstream of all three Projects was 143.1 hours (6.0 days; P25 = 2.0 days; P75 = 10.2 days). Radio-tagged silver-phase eels released in the tailrace at Rolfe Canal (median = 30.1 hours) and in the tailrace at PUF (median = 4.3 hours) were shorter than that observed for fish released upstream of Rolfe Canal. Radio-tagged eels released upstream of Rolfe Canal had to transit 10 miles of the Contoocook River as well as navigate downstream of Rolfe Canal, adding to their overall time upstream of the three Projects.

64.9.2 Downstream Reach Transit

Two monitoring stations were installed downstream of PLF for the purpose of detecting radio-tagged eels following outmigration from the Contoocook River during the fall passage assessment. Those receivers were located approximately 7.0 (Station 18) and 13.3 (Monitoring Station 19) miles downstream of the confluence of the Contoocook and Merrimack Rivers. Quartile transit times for adult eels (1) following downstream passage at PLF to Station 18, (2) from Station 18 to Station 19, and (3) for the full downstream river section are presented in Table 5-16. The median transit time durations for all tagged eels moving downstream of PLF were 44.7, 23.0, and 73.1 hours for the three downstream reaches, respectively. The median values and quartile ranges were comparable among the three release locations (upstream of Rolfe Canal, Rolfe Canal tailrace, and PUF tailrace) when the time from downstream passage at PLF until arrival at Garvins Falls Dam is considered.

Table 60–19. Summary of release and biological information (total length and sex) for silver-phase adult eels radio-tagged and released upstream of the Briar Hydro Projects (October 2021)

Silver-Phase Eels	Release Location			
	US Rolfe Canal	US PUF	US PLF	All
Release Dates (Oct)	12, 20, 26	12, 20, 26	12, 20, 26	12, 20, 26
Number Released	63	21	21	105
Min. Total Length (mm)	552	690	660	552
Max. Total Length (mm)	970	986	895	986
Mean Total Length (mm)	811	804	781	804
Eye Index (range)	6.9-13.3	8.3-11.7	7.3-12.6	6.9-13.3

Table 60–20. Minimum, maximum and quartile values for Rolfe Canal impoundment duration (by release date) during the adult eel downstream passage study period, October 12 – November 30, 2021

American Eel - Rolfe Canal Impoundment Duration (hrs)					
Release Date	Minimum	P25	P50 (Median)	P75	Maximum
12-Oct	6.5	8.5	29.6	102.5	384.2
20-Oct	8.5	56.7	123.6	143.7	243.5
26-Oct	7.2	7.8	23.9	48.4	103.2
All	**6.5**	**9.9**	**46.9**	**106.9**	**384.2**

Table 60–21. Minimum, maximum and quartile values for Rolfe Canal upstream residence duration (by project behavior) during the adult eel downstream passage study period, October 12 – November 30, 2021

American Eel - Upstream Residence Duration (hrs)					
Rolfe Approach	Minimum	P25	P50 (Median)	P75	Maximum
Powerhouse & York Dam	43.9	73.1	87.7	97.8	281.8
Powerhouse	0.3	0.7	0.7	0.9	114.2
York Dam	<0.1	0.1	0.1	0.2	3.1
All	**<0.1**	**0.1**	**0.3**	**0.8**	**281.8**

Table 60–22. Minimum, maximum and quartile values for Rolfe Canal upstream residence duration (by approach date) during the adult eel downstream passage study period, October 12 – November 30, 2021

American Eel – Upstream Residence Duration (hrs)				
Approach Date	n	P25	P50 (Median)	P75
13-Oct	9	0.6	0.7	0.8
14-Oct	5	3.1	18.7	97.8
15-Oct	1	73.1	73.1	73.1
17-Oct	2	43.9	79.1	114.2
18-Oct	1	0.2	0.2	0.2
21-Oct	3	0.6	0.7	0.7
22-Oct	2	0.8	45.3	89.8
23-Oct	3	0.7	0.8	0.9
24-Oct	1	0.9	0.9	0.9
25-Oct	4	0.1	0.3	43.0
26-Oct	6	0.1	0.2	0.4
27-Oct	14	0.1	0.1	0.1
28-Oct	9	0.1	0.1	0.1
29-Oct	1	0.4	0.4	0.4
30-Oct	1	0.1	0.1	0.1
31-Oct	1	0.1	0.1	0.1
All	**63**	**0.1**	**0.3**	**0.8**

Table 60–23. Minimum, maximum and quartile values for PUF upstream residence duration (by release location) during the adult eel downstream passage study period, October 12 – November 30, 2021

American Eel - Upstream Residence Duration (hrs)					
Release Location	Minimum	P25	P50 (Median)	P75	Maximum
Upstream Rolfe Canal	0.1	0.1	0.2	1.4	335.2
Rolfe Canal Tailrace	0.1	0.1	0.4	1.6	314.4
All	**0.1**	**0.1**	**0.3**	**1.6**	**335.2**

Table 60–24. Minimum, maximum and quartile values for PUF upstream residence duration (by passage route) during the adult eel downstream passage study period, October 12 – November 30, 2021

American Eel - Upstream Residence Duration (hrs)					
Passage Route	Minimum	P25	P50 (Median)	P75	Maximum
Spill	0.1	0.1	0.3	1.4	335.2
Turbine	0.1	0.1	0.2	1.6	92.7
All	**0.1**	**0.1**	**0.3**	**1.6**	**335.2**

Table 60–25. Minimum, maximum and quartile values for PUF upstream residence duration (by approach date) during the adult eel downstream passage study period, October 12 – November 30, 2021

American Eel - Upstream Residence Duration (hrs)				
Approach Date	n	P25	P50 (Median)	P75
12-Oct	6	0.2	0.5	0.9
13-Oct	3	0.1	0.5	36.8
14-Oct	4	0.1	131.9	264.5
15-Oct	2	268.8	302.0	335.2
18-Oct	3	0.1	0.1	0.1
19-Oct	1	140.1	140.1	140.1
20-Oct	4	0.4	1.1	4.7
21-Oct	4	2.9	36.1	79.6
24-Oct	1	0.1	0.1	0.1
25-Oct	5	0.2	0.5	1.6
26-Oct	12	0.1	0.2	0.5
27-Oct	16	0.1	0.2	0.7
28-Oct	11	0.1	0.2	1.0
29-Oct	2	0.3	1.1	1.8
30-Oct	1	0.1	0.1	0.1
31-Oct	2	0.1	10.4	20.8
All	**77**	**0.1**	**0.3**	**1.6**

Table 60–26. Minimum, maximum and quartile values for PLF upstream residence duration (by release location) during the adult eel downstream passage study period, October 12 – November 30, 2021

American Eel - Upstream Residence Duration (hrs)					
Release Location	Minimum	P25	P50 (Median)	P75	Maximum
Upstream Rolfe Canal	0.1	0.3	1.2	18.5	193.1
Rolfe Canal Tailrace	0.2	0.4	2.1	9.1	82.7
PUF Tailrace	0.2	0.4	1.0	1.3	48.3
All	**0.1**	**0.4**	**1.0**	**8.8**	**193.1**

Table 60–27. Minimum, maximum and quartile values for PLF upstream residence duration (by passage route) during the adult eel downstream passage study period, October 12 – November 30, 2021

American Eel - Upstream Residence Duration (hrs)					
Passage Route	Minimum	P25	P50 (Median)	P75	Maximum

Spill	0.2	0.4	1.0	4.5	193.1
Turbine	0.1	0.3	1.2	21.3	192.5
All	**0.1**	**0.4**	**1.0**	**8.8**	**193.1**

Table 60–28. Minimum, maximum and quartile values for PLF upstream residence duration (by approach date) during the adult eel downstream passage study period, October 12 – November 30, 2021

American Eel - Upstream Residence Duration (hrs)				
Approach Date	n	P25	P50 (Median)	P75
12-Oct	5	0.3	0.4	0.4
13-Oct	1	0.7	0.7	0.7
14-Oct	2	0.2	33.0	65.8
17-Oct	2	0.2	17.1	33.9
18-Oct	3	18.9	192.5	193.1
20-Oct	6	0.3	1.0	8.0
21-Oct	2	0.1	0.6	1.1
22-Oct	1	82.7	82.7	82.7
24-Oct	2	0.3	0.8	1.2
25-Oct	8	5.5	14.5	33.1
26-Oct	22	0.4	1.1	3.9
27-Oct	15	0.5	1.7	14.6
28-Oct	12	0.4	0.5	0.8
29-Oct	1	0.3	0.3	0.3
30-Oct	3	0.1	0.2	0.4
31-Oct	2	0.2	24.4	48.5
1-Nov	1	1.4	1.4	1.4
All	**88**	**0.4**	**1.0**	**8.8**

Table 60–29. Downstream passage route selection for radio-tagged silver-phase American eels released upstream of Rolfe Canal during the fall downstream passage study period, October 12 – November 30, 2021

American Eel - Rolfe Canal Downstream Passage Route					
Release Date	Release Location	No. Released	No. Detected	Turbine	York Dam
12-Oct	US Rolfe	21	21	12	9
20-Oct	US Rolfe	21	21	7	14
26-Oct	US Rolfe	21	21	1	20
All		**63**	**63**	**20**	**43**
% of Total Detected				**32%**	**68%**

Table 60–30. Downstream passage route selection for radio-tagged silver-phase American eels released upstream of PUF during the fall downstream passage study period, October 12 – November 30, 2021

American Eel - PUF Downstream Passage Route						
Release Date	Release Location	No. Released	No. Detected	Turbine	Spill	No Pass
12-Oct	US Rolfe	21	20	6	14	0
	DS Rolfe	7	7	4	3	0
20-Oct	US Rolfe	21	19	4	13	2
	DS Rolfe	7	7	3	4	0
26-Oct	US Rolfe	21	21	1	20	0
	DS Rolfe	7	7	0	7	0
All		**84**	**81**	**18**	**61**	**2**
% of Total Detected				**22%**	**75%**	**3%**

Table 60–31. Downstream passage route selection for radio-tagged silver-phase American eels released upstream of PLF during the fall downstream passage study period, October 12 – November 30, 2021

American Eel - PLF Downstream Passage Route						
Release Date	Release Location	No. Released	No. Detected	Turbine	Spill	No Pass
12-Oct	US Rolfe	21	16	5	8	3
	DS Rolfe	7	6	4	1	1
	DS PUF	7	7	6	1	0
20-Oct	US Rolfe	21	17	3	13	1
	DS Rolfe	7	6	4	2	0
	DS PUF	7	7	6	1	0
26-Oct	US Rolfe	21	21	3	17	1
	DS Rolfe	7	7	0	7	0
	DS PUF	7	7	0	7	0
All		**105**	**94**	**31**	**57**	**6**
% of Total Detected				**33%**	**61%**	**6%**

Table 60–32. Quartile values for the project reach transit duration (by release location) observed for radio-tagged adult eels released during the fall downstream passage study period, October 12 – November 30, 2021

American Eel - Project Reach Transit (hrs)			
Release Location	P25	P50 (Median)	P75
Upstream Rolfe Canal	48.4	143.1	244.6
Rolfe Canal Tailrace	3.6	30.1	152.8
PUF Tailrace	2.6	4.3	31.0
All	**7.8**	**50.9**	**162.9**

Table 60–33. Quartile values for the downstream transit duration (by release location) observed for radio-tagged adult eels released during the fall downstream passage study period, October 12 – November 30, 2021

American Eel - Downstream Transit (hrs)				
River Reach	Release Location	P25	P50 (Median)	P75
PLF to Station 18	Upstream Rolfe Canal	14.5	39.3	68.7
	Rolfe Canal Tailrace	15.6	68.5	99.2
	PUF Tailrace	22.1	47.9	146.6
	All	*14.5*	*44.7*	*88.0*
Station 18 to Station 19	Upstream Rolfe Canal	15.7	24.5	45.4
	Rolfe Canal Tailrace	4.4	17.6	24.8
	PUF Tailrace	4.6	24.2	40.5
	All	*4.8*	*23.0*	*42.2*
PLF to Station 19	Upstream Rolfe Canal	43.1	71.0	97.4
	Rolfe Canal Tailrace	30.0	95.6	122.4
	PUF Tailrace	48.2	97.4	169.1
	All	*42.1*	*73.1*	*107.7*

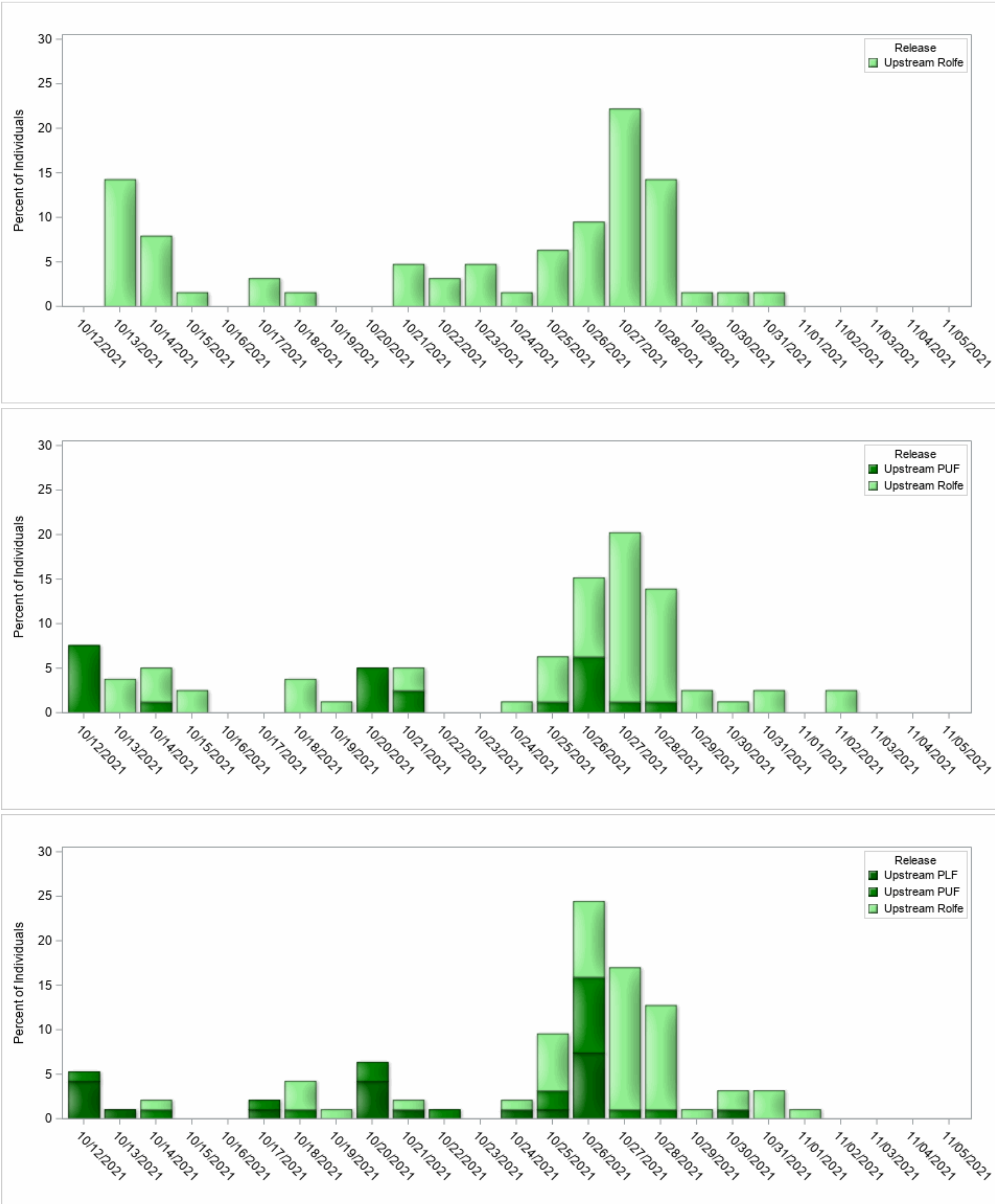


Figure 60–20. Approach date (by release location) for radio-tagged adult eels at Rolfe Canal (upper), PUF (middle), and PLF (lower) during the downstream passage study period, October 12 – November 30, 2021.

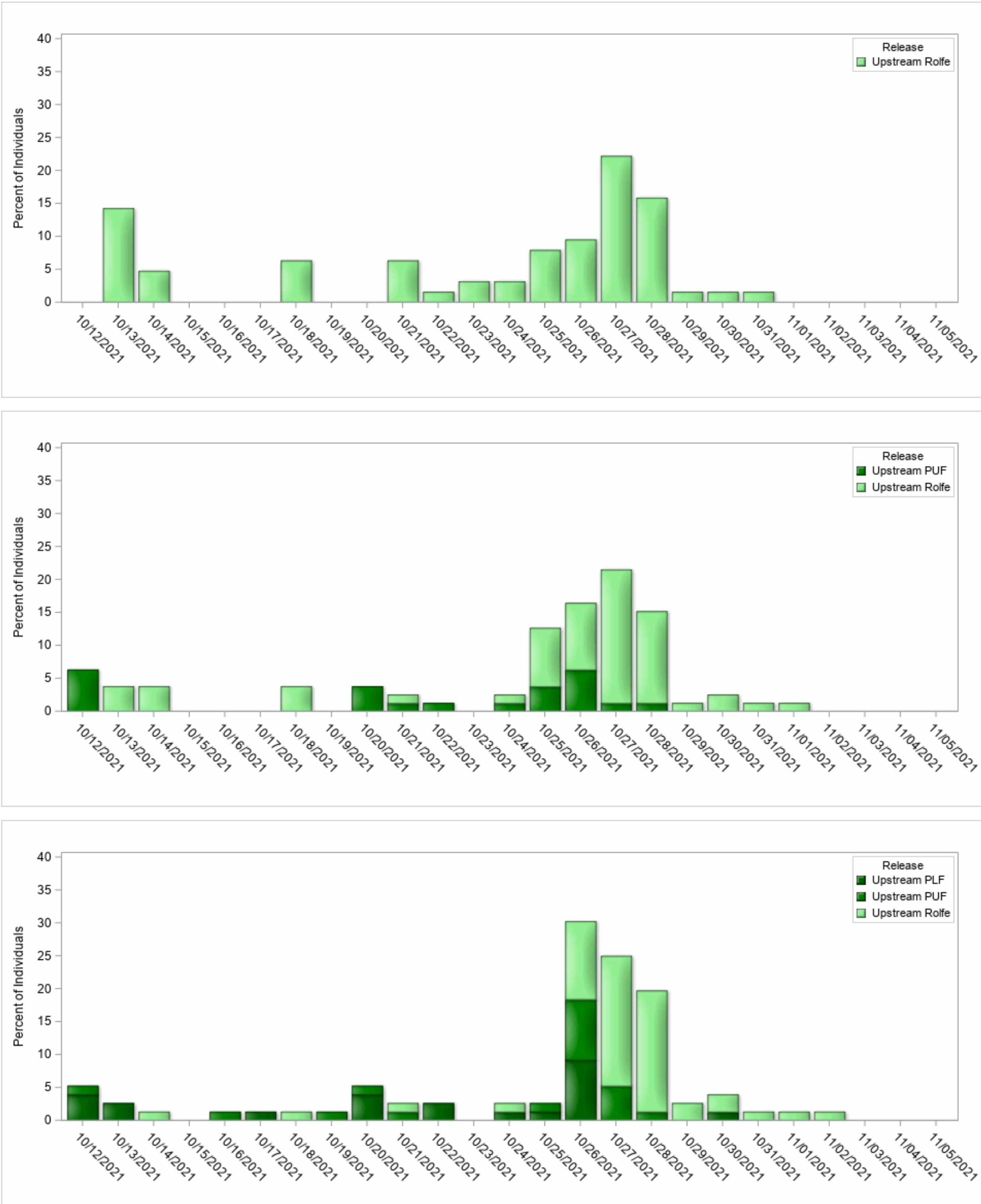
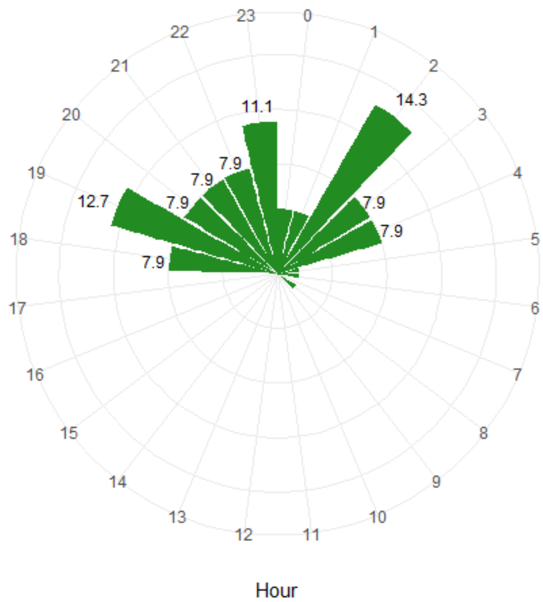


Figure 60–21. Downstream passage date (by release location) for radio-tagged adult eels at Rolfe Canal (upper), PUF (middle), and PLF (lower) during the downstream passage study period, October 12 – November 30, 2021.



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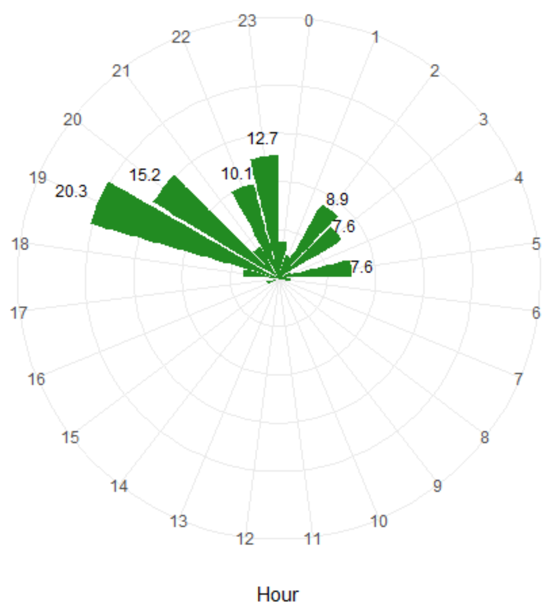

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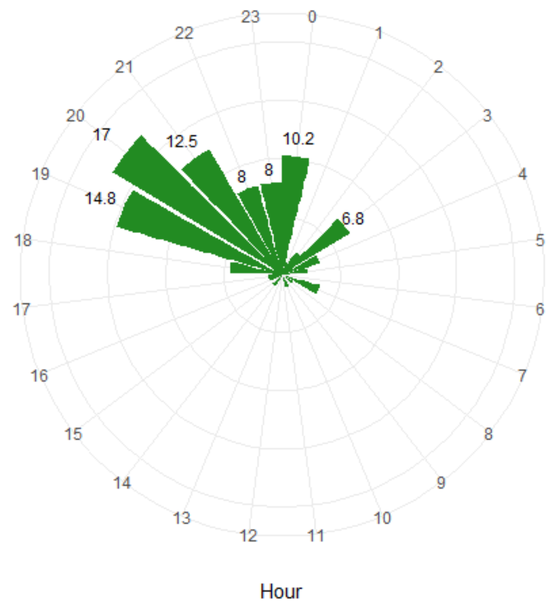


Figure 60–22. Downstream passage timing for radio-tagged adult eels at Rolfe Canal (upper left), PUF (upper right), and PLF (lower) during the downstream passage study period, October 12 to November 30, 2021.

64.10 Passage Survival

Cumulative Project Survival

The CJS model *Phi(t)p(t)* provided the best fit for the observed mark-recapture data associated with downstream movements of all radio-tagged adult American eels approaching and passing at Rolfe Canal, PUF, and PLF during the 2021 study period (Table 5-17). The detection efficiency for telemetry receivers recording passage of adult eels at locations incorporated into the CJS model ranged from 1.0 to 0.98. The reach-specific survival estimates for the Project reach are presented in Table 5-18. Project-specific estimates of passage survival were 92.1% (95% CI = 82.3-96.7%) for Rolfe Canal, 84.8% (95% CI = 75.1-91.2%) for PUF, and 90.9% (95% CI = 82.9-95.4%) for PLF. Downstream passage success for adult eels at the full set of Projects was calculated as the joint probability of the three reach-specific survival estimates which encompassed the riverine section from arrival at Rolfe Canal downstream to a point approximately 7.0 miles below the confluence of the Contoocook and Merrimack Rivers. This resulted in a cumulative estimated downstream passage survival for silver-phase American eels of 71.0% (95% CI = 60.8-80.4%).

Route-Specific Survival

Radio-tagged adult eels approached and passed downstream at Rolfe Canal, PUF, and PLF via either spill or entrainment through Project turbines (Section 5.8). Individual CJS models were run for the subset of individuals utilizing each passage route at the three Projects (Table 5-19). Survival rates for adult eels passing downstream through project turbines ranged from 50.0% to 75.0%. Survival rates for silver-phase eels passing downstream via spill ranged from 95.1% to 100%.

Nighttime Shutdown Effectiveness

Briar Hydro currently shuts down turbine operation at Rolfe Canal, PUF, and PLF for a three-night period following a quarter inch of rain to facilitate downstream eel passage. To evaluate the effectiveness of these trigger-based shutdown events, paired CJS models were developed for the subset of radio-tagged eels passing downstream at each Project when the turbine unit was online and generating versus periods of intentional turbine shutdown. Downstream passage survival for adult eels passing at Rolfe Canal, PUF, and PLF under the trigger-based shutdown condition was 21.7%, 39.9%, and 21.6% higher than that observed under the normal operating condition (Table 5-20).

Drift-Adjusted Cumulative Survival

As described in Section 4.5.2, an adjusted estimate for cumulative downstream passage survival of adult American eels at the Projects was generated following the manual modification of the individual encounter histories for test eels with downstream travel times to Station 18 in excess of the average drift duration observed for three of the nine freshly dead radio-tagged eels released downstream of PLF (Figure 5-9). Based on this assumption, nine test eels were adjusted because they exhibited downstream transit durations from PLF to Garvins Falls Dam longer than 163.4 hours (n = 9; range = 169.1-459.4 hours).

When informed using the adjusted encounter histories, the CJS model *Phi(t)p(t)* provided the best fit for the observed mark-recapture data associated with eels approaching and passing at Rolfe Canal, PUF, and

PLF during the 2021 study period (Table 5-21). This resulted in an adjusted cumulative estimate of downstream passage survival for silver-phase American eels passing Rolfe Canal, PUF, and PLF of 63.0% (95% CI = 52.4-73.2%).

Table 60–34. CJS model selection criteria for survival of radio-tagged adult eels released during the fall downstream passage study period, October 12 to November 30, 2021

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
Phi(t) p(t)	174.71	0.00	0.81	1.00	4	4.00
Phi(t) p(.)	177.57	2.86	0.19	0.24	4	6.87
Phi(.) p(t)	198.01	23.30	0.00	0.00	2	31.38
Phi(.) p(.)	201.01	26.30	0.00	0.00	2	34.38

Table 60–35. Reach-specific survival probability estimates (*phi)*, standard errors, and 95% confidence intervals for for radio-tagged adult eels released during the fall downstream passage study period, October 12 to November 30, 2021

River Reach	*Phi*	SE	95% CI	
Release to Rolfe Canal	0.967	0.023	0.876	0.992
Rolfe Canal to PUF	0.914	0.037	0.809	0.964
PUF to PLF	0.918	0.032	0.829	0.963
PLF to Station 18	0.759	0.046	0.658	0.837

Table 60–36. Project and passage route-specific survival probability estimates (*phi)* and 95% confidence intervals for radio-tagged adult eels released during the fall downstream passage study period, October 12 to November 30, 2021

Project	Route	n	*Phi*	95% CI	
Rolfe Canal	Turbine	20	0.750	0.522	0.892
	York Dam (spill)	43	1.000	-	-
PUF	Turbine	18	0.500	0.284	0.716
	Spill	61	0.951	0.858	0.984
PLF	Turbine	31	0.742	0.563	0.865
	Spill	57	1.000	-	-

Table 60–37. Project operational condition survival probability estimates (*phi)* and 95% confidence intervals for radio-tagged adult eels released during the fall downstream passage study period, October 12 to November 30, 2021

Project	Project Condition	n	*Phi*	95% CI	
Rolfe Canal	Generation	23	0.783	0.572	0.907
	Shutdown	40	1.000	-	-
PUF	Generation	23	0.565	0.363	0.748
	Shutdown	56	0.964	0.868	0.991
PLF	Generation	30	0.767	0.585	0.884
	Shutdown	58	0.983	0.888	0.998

Table 60–38. CJS model selection criteria for the survival of radio-tagged adult eels released during the fall downstream passage study period and adjusted to reflect the duration of drift for freshly dead individuals to the lowermost stationary receiver, October 12 to November 30, 2021

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
Phi(t) p(t)	207.24	0.00	0.81	1.00	4	11.86
Phi(t) p(.)	210.19	2.95	0.19	0.23	4	14.81
Phi(.) p(t)	239.99	32.76	0.00	0.00	2	48.69
Phi(.) p(.)	243.36	36.12	0.00	0.00	2	52.06

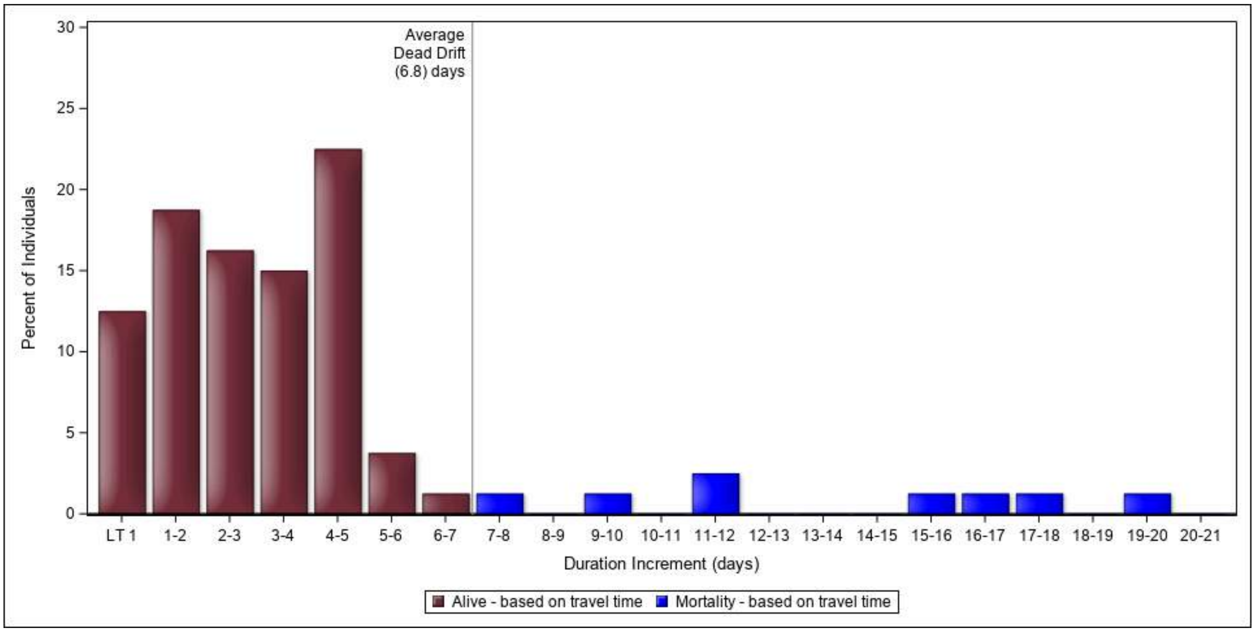


Figure 60–23. Distribution of travel time for upstream test eels in the reach from downstream of PLF to Garvins Falls. Vertical line represents average drift duration of freshly dead eel for same river reach. Subset of eels to left of line assumed alive based on "short" transit time and subset of eels to right of line assumed as mortalities based on "long" transit times.

64.11 Manual Tracking

Downstream passage timing, route selection, and survival were informed using the stationary telemetry data collected at the seventeen receiver locations detailed in Section 4.2. Based on those data downstream passage occurred from the date of initial eel release until November 2, 2021 when the final passage event was recorded at PLF. Manual tracking information was collected by both Normandeau and New Hampshire Fish and Game Department (NHFGD) staff on a number of dates starting on November 15 and is summarized in Table 5-22. Of the 105 live eels released at points upstream of Rolfe Canal, PUF, or PLF, 34 individuals were detected. The majority of individuals (24 of 34) were detected at points within the project area (i.e., the reach between Rolfe Canal and Station 18) and their final position as determined by manual tracking was in agreement with that identified by the stationary receiver array. Of the 34 manually located eels, seven were detected in the Merrimack River at points downstream of the lowermost stationary receiver (i.e., Station 19 at Garvins Falls Dam). All seven of those had been detected at Station 19 prior to manual detection in the Merrimack River downstream of the monitored reach for this study. Three individuals identified by NHFGD staff during manual tracking effort in mid-November did not line up with information collected from the stationary monitoring array. Two individuals determined to have approached but not passed downstream of PLF were reported as detected from a point in the Merrimack River downstream of the confluence with the Contoocook but upstream of Station 18. Regardless of passage status at PLF these two eels were considered as Project mortalities in all models presented in Section 5.10. An additional eel was reported by NHFGD staff as present in the tailrace at PLF in mid-November. However, this eel was clearly detected at Stations 18 and 19 soon after downstream passage at Rolfe Canal (spill at York Dam), PUF (spill) and PLF (spill). For the purposes of this assessment that individual was considered as alive following passage at the Projects based on timely detection at the downstream stations.

Table 60–39. Summary of relative location for manual tracking observations (as documented on or after November 15) and final recorded stationary receiver location for silver-phase eels originally released upstream of Rolfe Canal, PUF, or PLF during October 2021

Frequency	ID	Manual Location	Stationary Location
149.440	70	PUF Tailrace	DS PUF
149.440	71	Confluence Contoocook & Merrimack	DS PLF
149.440	72	PUF Tailrace	DS PUF
149.440	73	Upstream PLF	US PLF
149.440	75	PLF Forebay	US PLF
149.440	76	Upper Falls	DS PUF
149.440	79	DS Hooksett	Garvins
149.440	80	DS Hooksett	Garvins
149.440	81	Between PUF/PLF	US PLF
149.440	82	Vicinity of PLF	US PLF
149.440	84	Rolfe Canal tailrace	DS Rolfe Canal
149.440	85	Vicinity of PLF	DS PLF
149.440	95	Vicinity of PUF	DS PUF
149.440	102	Confluence Contoocook & Merrimack	DS PLF
149.440	107	Rolfe Canal tailrace	DS Rolfe Canal
149.440	110	Merrimack River near Sewalls Falls	DS PLF
149.440	117	PUF Forebay	US PUF
149.440	121	DS Hooksett	Garvins
149.440	124	DS Hooksett	Garvins
149.480	52	PUF Tailrace	DS PUF
149.480	56	PUF Forebay	US PUF
149.480	64	DS Hooksett	Garvins
149.480	85	PLF Tailrace	DS PLF
149.480	86	DS Hooksett	Garvins
149.480	87	Confluence Contoocook & Merrimack	DS PLF
149.480	88	Confluence Contoocook & Merrimack	DS PLF
149.480	91	PLF Tailrace	DS PLF
149.480	95	PUF Tailrace	DS PUF
149.480	97	PUF Forebay	US PUF
149.480	98	Merrimack River near Sewalls Falls	US PLF
149.480	119	Merrimack River near Sewalls Falls	DS PLF
149.480	135	Vicinity of PLF	Garvins
149.480	138	DS Hooksett	Garvins
149.480	142	Merrimack River near Sewalls Falls	US PLF

Note: Frequency Information presented in this table for eel IDs 85, 95, and 119 corresponds to individual tags released upstream of the Project. Manual tracking notes provided by NHFGD listed alternate frequencies for these eels. However, since their reported locations lined up with last known positions based on stationary information those frequencies were corrected for reporting purposes.

65 Summary

An evaluation of downstream passage success for adult silver-phase American eels was conducted in support of the FERC relicensing of the Rolfe Canal, PUF, and PLF Projects. Passage effectiveness was evaluated using radio-telemetry during the 2021 fall passage season (October-November). Contoocook River inflow ranged between 673 to 5,581 cfs, with flows greater than ~2,000 cfs in excess of the station capacity at each of the three Projects. Project turbines were offline due to precipitation triggered nighttime outages on the nights of October 17-18, 18-19, 19-20, 25-26, 26-27, 27-28, 28-29, and 30-31, October 31-November 1, November 1-2, and 2-3 at all three Projects. Briar Hydro did not operate the downstream bypasses at PUF or PLF but did provide at least 100 cfs of flow at York Dam to meet minimum flow requirements for the downstream bypass reach (during non-spill periods).

A total of 105 adult eels were radio-tagged and released on one of three dates during October (October 12, 20, and 26). Of that total, 63 were tagged and released upstream of Rolfe Canal, 21 were tagged and released in the Rolfe Canal tailrace, and 21 were tagged and released in the PUF tailrace. Outmigration of radio-tagged adult eels was observed over a range of dates from October 12 to November 2 with peaks in downstream passage activity occurring after October 21 at Rolfe Canal, October 25-28 at PUF, and October 26-28 at PLF. The median duration of time for radio-tagged eels released upstream of Rolfe Canal to move from the release location and pass downstream of all three projects was 6.0 days. When examined among projects, the median upstream residence duration for adult eels originating at the release location upstream of all three Projects was 0.3 hours at Rolfe Canal, 0.2 hours at PUF, and 1.2 hours at PLF.

The majority of downstream passage at Rolfe Canal occurred at York Dam. The majority of those passage events occurred during precipitation-triggered shut down events between October 18 and 31. Approximately a quarter of radio-tagged eels passed downstream of PUF using the turbine unit. However, the majority of radio-tagged eels which passed downstream at PUF did so via spill with the majority of those occurring during precipitation-triggered shut down events between October 18 and November 1. Downstream passage of adult eels at PLF occurred via the Project turbine (33% of all events) and spill (61% of all events). Most of the spill passage events occurred during precipitation-triggered shut down events between October 25 and November 1.

Project-specific estimates of passage survival were 92.1% at Rolfe Canal, 84.8% at PUF, and 90.9% at PLF. Cumulative estimated downstream passage survival for adult eels passing all three projects was estimated at 71.0%. These estimates of downstream passage survival for adult eels at the Briar Projects includes any background mortality (i.e., natural mortality) for the species in the downstream reach, along with any tagging-related mortalities or tag regurgitations. As a result, these estimates should be viewed as a minimum estimate of total project survival (i.e., due solely to project effects) for adult eels at these locations. In addition to cumulative survival both route-specific and operational scenario rates were evaluated. Survival rates for adult eels passing downstream through project turbines ranged from 50.0% to 75.0%. Survival rates for silver-phase eels passing downstream via spill ranged from 95.1% to 100%.

Downstream passage survival for adult eels passing at Rolfe Canal, PUF, and PLF under the trigger-based shutdown condition was 21.7%, 39.9%, and 21.6% higher than that observed under the normal operating condition.

• Variances from Approved Study Plan

This study was conducted following the methodology described in the RSP which was finalized in March 2021 and filed with FERC on July 6, 2021

- ## Appendices

Appendix A. Adult American Eel – Tagging Information.

Frequency	ID	Eel Type	Length (mm)	Eye Index	Release Date	Release Location
149.760	160	Drift	872	9.0	10/12/2021	PLF Tailrace
149.760	161	Drift	777	10.8	10/12/2021	PLF Tailrace
149.760	162	Drift	817	9.3	10/12/2021	PLF Tailrace
149.440	69	Live	730	8.0	10/12/2021	PUF Tailrace
149.480	53	Live	785	9.6	10/12/2021	PUF Tailrace
149.480	54	Live	875	7.6	10/12/2021	PUF Tailrace
149.480	58	Live	710	8.5	10/12/2021	PUF Tailrace
149.480	60	Live	838	7.3	10/12/2021	PUF Tailrace
149.480	62	Live	830	8.4	10/12/2021	PUF Tailrace
149.480	66	Live	725	8.7	10/12/2021	PUF Tailrace
149.440	76	Live	716	9.4	10/12/2021	Rolfe Tailrace
149.440	79	Live	865	10.2	10/12/2021	Rolfe Tailrace
149.440	80	Live	767	11.4	10/12/2021	Rolfe Tailrace
149.440	82	Live	820	9.0	10/12/2021	Rolfe Tailrace
149.480	55	Live	885	10.2	10/12/2021	Rolfe Tailrace
149.480	57	Live	710	8.6	10/12/2021	Rolfe Tailrace
149.480	59	Live	750	8.4	10/12/2021	Rolfe Tailrace
149.440	68	Live	750	8.3	10/12/2021	US Rolfe
149.440	70	Live	868	7.7	10/12/2021	US Rolfe
149.440	71	Live	685	6.9	10/12/2021	US Rolfe
149.440	72	Live	735	8.9	10/12/2021	US Rolfe
149.440	73	Live	807	7.6	10/12/2021	US Rolfe
149.440	74	Live	794	7.8	10/12/2021	US Rolfe
149.440	75	Live	800	8.1	10/12/2021	US Rolfe
149.440	77	Live	760	10.1	10/12/2021	US Rolfe
149.440	78	Live	935	9.8	10/12/2021	US Rolfe
149.440	81	Live	867	9.3	10/12/2021	US Rolfe
149.440	83	Live	925	10.7	10/12/2021	US Rolfe
149.440	84	Live	867	9.4	10/12/2021	US Rolfe
149.480	50	Live	760	9.4	10/12/2021	US Rolfe
149.480	51	Live	890	11.8	10/12/2021	US Rolfe
149.480	52	Live	865	9.9	10/12/2021	US Rolfe
149.480	56	Live	875	8.7	10/12/2021	US Rolfe
149.480	61	Live	847	8.0	10/12/2021	US Rolfe
149.480	63	Live	790	10.2	10/12/2021	US Rolfe
149.480	64	Live	878	10.2	10/12/2021	US Rolfe

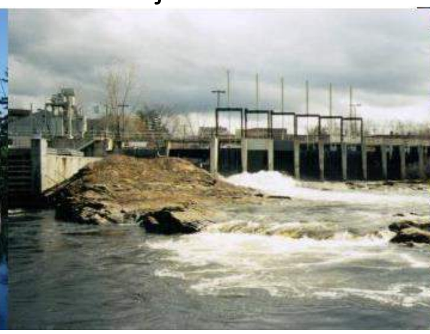
Frequency	ID	Eel Type	Length (mm)	Eye Index	Release Date	Release Location
149.480	65	Live	552	11.6	10/12/2021	US Rolfe
149.480	67	Live	755	9.4	10/12/2021	US Rolfe
149.760	163	Drift	910	7.8	10/20/2021	PLF Tailrace
149.760	164	Drift	685	9.9	10/20/2021	PLF Tailrace
149.760	165	Drift	675	8.7	10/20/2021	PLF Tailrace
149.480	85	Live	796	10.5	10/20/2021	PUF Tailrace
149.480	86	Live	818	11.1	10/20/2021	PUF Tailrace
149.480	87	Live	810	11.1	10/20/2021	PUF Tailrace
149.480	88	Live	865	9.7	10/20/2021	PUF Tailrace
149.480	89	Live	660	11.4	10/20/2021	PUF Tailrace
149.480	90	Live	775	9.4	10/20/2021	PUF Tailrace
149.480	91	Live	895	10.8	10/20/2021	PUF Tailrace
149.440	102	Live	702	11.7	10/20/2021	Rolfe Tailrace
149.440	103	Live	808	9.1	10/20/2021	Rolfe Tailrace
149.440	104	Live	750	8.3	10/20/2021	Rolfe Tailrace
149.480	92	Live	986	9.5	10/20/2021	Rolfe Tailrace
149.480	93	Live	690	11.2	10/20/2021	Rolfe Tailrace
149.480	94	Live	863	10.2	10/20/2021	Rolfe Tailrace
149.480	95	Live	900	10.7	10/20/2021	Rolfe Tailrace
149.440	105	Live	838	10.8	10/20/2021	US Rolfe
149.440	106	Live	752	8.0	10/20/2021	US Rolfe
149.440	107	Live	808	10.5	10/20/2021	US Rolfe
149.440	108	Live	815	9.4	10/20/2021	US Rolfe
149.440	109	Live	837	9.9	10/20/2021	US Rolfe
149.440	110	Live	708	10.3	10/20/2021	US Rolfe
149.440	111	Live	674	9.2	10/20/2021	US Rolfe
149.440	112	Live	765	8.9	10/20/2021	US Rolfe
149.440	113	Live	857	10.3	10/20/2021	US Rolfe
149.440	114	Live	795	10.4	10/20/2021	US Rolfe
149.440	115	Live	750	10.1	10/20/2021	US Rolfe
149.440	116	Live	673	9.3	10/20/2021	US Rolfe
149.440	117	Live	790	7.8	10/20/2021	US Rolfe
149.440	118	Live	937	8.5	10/20/2021	US Rolfe
149.440	119	Live	890	8.8	10/20/2021	US Rolfe
149.480	96	Live	810	10.1	10/20/2021	US Rolfe
149.480	97	Live	800	10.2	10/20/2021	US Rolfe
149.480	98	Live	876	9.3	10/20/2021	US Rolfe
149.480	99	Live	900	12.8	10/20/2021	US Rolfe
149.480	100	Live	740	11.0	10/20/2021	US Rolfe
149.480	101	Live	774	9.4	10/20/2021	US Rolfe
149.760	166	Drift	873	10.0	10/26/2021	PLF Tailrace
149.760	167	Drift	651	9.1	10/26/2021	PLF Tailrace

Frequency	ID	Eel Type	Length (mm)	Eye Index	Release Date	Release Location
149.760	168	Drift	708	9.7	10/26/2021	PLF Tailrace
149.440	132	Live	882	10.2	10/26/2021	PUF Tailrace
149.440	133	Live	761	12.6	10/26/2021	PUF Tailrace
149.440	134	Live	740	10.4	10/26/2021	PUF Tailrace
149.480	151	Live	691	8.3	10/26/2021	PUF Tailrace
149.480	152	Live	755	9.9	10/26/2021	PUF Tailrace
149.480	153	Live	718	7.8	10/26/2021	PUF Tailrace
149.480	154	Live	732	7.3	10/26/2021	PUF Tailrace
149.440	129	Live	776	8.5	10/26/2021	Rolfe Tailrace
149.440	130	Live	734	9.7	10/26/2021	Rolfe Tailrace
149.440	131	Live	907	9.8	10/26/2021	Rolfe Tailrace
149.480	147	Live	839	10.5	10/26/2021	Rolfe Tailrace
149.480	148	Live	753	9.4	10/26/2021	Rolfe Tailrace
149.480	149	Live	776	11.4	10/26/2021	Rolfe Tailrace
149.480	150	Live	896	9.8	10/26/2021	Rolfe Tailrace
149.440	120	Live	821	11.3	10/26/2021	US Rolfe
149.440	121	Live	832	12.1	10/26/2021	US Rolfe
149.440	122	Live	697	11.2	10/26/2021	US Rolfe
149.440	123	Live	895	11.6	10/26/2021	US Rolfe
149.440	124	Live	970	10.7	10/26/2021	US Rolfe
149.440	125	Live	805	13.3	10/26/2021	US Rolfe
149.440	126	Live	903	10.5	10/26/2021	US Rolfe
149.440	127	Live	818	11.2	10/26/2021	US Rolfe
149.440	128	Live	910	11.7	10/26/2021	US Rolfe
149.480	135	Live	784	10.2	10/26/2021	US Rolfe
149.480	136	Live	742	11.3	10/26/2021	US Rolfe
149.480	137	Live	782	10.9	10/26/2021	US Rolfe
149.480	138	Live	723	11.8	10/26/2021	US Rolfe
149.480	139	Live	840	11.3	10/26/2021	US Rolfe
149.480	140	Live	906	10.2	10/26/2021	US Rolfe
149.480	141	Live	887	11.9	10/26/2021	US Rolfe
149.480	142	Live	723	13.2	10/26/2021	US Rolfe
149.480	143	Live	870	12.2	10/26/2021	US Rolfe
149.480	144	Live	885	10.6	10/26/2021	US Rolfe
149.480	145	Live	797	11.8	10/26/2021	US Rolfe
149.480	146	Live	740	10.9	10/26/2021	US Rolfe

American Eel Upstream Passage Study

Briar Hydro Associates

Penacook Lower Falls	Penacook Upper Falls	Rolfe Canal
Hydroelectric Project	Hydroelectric Project	Hydroelectric Project
Project No. 3342	Project No. 6689	Project No. 3240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March 2022

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9. Introduction and Background

Briar Hydro Associates (Briar Hydro or Licensee) is in the process of relicensing the Rolfe Canal (FERC No. 3240), Penacook Upper Falls (PUF; FERC No. 6689), and Penacook Lower Falls (PLF; FERC No. 3342) Hydroelectric Projects (Project; collectively, Projects) with the Federal Energy Regulatory Commission (FERC or Commission). The Projects are located on the Contoocook River in Boscawen and Concord, New Hampshire. PLF sits at river mile 0 of the Contoocook River, above the confluence with the Merrimack River. The Upper Penacook and Rolfe Canal Projects are located upstream at river miles 1.0 and 2.0, respectively.

The current Project licenses were issued by the Federal Energy Regulatory Commission (FERC or Commission) in accordance with the Commission's delegated authority under the Federal Power Act on November 17, 1982 (PLF) and December 5, 1984 (Rolfe Canal and PUF). By FERC order the original April 17, 2018 license expiration for PLF was extended from October 31, 2022 to November 30, 2024 and matching the expiration for the Rolfe Canal and PUF Projects. Briar Hydro is pursuing a new license for the three Projects through the Commission's Traditional Licensing Process (TLP).

In response to requests provided by the resource agencies as part of the TLP process, Briar Hydro prepared a Preliminary Study Plan (PSP). The intent of the PSP was that the goals, methodology, scope, and schedule would be refined in consultation with interested stakeholders, as necessary. Briar Hydro distributed a copy of the PSP to representatives from the representatives from the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFGD) and the New Hampshire Department of Environmental Services (NHDES) on December 14, 2020. Following receipt and consultation related to comments on the PSP, Briar Hydro prepared a Revised Study Plan (RSP) which was finalized in March 2021 and filed with FERC on July 6, 2021. This report describes the American Eel Upstream Passage Study conducted in support of obtaining a new license for the Project.

10. Goals and Objectives

The goal of this study was to provide baseline data on the presence of American eels attempting to move upstream of Rolfe Canal, PUF, and PLF and the locations where they congregate while attempting upstream passage. The specific objective of this study was to evaluate juvenile eel presence/abundance at selected locations at the Rolfe Canal, and PLF Projects to identify an appropriate location for a future volitional upstream passage facility.

11. Study Area

The study area for this evaluation encompassed the PLF bypass reach (i.e., diversion and auxiliary dam areas), PUF eel lift and trap, and the areas downstream of the Rolfe Canal Project York Dam and Rolfe Canal headgate dam (Figure 3-1).

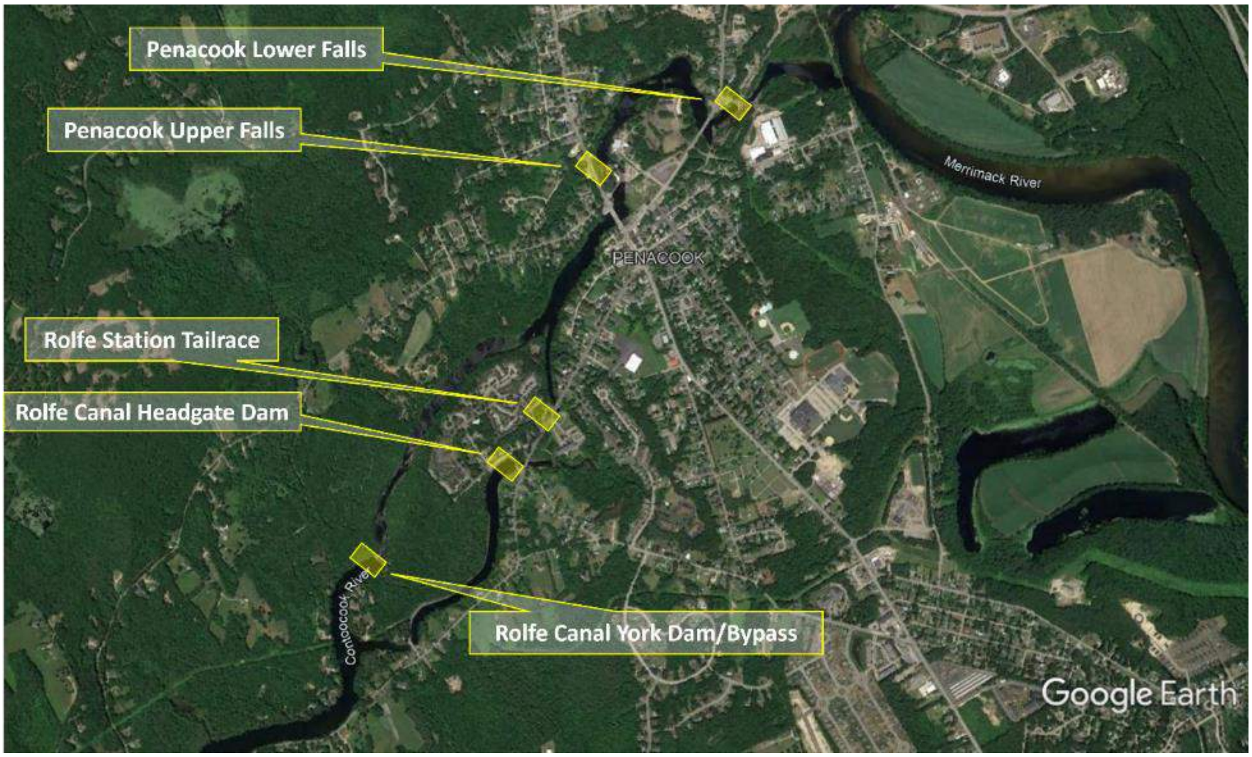


Figure 60-24. Briar Hydro Project facilities on the Penacook River, NH 2021.

12. Methodology

65.1 Night Surveys and Electrofishing

A total of four visual nighttime surveys to document the spatial distribution of juvenile eels downstream of the Rolfe Canal and PLF Projects were conducted over a period of eight weeks starting in late-June and terminating in early-August. Nighttime surveys focused on areas at the PLF diversion and auxiliary dam and Rolfe Canal Project York Dam and headgate structure where eels would be likely to congregate while attempting upstream passage (i.e. areas of leakage at the base of spillways, gates etc.). General search locations for the Rolfe Canal and PLF Projects are provided in Figures 4-1 through 4-3. Areas at Rolfe Canal include immediately downstream of York Dam, the Rolfe Canal tailrace and historic canal discharge area and the head of the historic canal. Areas at PLF include the shoreline immediately downstream of the powerhouse and areas immediately downstream of the diversion, auxiliary, and main spillways. Data collected from each survey area included observations of eels (i.e., presence, absence, numbers, and estimated sizes), time and date of observation, field notes on weather conditions, and moon phase. Locations with observations were geo-referenced and notes on Project operations were recorded during each survey.

To supplement the visual nighttime surveys and to provide a more robust estimate of the relative abundance of juvenile American eels downstream of the Rolfe Canal and PLF Projects, each survey area identified in Figures 4-1 through 4-3 was electrofished twice during the eight- week survey period. Like data recorded during the visual nighttime surveys, data collection during electrofish sampling included the presence/absence of juvenile eels, count and duration of sampling (i.e., seconds of sample time to allow for calculation of a catch per unit of effort). Juvenile eel length of captured individuals was estimated to the nearest size class (i.e., 0 to 6 inches, 6 to 12 inches, greater than 12 inches) and GPS coordinates were recorded for locations where individuals were collected.

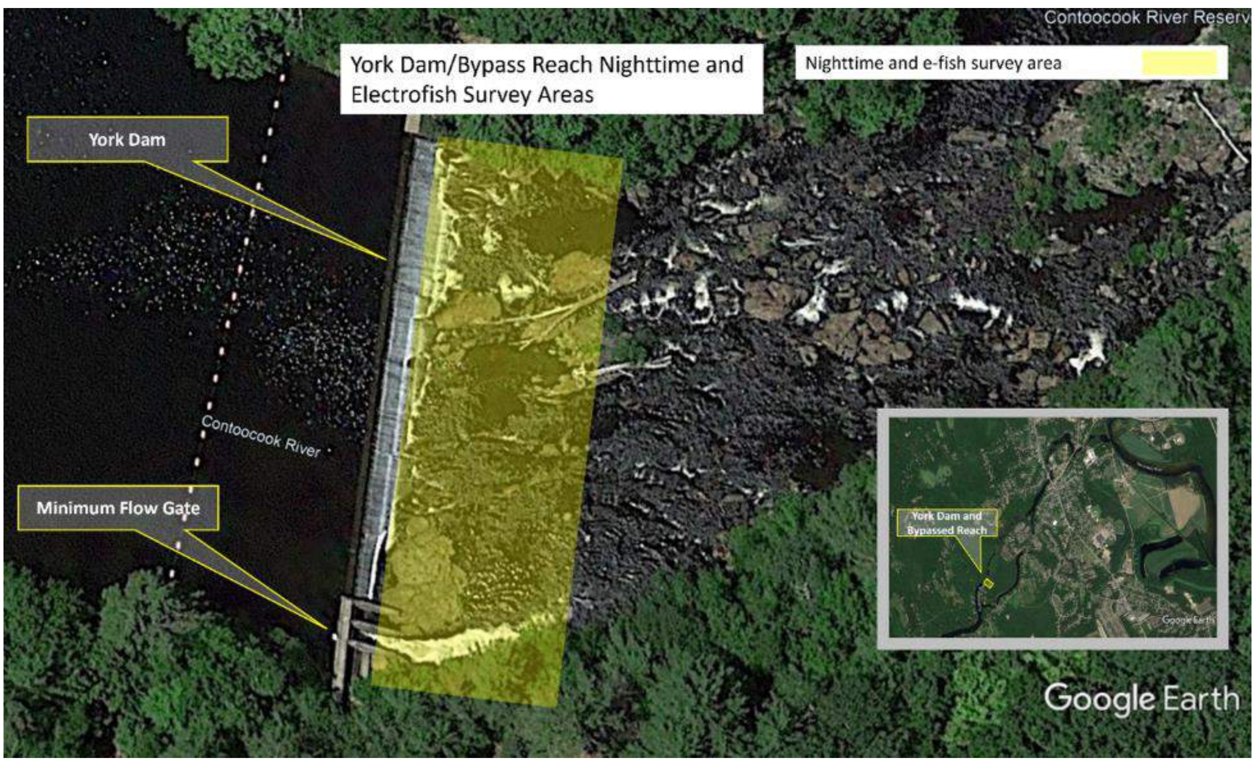


Figure 60-25. Visual nighttime survey and electrofishing locations at York Dam (bypassed reach), June-August 2021.

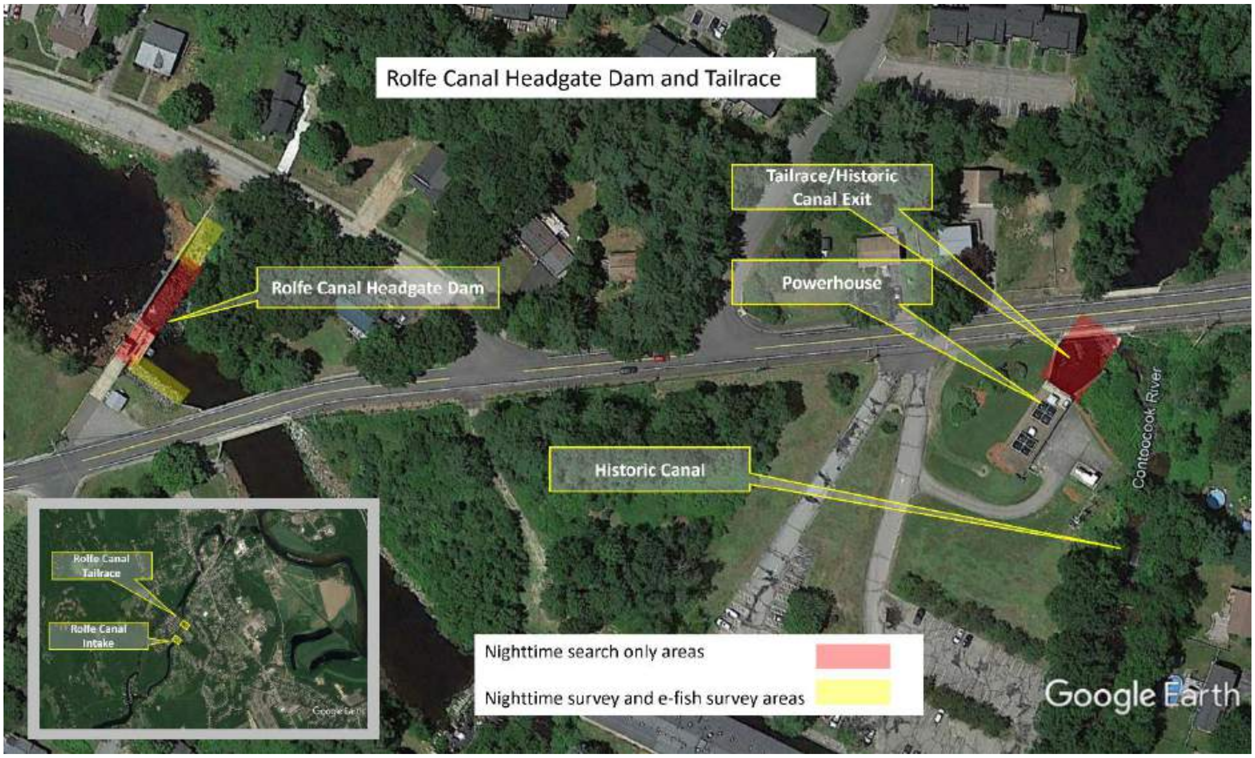


Figure 60-26. Visual nighttime survey and electrofishing locations at Rolfe Canal headgate dam and powerhouse, June-August 2021.

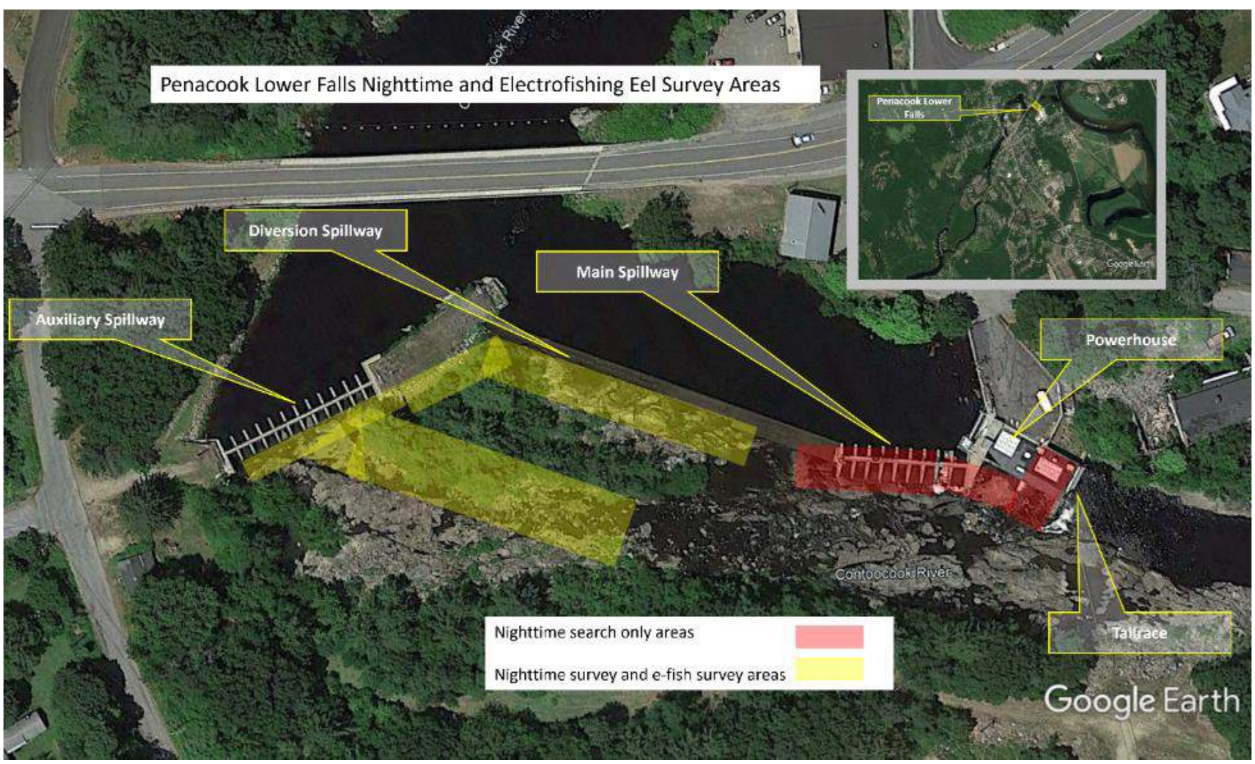


Figure 60-27. Visual nighttime survey and electrofishing locations at PLF, June-August 2021.

65.2 Mark Recapture at PUF

Briar Hydro conducted a mark-recapture study to evaluate effectiveness of the existing permanent upstream juvenile eel passage facility installed at PUF. Prior to the onset of the mark-recapture study Briar Hydro operations staff collected juvenile eels captured in the PUF eel lift hopper and maintained them in a holding tank supplied with recirculating Contoocook River water. Following the initial collection period, 100 juvenile eels were marked using Visual Elastomer (VIE) tags in July and August. To mark these individuals, eels were lightly anesthetized to allow for safe handling. The nearest size class (i.e., 0 to 6 inches, 6 to 12 inches, greater than 12 inches) of each individual was recorded and a colored VIE mark was inserted at the base of the ventral fin margin (Figure 4-4).

Separate VIE colors were used to identify eels marked during the July tagging (yellow) and August tagging (red) events. Following the first release, Normandeau biologists examined all eels collected in the hopper by Briar Hydro Operations staff over a two-week period for VIE marks. At the completion of the two-week monitoring period, a second collection was initiated. When a substantial group was captured and held at the PUF, the second tagging event was completed. Eel catch was examined for one month after the second tagging cohort was released and VIE tag marks were recorded.

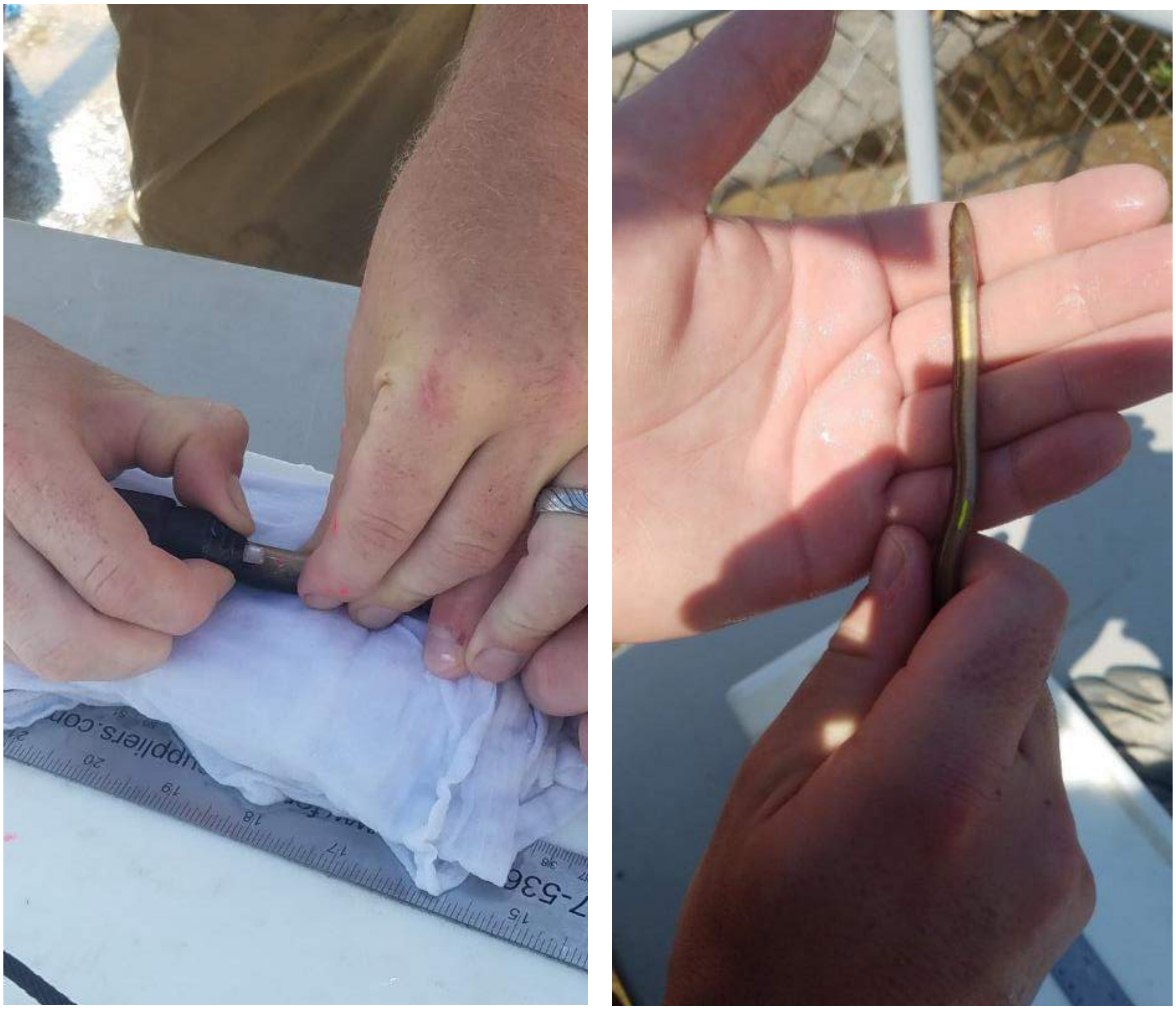


Figure 60-28. VIE tagging juvenile American eel at Penacook Upper Falls, 2021.

13. Results

65.3 Nighttime Eel Surveys

Four nighttime surveys were conducted at the York Dam bypass reach, downstream of the Rolfe Canal headgate dam, and below PLF starting on June 22 and ending on August 12, 2022 (Figures 5-1 through 5-3). Environmental and operations data at the time of these sampling events are presented in Tables 5-1 to 5-3. Eels observed during nighttime surveys are presented by location, date, and size class in Table 5-4. Survey summaries showing the georeferenced location of eels observed for each sample date are provided in Appendix A. Overall, lunar illumination ranged from a low of 1.7% on August 12 to a high of 96% on June 22. Contoocook River water temperature ranged from 20°C on June 7 to 27.5°C on June 30.

Weather during the nighttime eel surveys ranged from overcast to rain with hot/humid conditions. A survey originally scheduled for July 14 was canceled due to high water creating unsafe survey conditions below both Projects. This survey was rescheduled and conducted on August 12.

65.3.1 York Dam Bypass Reach

Table 5-1 presents the available operations and environmental conditions during nighttime surveys at the York Dam bypass reach. Generation flow reported for the Rolfe Canal powerhouse during nighttime surveys ranged from 0 to 1,957 cfs and bypass flows at York Dam ranged from 93 to 195 cfs. Spill in the form of minor overtopping was present during all the surveys, wetting the surface of the dam and decreasing visibility at the dam toe.

Surveys at the York Dam bypass reach focused on the dam toe and the area adjacent to the minimum bypass gate. Surveys were described as either 'near' or 'distant' viewing. Near viewing indicates that surveyors were able to safely access and view the areas of eels from a close distance (~ 10 feet or less). Distance viewing was used for areas that could not be safely accessed (i.e. due to deep water, inaccessible areas, height, etc.). Due to low inflow, the Rolfe Canal turbine unit was offline during the first survey on June 22 and June 30 which increased flow through the York Dam bypass reach. This created higher spill over the York Dam, decreasing safe access and the ability for field personnel to move beyond the minimum flow gate (Figure 5-4). During this survey, areas were observed closely in the vicinity of the minimum flow gate but were viewed from a distance beyond there (Figure 5-1). Access to the lower section (river left) was also limited and viewed from a distance on June 30. On the remaining two dates, surveyors were able to closely survey most of the dam toe and areas around the minimum flow gate. Visual summaries of the approximate areas surveyed by date are provided in Appendix A.

Three eels were observed at the York Dam bypass reach during surveys in 2022 (Table 5-4). All eels were identified during the final survey on August 12 and were distributed across the spillway. The largest eel (12+ inches) was observed next to the minimum bypass flow gate while the two other eels (6-12 inch size class) were observed along the middle and river left portion of the dam (Appendix A).

65.3.2 Rolfe Canal Intake Structure, Tailrace, and Historic Canal Discharge

Table 5-2 presents the available operations and environmental conditions during nighttime surveys at the Rolfe Canal headgate dam, tailrace, and historic canal discharge sites. Available operations and environmental data during surveys at the Rolfe Canal Project shows generation flows ranging from 0 to

1,923 cfs. Spill in the form of minor overtopping did not occur at the intake structure although some leakage did wet the surface of the dam.

Surveys at the Rolfe Canal Project structures were limited due to access. Figure 5-2 shows areas that were viewed close and from a distance. Areas around the intake structure that could be accessed by shore were viewed close, but areas of deep water necessitated distance viewing along the structure center. Distance viewing was also a necessity at the Rolfe Canal Tailrace and historic canal exit where no access was available for safe close viewing.

No eels were observed at any of the Rolfe Canal Project headgate dam, tailrace, or historic canal survey areas.

65.3.3 Penacook Lower Falls

Table 5-3 presents the available operations and environmental conditions during nighttime surveys at the PLF spillway and powerhouse locations. Available operations and environmental data during surveys at the PLF show generation flows ranging from 0 to 1,212 cfs. Spill in the form of minor overtopping was present during all of the surveys, wetting the surface of the dam and providing potential attraction points for eels at both the auxiliary, diversion, and main spillways (Figure 5-5).

Close surveys at the PLF focused on the auxiliary and diversion spillways as well the river left bypass reach extending from where the auxiliary spillway flows converge with the diversion spillway flows. Two eels were observed at the auxiliary spillway during surveys in 2022 (Table 5-4). Both eels were identified during the July 7 survey in areas of leakage associated with the spillway stoplogs (Appendix A).

Table 60–40. Operational and environmental conditions for visual nighttime and electrofishing surveys conducted at the York Dam bypass reach, June-August, 2021

Date	Survey Type	Survey Start Time	Rolfe Canal Generation	Bypass Flow	Lunar Illumination	Visible Spill/overflow	Water Temperature	Weather
			cfs	cfs	%	Yes/No	°C	
6/22/2021	Night	21:01	0	195	96.0	Yes	23.6	Overcast
6/30/2021	Night	21:05	0	153	64.7	Yes	27.5	Rain/Overcast
7/6/2021	Electrofish	10:45	1957	93	10.9	Yes	20	Hot/Humid
7/7/2021	Night	21:00	1007	96	5.6	Yes	N/A	Overcast
8/9/2021	Electrofish	10:45	1098	93	20.5	Yes- minimal	23.6	Hot/Clear
8/12/2021	Night	20:55	598	93	1.7	Yes	24.6	Rain/Overcast

Table 60–41. Operational and environmental conditions for visual nighttime and electrofishing surveys conducted at the Rolfe Canal headgate dam, tailrace, and historic canal, June-August, 2021

Date	Survey Type	Survey Start Time	Rolfe Canal Generation Flow	Lunar Illumination	Visible Spill/overtopping	Water Temperature	Weather
			cfs	%	Yes/No	°C	
6/22/2021	Night	21:12	0	96.0	No	23.6	Overcast
6/30/2021	Night	21:38-21:57	0	64.7	No	27.5	Rain/Overcast
7/6/2021	Electrofish	11:24-11:34	1927	10.9	No	20.1	Hot/Humid
7/7/2021	Night	21:25-21:40	1005	5.6	No	N/A	Overcast
8/9/2021	Electrofish	11:57-12:08	1102	20.5	No	24.2	Hot/Clear
8/12/2021	Night	21:42-21:57	601	1.7	No	24.6	Rain/Overcast

Table 60–42. Operational and environmental conditions for visual nighttime and electrofishing surveys conducted at PLF, June-August, 2021

Date	Survey Type	Survey Start Time	PLF Generation Flow	Lunar Illumination	Visible Spill/overtopping	Water Temperature	Weather
			cfs	%	Yes/No	°C	
6/22/2021	Night	21:30	0	96.0	No	23.6	Overcast
6/30/2021	Night	22:10	0	64.7	No	27.5	Rain/Overcast
7/6/2021	Electrofish	11:50	1212	10.9	No	20.1	Hot/Humid
7/7/2021	Night	21:45	1134	5.6	No	N/A	Overcast
8/9/2021	Electrofish	12:55	1199	20.5	No	24.2	Hot/Clear
8/12/2021	Night	21:50	788	1.7	No	24.6	Rain/Overcast

Table 60–43. Nighttime survey results at the Briar Hydro Projects by date, location, and size class, June-August, 2021

Survey Date	York Dam Bypass Reach				Rolf Canal Headgate Dam				Rolf Canal Tailrace				Penacook Lower Falls			
	Eel Size Class (inches)			Total	Eel Size Class (inches)			Total	Eel Size Class (inches)			Total	Eel Size Class (inches)			Total
	0-6	6-12	12+		0-6	6-12	12+		0-6	6-12	12+		0-6	6-12	12+	
6/22/2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/30/2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/7/2022	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
8/12/2022	0	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0
Total	**0**	**2**	**1**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**2**

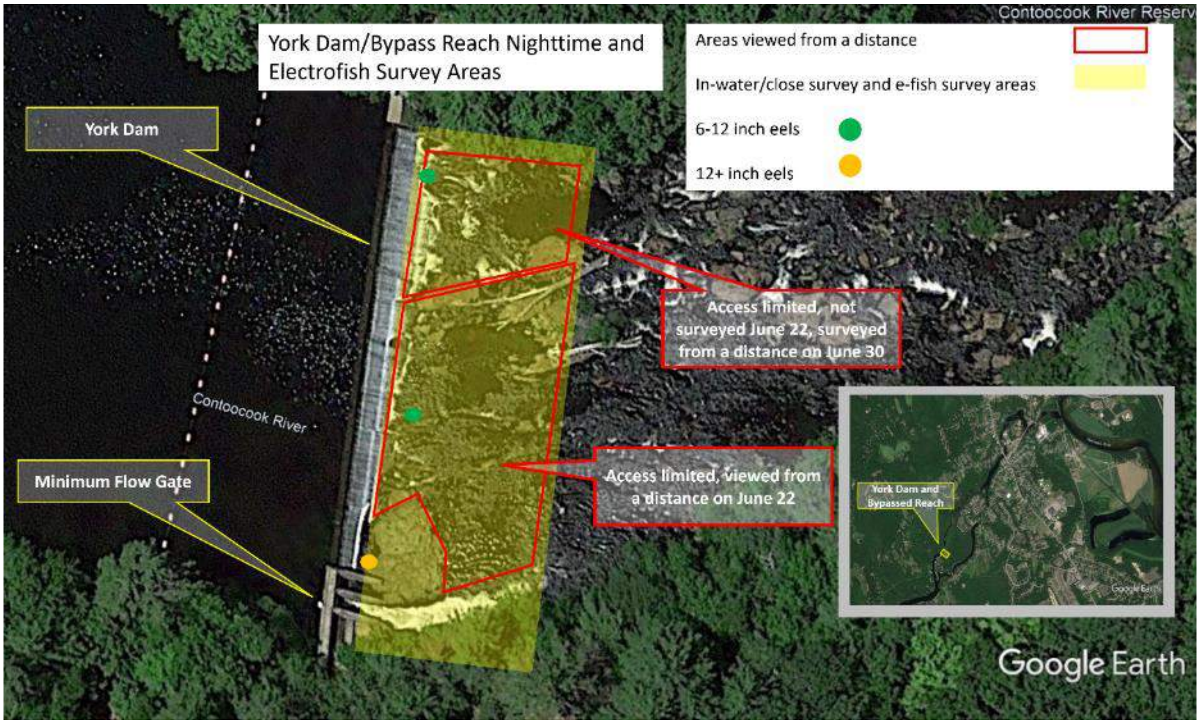


Figure 60-29. Survey and electrofishing areas at the York Dam bypass reach during 2021 including the location of eels observed on the August 12 nighttime survey.

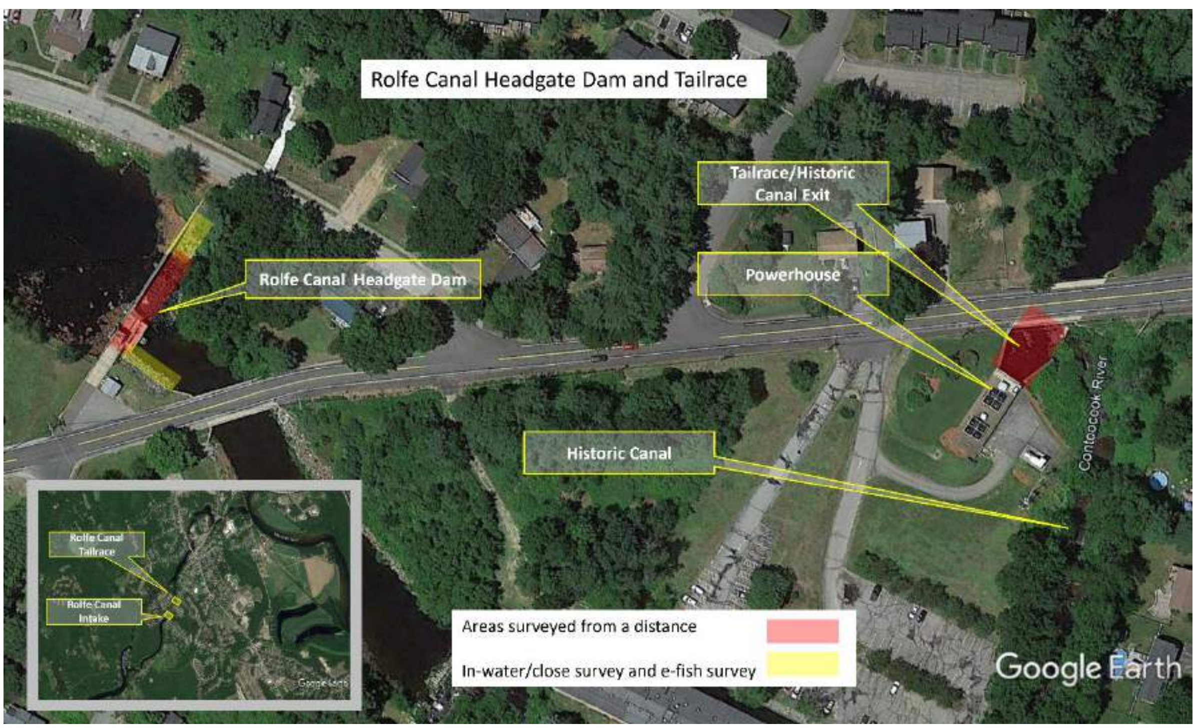


Figure 60-30. Survey and electrofishing areas at the Rolfe Canal intake structure and tailrace/historic canal discharge during 2021.

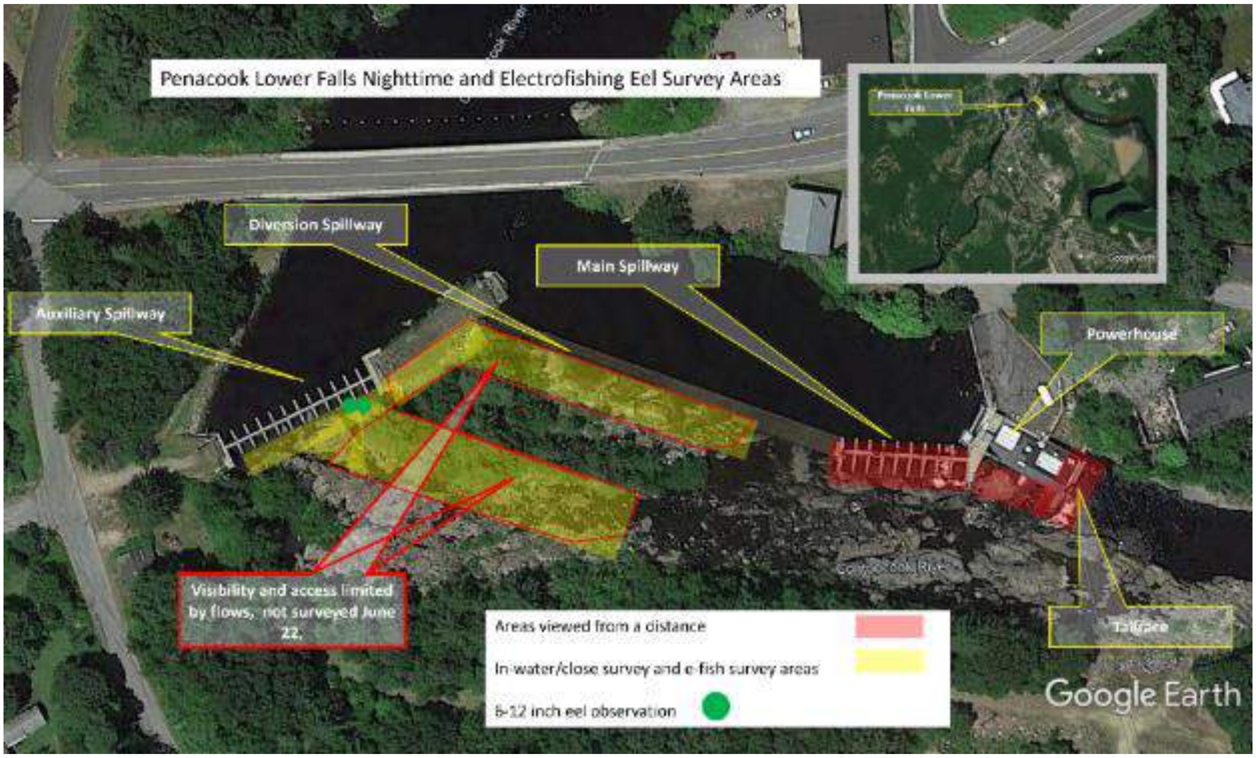


Figure 60-31. Survey and electrofishing areas at PLF during 2021 including the location of eels observed on the July 7 nighttime survey.

Figure 60-32. Conditions below York Dam on June 22, 2021, making access and visual surveys for juvenile eels difficult.

Figure 60-33. Typical conditions below the auxilliary spillway (left) and diversion spillway (right) at PLF showing where leakeage/spill created potential attraction areas for migrating juvenile eels.

65.4 Electrofishing Surveys

Backpack electrofish surveys were conducted at the York Dam bypass reach, downstream of the Rolfe Canal headgate dam, and below PLF on July 6 and August 9 (Figures 5-1 to 5-3). Environmental and operations data for these events are presented in Tables 5-1 through Table 5-3.

Table 5-5 presents the electrofishing effort expended at each Project location. The actual extent of electrofishing effort in terms of area searched are provided as summary reports in Appendix B. No juvenile eels were captured during either electrofishing event. Project staff indicated that overall, very few fish were observed with the majority being either Smallmouth Bass (4-8 inches) or Bluegill.

Table 60-44. Abundance and Catch-Per-Unit-of-Effort (CPUE) for juvenile American Eels during backpack electrofish sampling downstream of Rolfe Canal and PLF, July-August 2021.

Date	Eel Catch by Size Class				Electrofish Time in Seconds
	0-6 inch	6-12 inch	12+ inch	Total	
7/6/2021	0	0	0	0	1,788
8/9/2021	0	0	0	0	2,022
Total	0	0	0	0	3,810

65.5 PUF Mark-Recapture

The frequency and abundance of eel capture at the PUF eel lift determined the seasonal timing of the mark-recapture study at that Project during 2022. Figure 5-6 presents the 2021 daily and cumulative eel capture at the PUF lift and the mean daily river flows (cfs). Catch during 2021 was episodic, a large percentage of the annual catch (32%) occurring in two days, and visually appears to be associated with sharp increases in river discharge. Due to the inconsistent and unpredictable occurrence for the collection of juvenile eels in the PUF eel lift it was necessary to hold collected individuals in a flow through tank on-site for multiple days prior to initiating a tagging event so that an adequate number of test eels could be obtained. Caution was taken to prevent holding eels for longer than one week prior to tagging over concerns it my potentially impact their ability/motivation to continue their upstream movement. As a result, both tagging events were initiated at a point in time when a relatively large number of eels (~75-100) were captured over a limited number of consecutive dates at the lift.

Table 5-6 presents VIE tagging for eels by date and size classification. The first tagging event of 100 juvenile eels (yellow VIE marks) was conducted on July 20, 2021. The majority of eels from the first release group

(89 of 100) were classified within the 6 to 12 inch size class. These eels were maintained over night to ensure survival following handling and tagging and were intended to be released on July 21. However, the release of the first test group was delayed by high water until July 23. At that point a location approximately 1/3 mile downstream was selected as a surrogate release location due to (1) the inability to safely access the confluence of the bypass and tailrace and (2) concern over further extending the tank holding period for VIE marked eels any longer than necessary (Figure 5-6). The second release (110 eels) were VIE marked on August 25 (red VIE). Similar to the first event, the release of the second group was delayed until high flows receded allowing safe access on August 30. The second release took place at the confluence of the bypass reach and tailrace (Figure 5-7).

Recapture results are presented by release group in Tables 5-7 and 5-8 and shown in relation to operations and environmental data in Figure 5-8. Eels captured in the PUF eel lift by Briar Hydro operations staff over the two weeks following the July 23 release were secured in labeled containers in an on-site flow through tank. Eels from each date were maintained in their own labeled container. The daily catches were then examined for the total number of individuals, number of individuals with a VIE mark, and size class information. Daily catches were examined for the period from July 24 through August 6 (14 days). During the two-week post-release period a total of 60 juvenile eels were lifted at the PUF, two of which were VIE marked recaptures, representing a 2% return. Recaptures occurred on day 8 and day 10 after release.

Briar Hydro collected a total of 124 juvenile eels in the lift on August 25, and 110 of those individuals were marked with red VIE. These eels were held in a holding tank until August 30 due to high flows that prevented access to the bypass reach release location. During a tank check on August 27, it was observed that one of the marked eels had died. Visible bruising near the head (unnoted during the tagging process) was the only visible injury and it is unknown if this was the cause of the mortality or if the injury was a result of lifting, removal from the hopper, VIE marking, or an unrelated event. With the receding flows, biologists were able to release the 109 VIE marked eels at the confluence of the tailrace and bypass reach (Figure 5-7). Eel captures at PUF were monitored for recaptures through October 1 (33 days; Table 5-8). During this timeframe, eels were collected in the PUF eel lift between the dates of August 31 and September 4 (11 total). However, there were no observations of VIE marked eels from the second release group.

Table 60-45. Size class distribution for juvenile eels marked using Visual Elastomer Implant (VIE) and released downstream of PUF

Tagging Date	Number of eels marked with VIE by date and size class

	0-6 inch	6-12 inch	12+ inch	Total
7/20/2021	5	89	6	100
8/25/2021	2	102	6	110
Total	**7**	**191**	**12**	**210**

Table 60-46. Daily eel catch and VIE marked recaptures at the PUF lift for the two week period following release of the first test group, July 24 through August 6.

Trap Check Date	VIE tag by Size Class				VIE recaptures			
	0-6 inch	6-12 inch	12+ inch	Total	0-6 inch	6-12 inch	12+ inch	Total
July 23 - 100 yellow VIE marked eels released 1/3-mile DS of PUF eel lift								
24-Jul	0	1	0	1	0	0	0	0
25-Jul	1	0	0	1	0	0	0	0
26-Jul	1	1	0	2	0	0	0	0
27-Jul	2	1	0	3	0	0	0	0
28-Jul	2	2	0	4	0	0	0	0
29-Jul	1	2	0	3	0	0	0	0
30-Jul	0	3	0	3	0	0	0	0
31-Jul	2	28	6	36	0	1	0	1
1-Aug	0	0	0	0	0	0	0	0
2-Aug	0	4	0	4	0	1	0	1
3-Aug	1	1	0	2	0	0	0	0
4-Aug	0	1	0	1	0	0	0	0
5-Aug	0	0	0	0	0	0	0	0
6-Aug	0	0	0	0	0	0	0	0
Total	**10**	**44**	**6**	**60**	**0**	**2**	**0**	**2**

Table 60-47. Daily eel catch and VIE marked recaptures at the PUF lift for the one month period following release of the second test group, August 31 through October 1.

	VIE tag by Size Class	VIE recaptures

Trap Check Date	0-6 inch	6-12 inch	12+ inch	Total	0-6 inch	6-12 inch	12+ inch	Total
August 30 - 112 red VIE marked eels released at confluence of PUF tailrace and bypass reach								
31-Aug	0	1	0	1	0	0	0	0
1-Sept	1	0	0	1	0	0	0	0
2-Sept	1	1	0	2	0	0	0	0
3-Sept	2	1	0	3	0	0	0	0
4-Sept	2	2	0	4	0	0	0	0
5-Sept through 1-Oct: Lift operational, no eels lifted at PUF								
Total	**6**	**5**	**0**	**11**	**0**	**0**	**0**	**0**

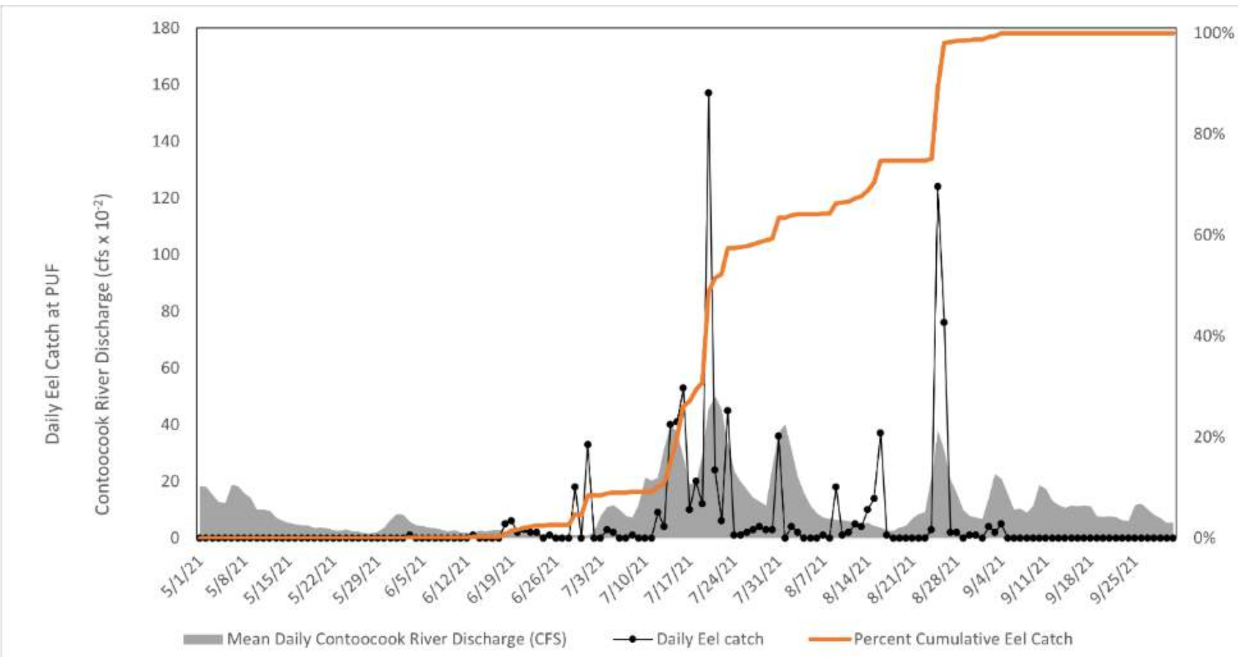


Figure 60-34. Daily and cumulative catch of juvenile American eels at PUF during 2021.

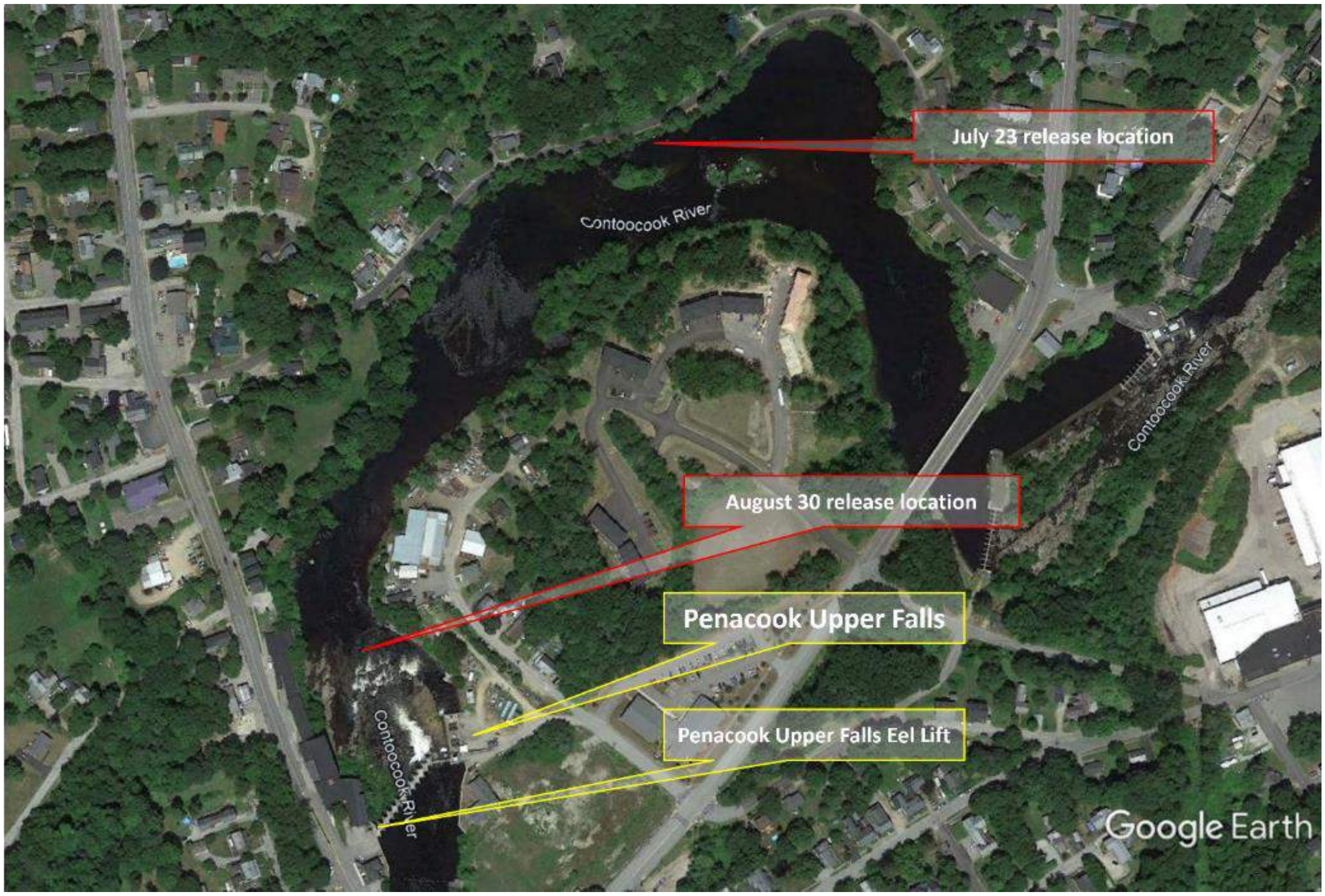


Figure 60-35. Eel trap at PUF and release locations for VIE marked eels on July 20, 2021 and August 25, 2021.

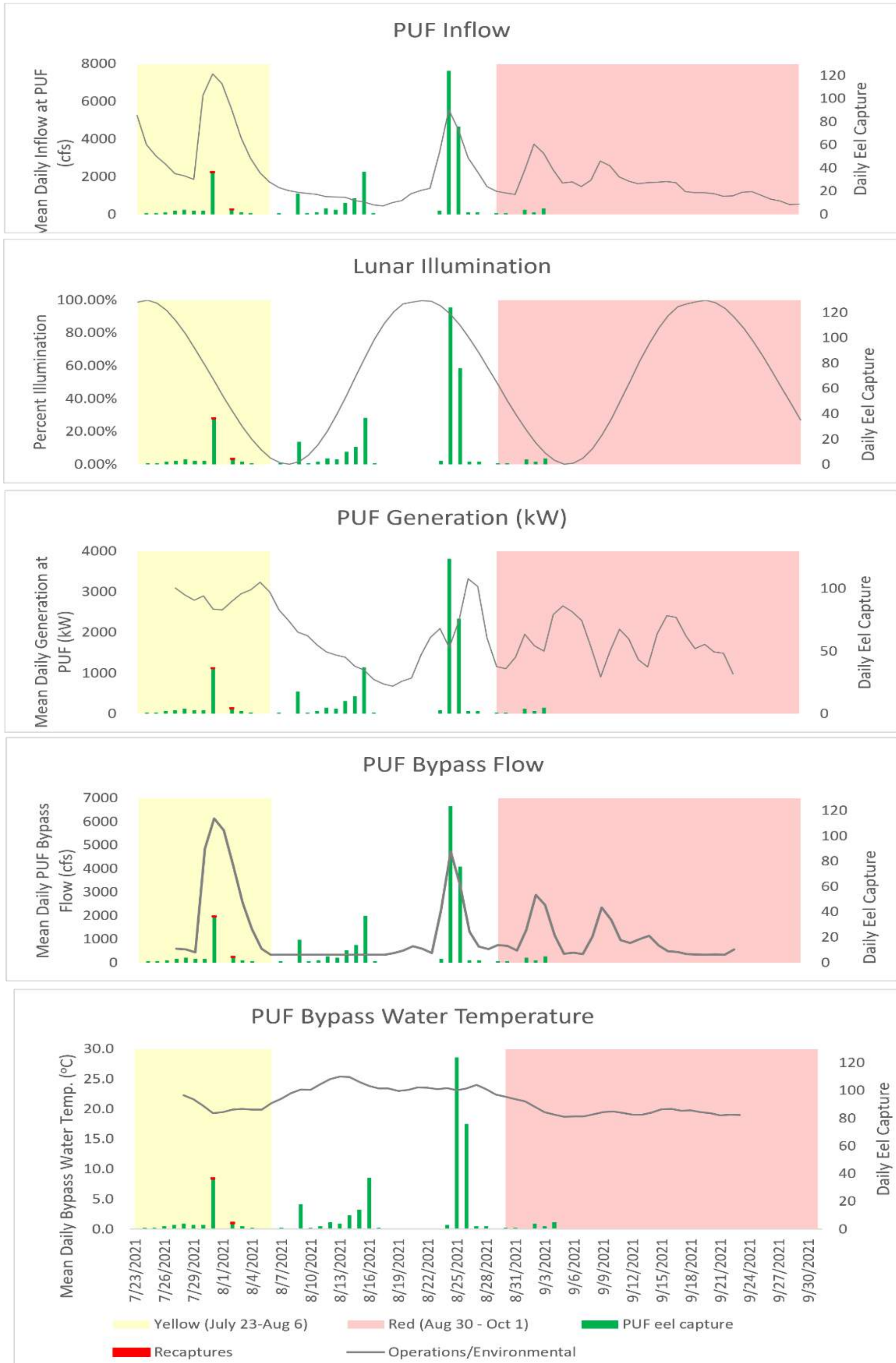


Figure 60-36. Eel capture at PUF (green bars) and VIE marked recaptures (red bars) during the July 24-August 6 (yellow VIE) and August 30-October 1 (red VIE) study periods alongside mean PUF inflow (cfs), lunar illumination (%), mean PUF generation (cfs), mean PUF bypass flow (cfs), and mean PUF water temperature (°C).

14. Summary

Nighttime visual surveys and supplementary electrofish sampling were conducted at the areas downstream of Rolfe Canal and PLF identified in the RSP. The results of these surveys indicated a low overall presence of juvenile eels at the locations surveyed downstream of Rolfe Canal and PLF during 2021. Daily and cumulative eel capture data from the lift facility at PUF characterizes the seasonality and episodic nature of eel migration in the lower Contoocook River during 2021 (Figure 5-6). The early surveys, i.e., those completed prior to mid-July, occurred during the period when a very low proportion (< 20%) of the annual catch had occurred. The two surveys conducted in August (one electrofishing and one visual) occurred during a period of low activity between two episodic peaks in capture. The 2021 season was further complicated by high flows during July and August. Figure 5-6 indicates that upstream eel activity, as indexed relative to the seasonal pattern of eel catch at PUF, may have been associated with high flow events during 2021. These high flow events, often occurring in conjunction with spill, prevented safe access below dams for nighttime surveys and electrofishing and may have had a negative effect on the overall set of visual observations.

The mark/recapture study conducted at PUF showed limited returns of VIE marked eels following the release of the first group approximately 1/3 mile downstream of the PUF bypass reach and no returns from the second release at the PUF bypass/tailrace confluence. Eels from the first release group were monitored for two weeks following release and a total of two individuals were observed (July 24-August 6). During tagging of the second release group (comprised of eels collected at PUF on August 25) an additional five VIE-marked eels from the first release effort were observed suggesting that limited upstream movement of the first set of eels continued for a period of time after the two-week daily check period. However, no marked eels from either release group were observed during the 33 consecutive day daily check period following the second release (August 31-October 1). As was discussed during the development of the study plan for upstream eel passage, interpretation of these types of passive mark-recapture studies can be very difficult given uncertainties around behavior of marked eels following release. It is uncertain as to the fate of marked eels not collected in the PUF lift during the active monitoring period. Marked eels may settle into suitable areas of habitat following release, may be predated, or the capture and marking of these individuals may negatively influence their continued upstream movement for a period of time. The inability to account for these behavioral responses downstream of PUF complicates the ability to properly assess the “near field effectiveness” of the current upstream eel lift. The second release of VIE marked eels at the end of August was released at the confluence of the tailrace and bypass reach (designated in the study plan) and was monitored for 33 days to assess recapture rates from this location. Very few eels (marked or unmarked) were captured after August 30 indicating that upstream movement in general may have slowed considerably during September.

15. Variances from Approved Study Plan

Several variances from the methodology described in the March 2021 RSP occurred during the field implementation of the nighttime surveys and VIE mark/recapture study.

Variances from the RSP during the nighttime surveys included:

1. Nighttime surveys were originally proposed as occurring '***once every other week over a period of eight weeks starting in late-June and terminating in early-August***'. However, unusually high flows during July 2021 prevented the safe completion of surveys within the originally proposed timeline. Despite needing to shift survey events due to sampling conditions, Briar Hydro did still complete the four nighttime surveys and two electrofish surveys identified in the RSP during the months of June, July, and August 2021.

Variances from the RSP during the VIE mark/recapture study included:

2. The release site in the RSP was defined as '***the confluence of the bypass reach and tailrace channel'.*** High flows prevented safe access to this reach during initial release (July 23). Due to uncertainty as to when the proposed release location would be safely accessible and to prevent continued holding of tagged eels in the tank at PUF, the release location was shifted to a location downstream approximately 1/3 mile from the confluence of the bypass and tailrace flows. The release of the second group of VIE marked eels occurred at the bypass/tailrace confluence as described in the RSP.

3. Methodology outlined in the RSP assumed the two release events would occur consecutively so that **'*At the completion of the two week monitoring period, the second release group will be released downstream and Briar Hydro will initiate a second two week monitoring period. During the second two-week monitoring period, the total number of marked (release #1 color and release #2 color) and unmarked eels will be recorded for each daily lift event that the second VIE marked individuals would be released two weeks after the initial release providing four continuous weeks of monitoring for VIE marked eels from the first release and two weeks of monitoring for VIE marked eels from the second release*.'** However, releases did not occur in this manner due to:

a. Concerns over whether untagged eels captured and anesthetized to examine for marks during the two-week check period following the initial VIE tagging event should be re-anesthetized, tagged, and then used as part of the second release event. It was unclear how this might impact survival, migration motivation, and ultimately returns to the lift. As a result, eels captured and checked during the two-week period following the initial release were released and a new collection period was initiated after two weeks.

b. Eels collections at PUF were sporadic, preventing the collection of a suitable sample size (100 eels) during the RSP designated time period (5 days) to initiate a tagging event. As a result, it took several days to gather a viable tagging sample over a short period of time (100 eel in less than 5 days) which delayed the second release until August 30. Monitoring during the second release was extended for 30 days to provide four weeks of monitoring for one of the releases as described in the study plan.

16. Appendices

Appendix A. Field summary notes from nighttime visual surveys for American eel at Rolfe Canal and PLF June-August 2021

Briar Hydro- Contoocook River Nighttime Visual Eel Survey Summary

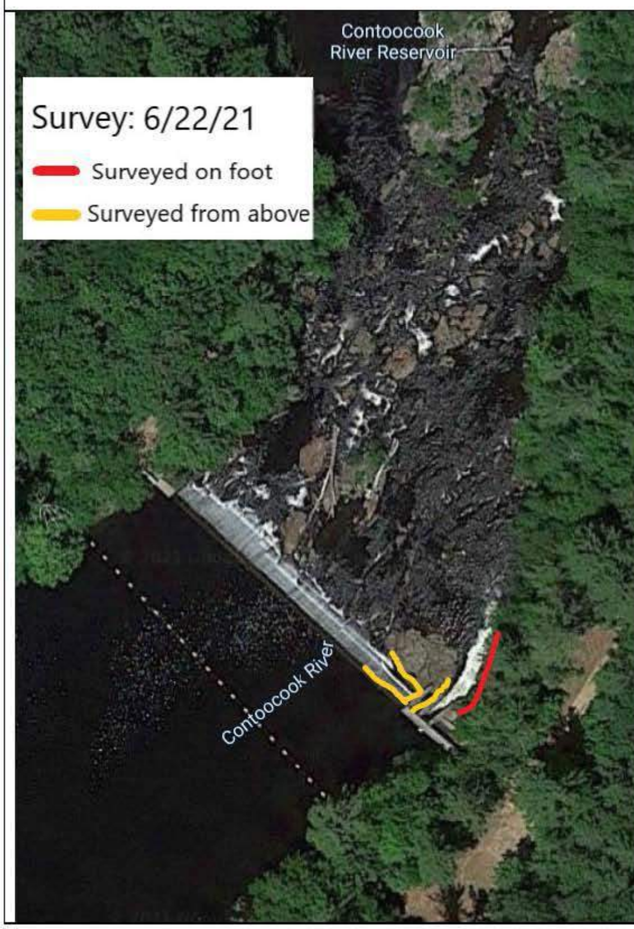
Search Summary for *Briar Hydro- Contoocook River*

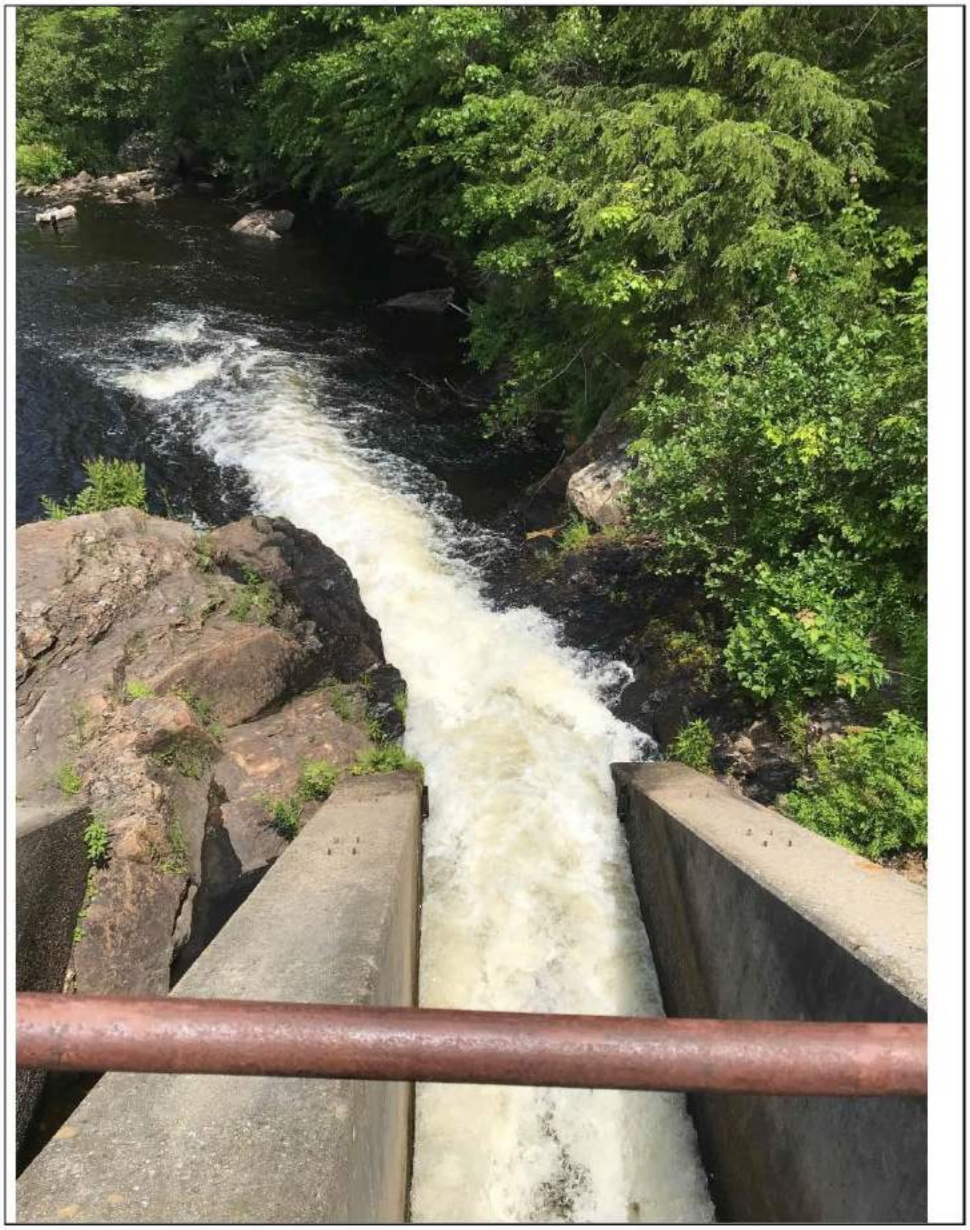
Search Date 6/22/21

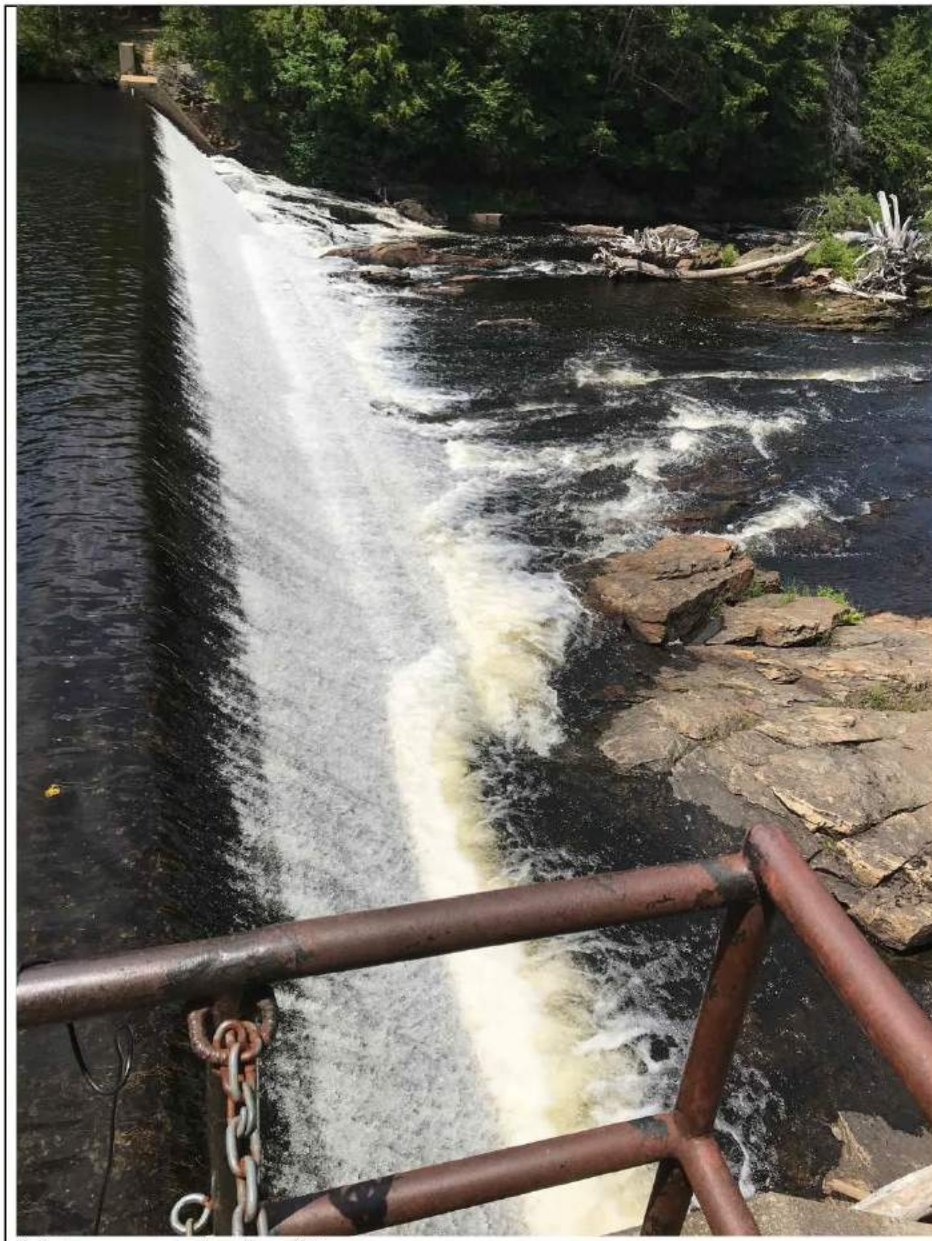
York Dam

Conditions: Water spilling over concrete dam and 1st spill bay open. Lots of whitewater. Light rain most of the day. Overcast at time of survey. CNG & SS.

Search Summary: Surveyed 21:01-21:07. Surveyed from above due to whitewater. 2nd spill bay has leakage in stoplogs and looks like it could be promising for finding eels. Surveyed on "catwalk" from above, walked wetted margin of spill bay 1 (bypass). No wading. NO EELS OBSERVED.







*photos representative of conditions

Head of Historic Canal

Conditions: Light rain most of the day. Overcast at time of survey. Only water entering historic channel is from "minimum flow pipe" (whitewater seen on image below). CNG & SS.

Search Summary: Surveyed 21:12-21:18. Survey rip rap shores on both sides of channel by foot. Surveyed remaining areas from above. Rip rap closest to Electric Ave and the wetted concrete wall of the dam look the most promising for eels. NO EELS OBSERVED.

Rolfe Canal Tailrace and Historic Channel Discharge

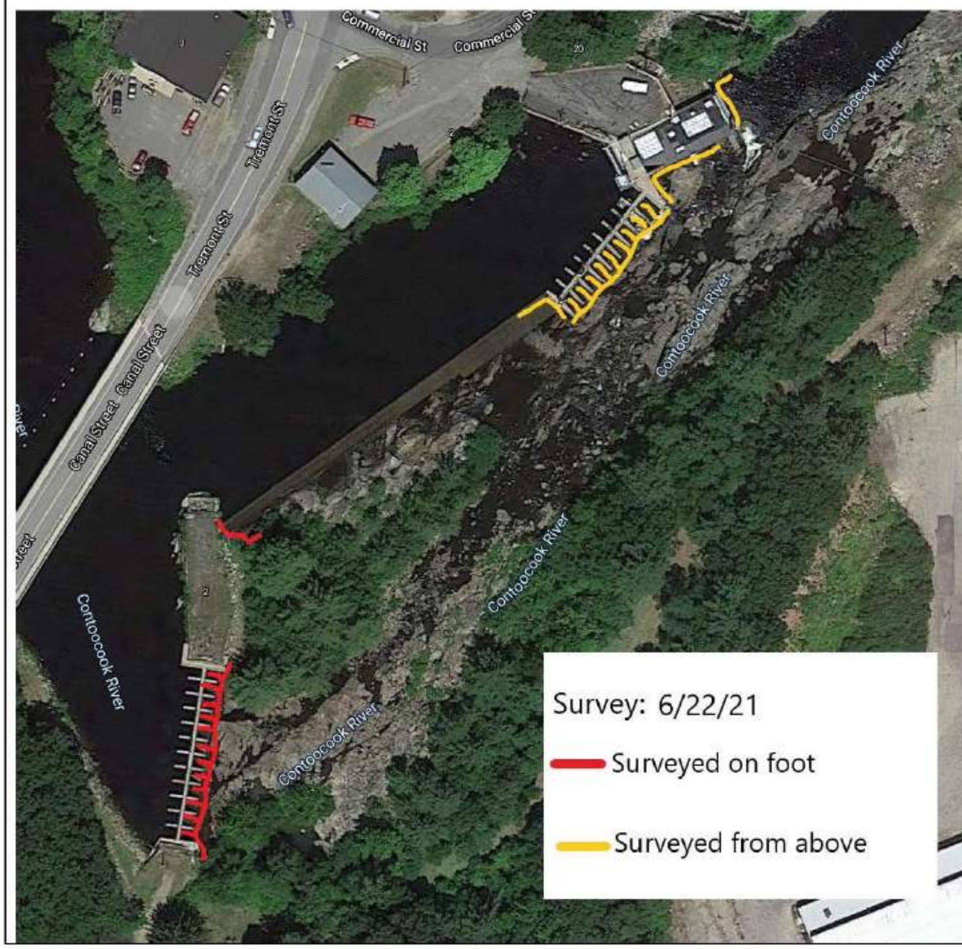
Conditions: Light rain most of the day. Overcast at time of survey. No power generation. CNG & SS.

Search Summary: Surveyed 21:23-21:25 from above. Too far away to realistically observe eels. Will rethink for next week. NO EELS OBSERVED.

PLF Diversion Spillway, Auxiliary Spillway, Main Spill and Tailrace

Conditions: Light rain most of the day. Overcast at time of survey. No power generation. Lots of water spilling over Diversion, Auxiliary and main spillways. CNG & SS.

Search Summary: Surveyed Diversion Spillway and upstream end of Auxiliary Spillway on foot from 21:30-21:53. Too much water to wade Auxiliary. Both of these places (Diversion & Upstream end of Auxiliary) look most promising for eels. NO EELS OBSERVED. Surveyed Main Spillway and Tailrace from above 22:00-22:10. Way too much flow to realistically observe eels. Units off at PLF. NO EELS OBSERVED.



Briar Hydro- Contoocook River Nighttime Visual Eel Survey Summary

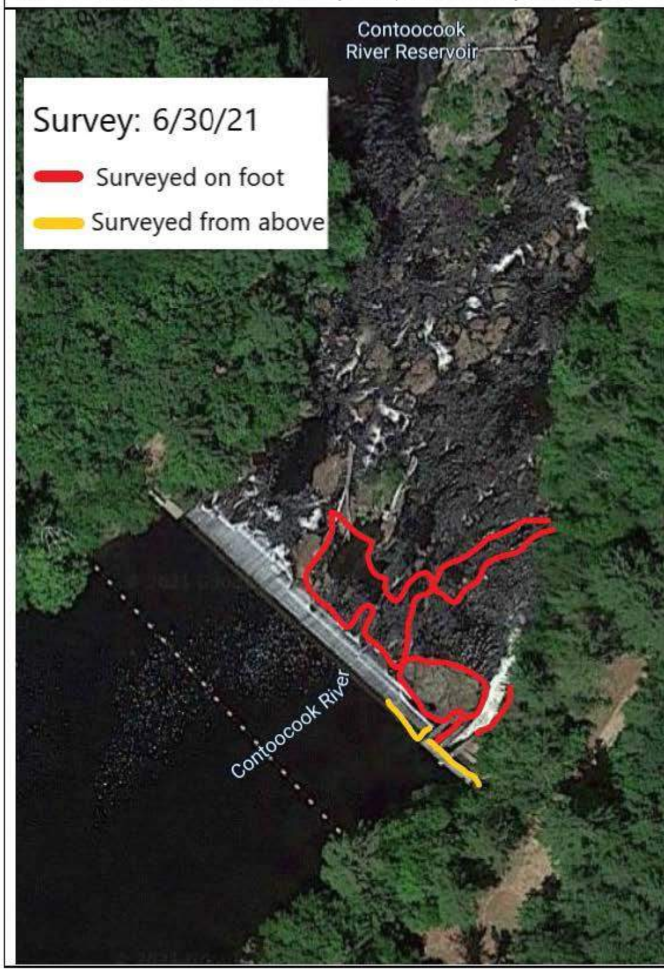
Search Summary for: *Briar Hydro- Contoocook River*

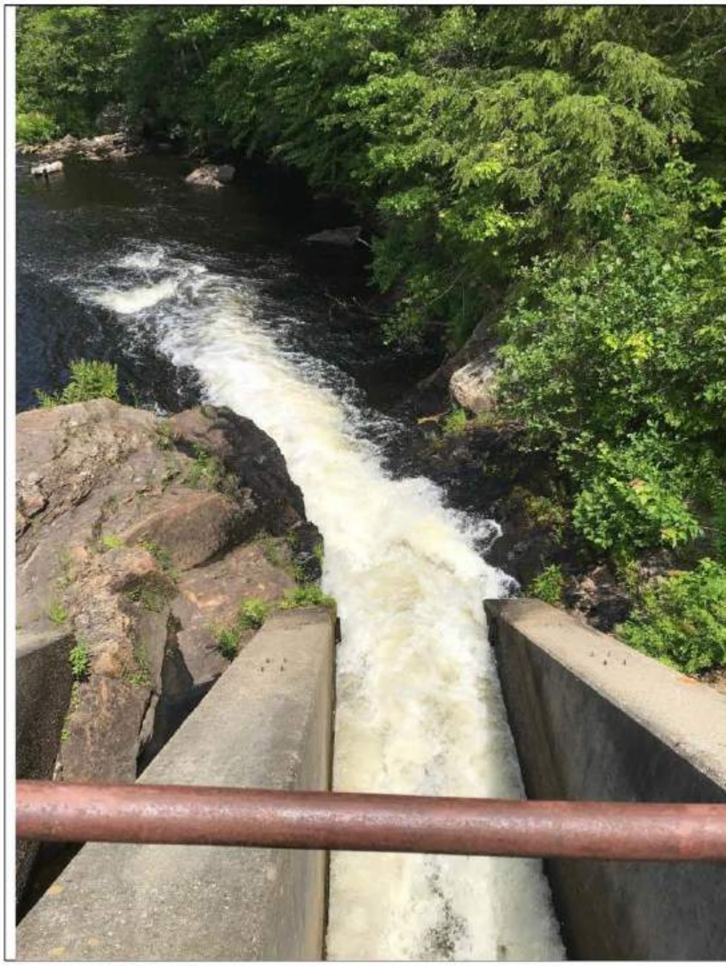
Search Date: 6/30/21

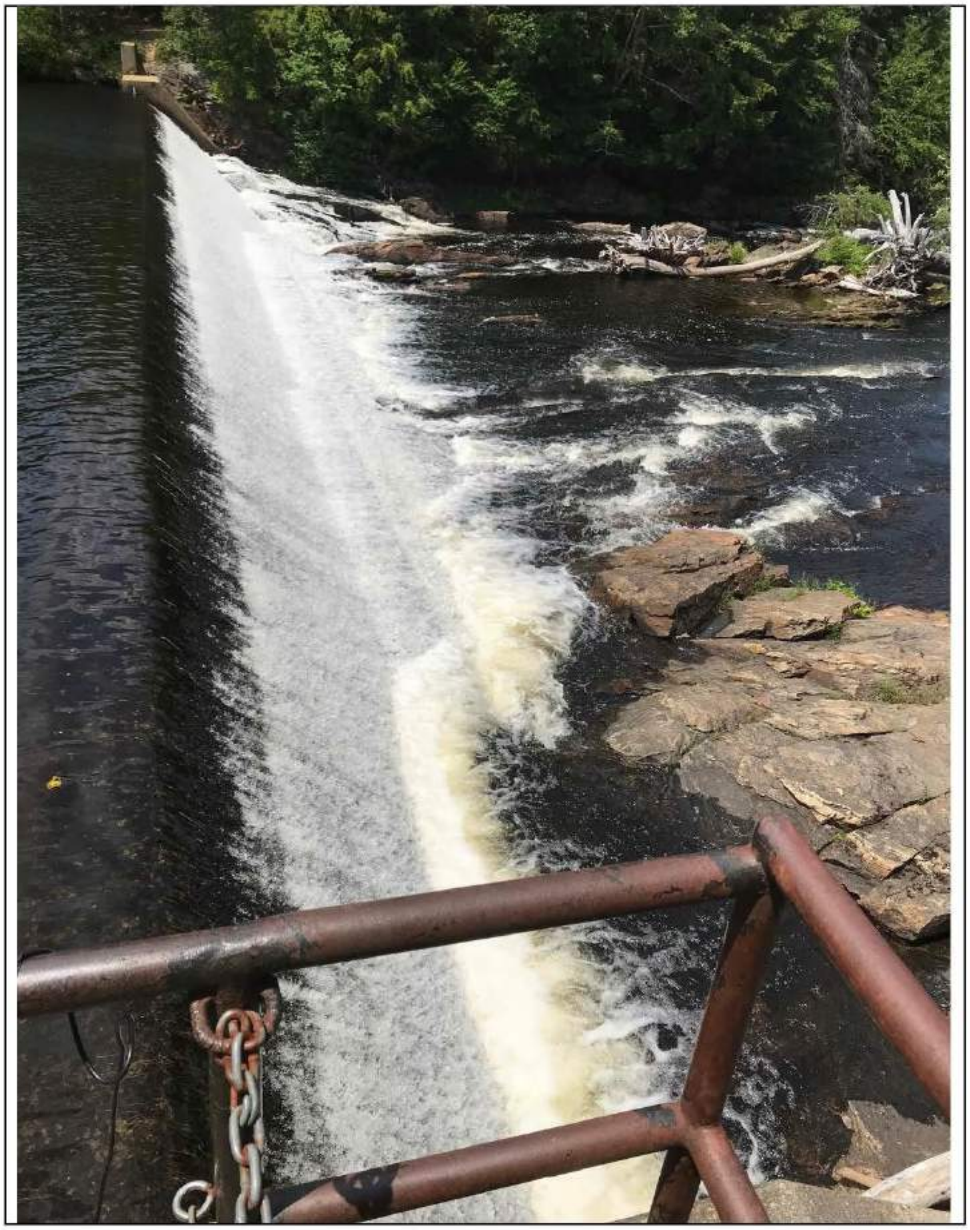
York Dam

Conditions: Very hot weather all day, cold front moving through bringing rain. Just finished raining and overcast for survey. Conditions similar to last week. CNG, SS

Search Summary: Surveyed 21:05-21:13. SS waded below dam. CNG surveyed from above. Conditions identical to last week. Spill bay 2 still looks promising but NO EELS OBSERVED.







Head of Historic Canal

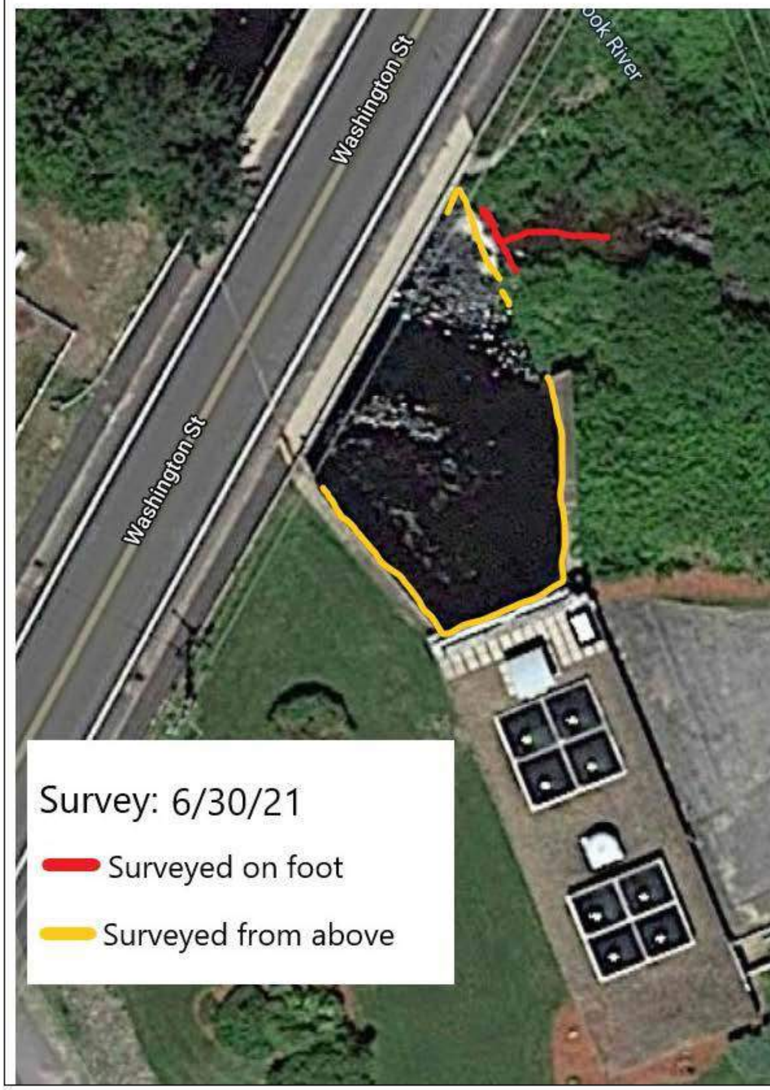
Conditions: Very hot weather all day, cold front moving through bringing rain. Just finished raining and overcast for survey. Conditions similar to last week. CNG, SS

Search Summary: Surveyed the same as last week. Surveyed 21:38-21:46. NO EELS OBSERVED.

Rolfe Canal Tailrace and Historic Channel Discharge

Conditions: Very hot weather all day, cold front moving through bringing rain. Just finished raining and overcast for survey. Conditions similar to last week. CNG, SS

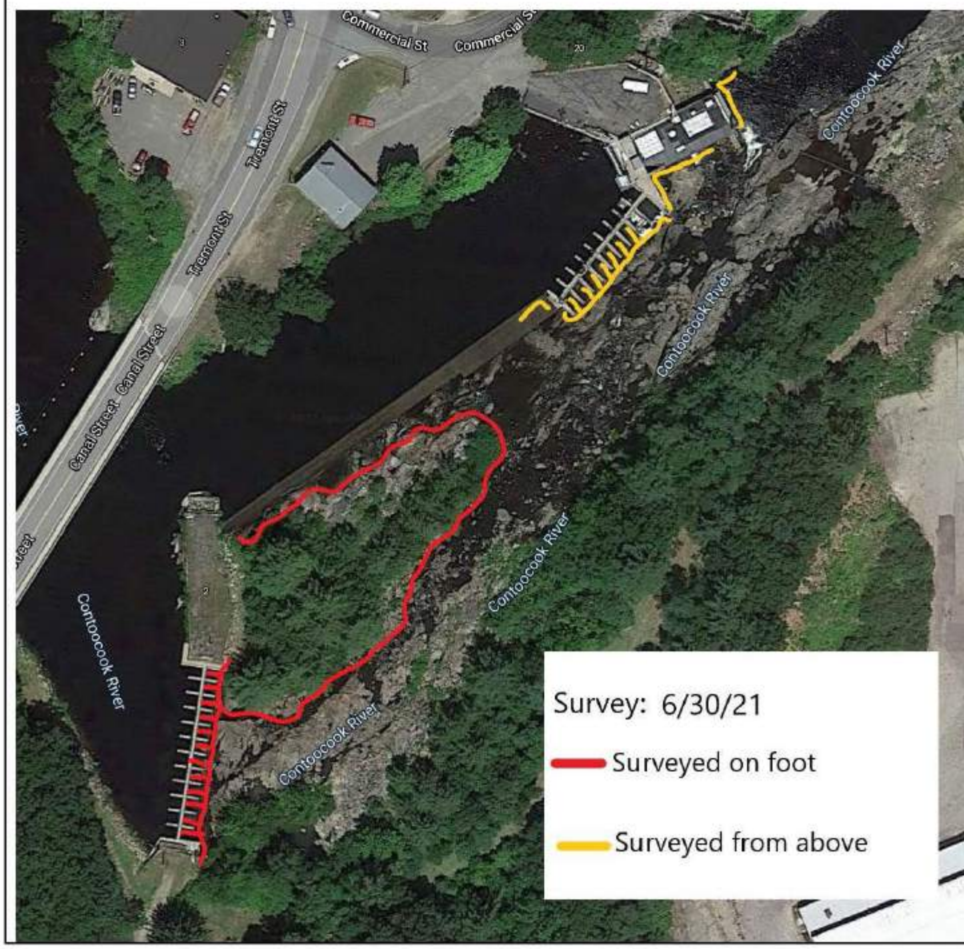
Search Summary: Surveyed from above and limited on foot by SS. 21:50-21:57. Still pretty ineffective. Units not generating. NO EELS OBSERVED.



PLF Diversion Spillway, Auxiliary Spillway, Main Spill and Tailrace

Conditions: Very hot weather all day, cold front moving through bringing rain. Just finished raining and overcast for survey. Conditions similar to last week, slightly less spill. CNG, SS

Search Summary: Diversion & Auxiliary Spillways surveyed on foot 22:10-22:27. Less spill at Auxiliary, enabling a more thorough survey by wading. Surveyed the Diversion spillway same as last week. NO EEL OBSERVED. Main Spillway and Tailrace surveyed 22:35-22:45 from above. Still relatively ineffective. Tailrace impossible with flow boil coming from bypass reach. Units not generating. NO EELS OBSERVED.



Briar Hydro- Contoocook River Nighttime Visual Eel Survey Summary

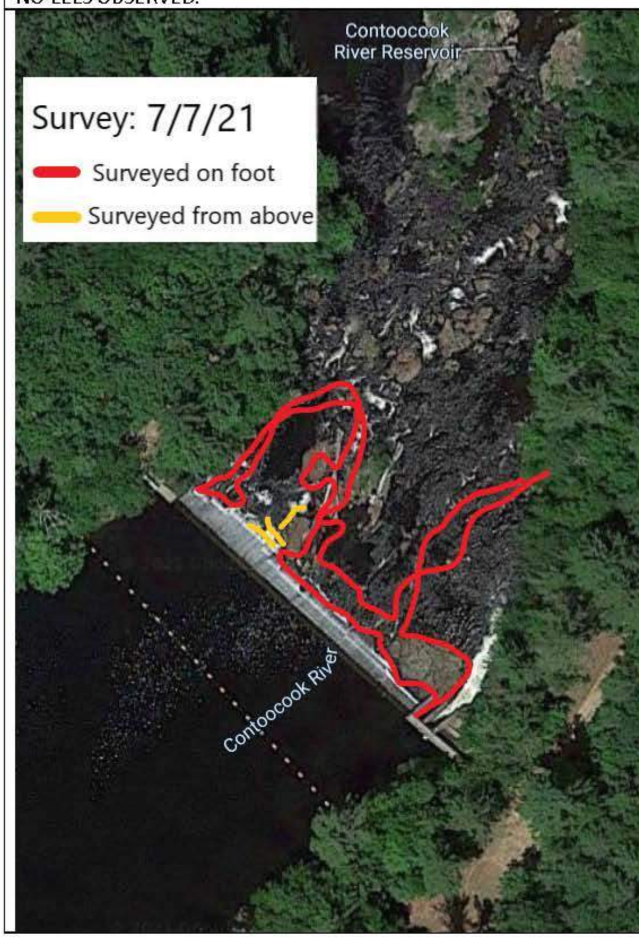
Search Summary for: *Briar Hydro - Contoocook River*

Search Date: 7/7/21

York Dam

Conditions: Weather today was hot with rain moving in in the future. Survey was overcast with no rain. Flow over dam was considerably less as compared to last week, most likely a result of hydro turbines back online. CNG, MJP

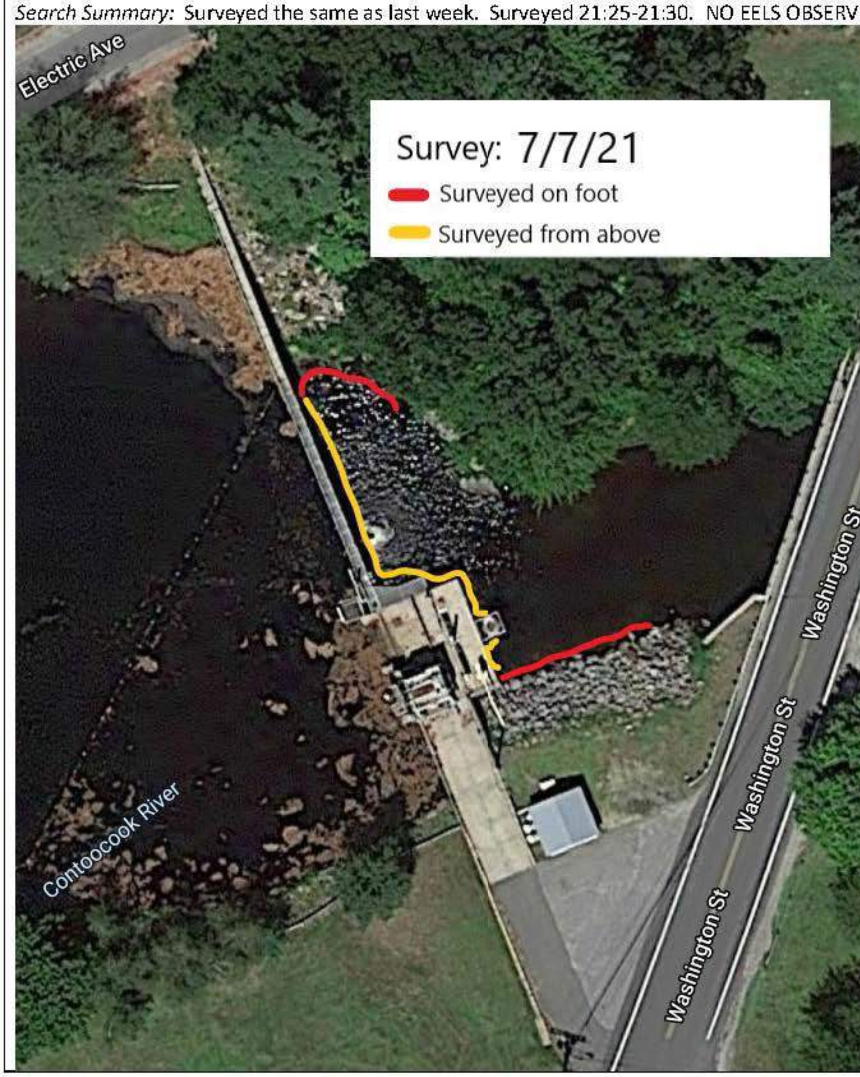
Search Summary: Surveyed 21:00-21:16. CNG & MJP waded below dam. Lower spill over dam enabled a survey of the north side of the dam, mirroring the electrofishing survey conducted on 7/6. NO EELS OBSERVED.



Head of Historic Canal

Conditions: Weather today was hot with rain moving in in the future. Survey was overcast with no rain. Conditions similar to last week. CNG, MJP

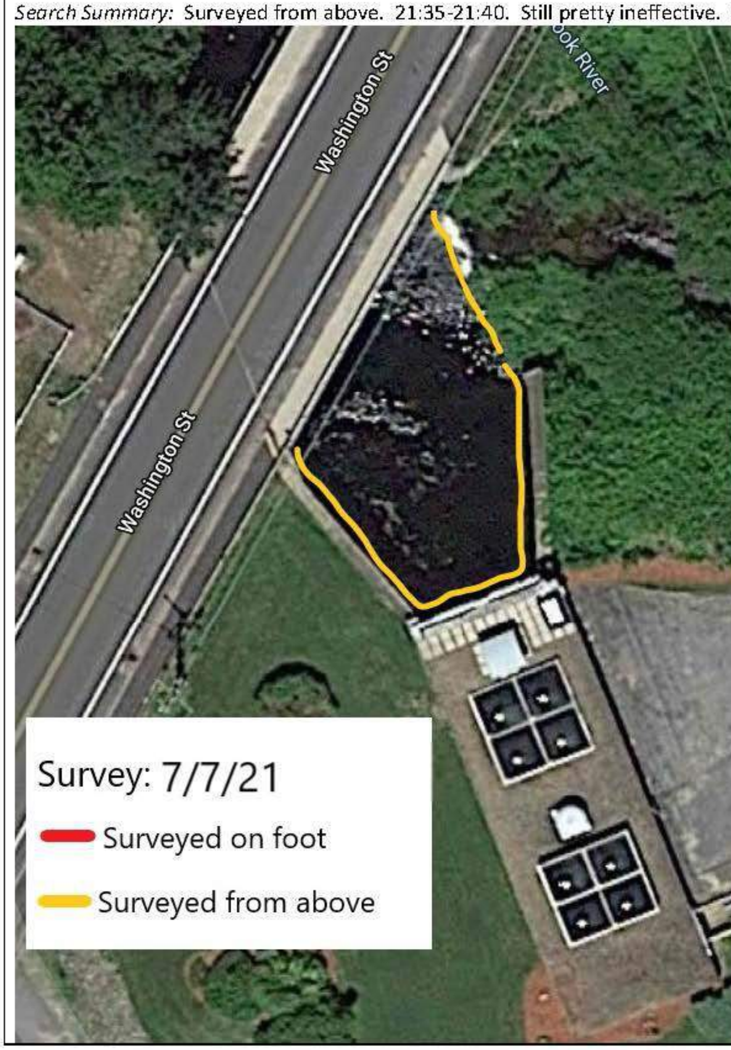
Search Summary: Surveyed the same as last week. Surveyed 21:25-21:30. NO EELS OBSERVED.



Rolfe Canal Tailrace and Historic Channel Discharge

Conditions: Weather today was hot with rain moving in in the future. Survey was overcast with no rain. Conditions similar to last week. CNG, MJP

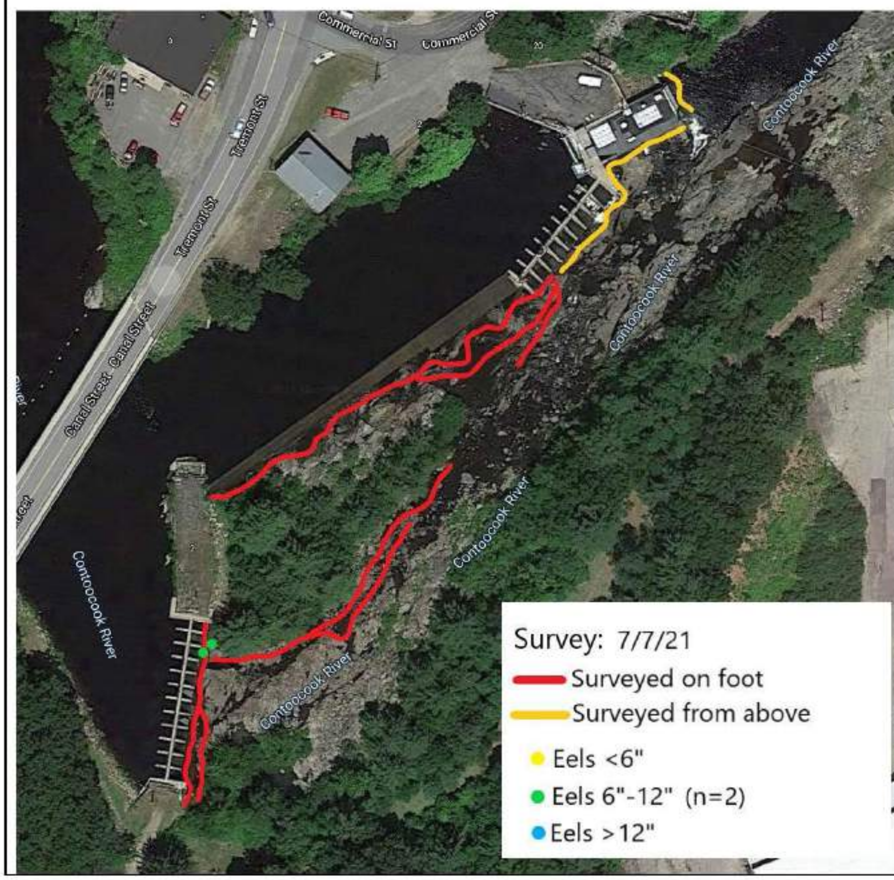
Search Summary: Surveyed from above. 21:35-21:40. Still pretty ineffective. NO EELS OBSERVED.



PLF Diversion Spillway, Auxiliary Spillway, Main Spill and Tailrace

Conditions: Weather today was hot with rain moving in in the future. Survey was overcast with no rain. Flow over dam was considerably less as compared to last week, most likely a result of hydro turbines back online. Conditions the same as when the electrofishing survey was conducted on 7/6. CNG, MJP

Search Summary: Surveyed Diversion, Auxiliary and partial Main Spillways on foot, the remaining Main and Tailrace from above 21:45-22:10. Much less spill and flow as compared to last week. Slower moving water made survey much more effective from a visibility standpoint. Survey from above still relatively ineffective. Units generating. Two 6"-12" eels observed at the north end of the diversion spillbays. Point of origin for the majority of spill/flow coming from the diversion spillway is leakage on this northern end.



EXTRAORDINARY EVENT/NONCONFORMITY REPORT

EE/NC Report Number: 21- 1

Project Name: Briar Hydro, Contoocook River Upstream Eel Nighttime Visual Surveys, 24534.003

Code: 5, No Sample

Date: 7/14/21

Originator: Name: Christian Gagne

Nighttime eel surveys postponed until flows decrease. Spill is very high at all survey locations making visual surveys completely ineffective.

York Dam

Problem:

Briar Eel Post Night Search Summary 7-14-21 (EENC1).Docx 2/22/2022

PLF Diversion Spillway

PLF Auxiliary Spillway

Briar Eel Post Night Search Summary 7-14-21 (EENC1).Docx 2/22/2022

PLF Main Spillway

Briar Eel Post Night Search Summary 7-14-21 (EENC1).Docx 2/22/2022

[illegible]

Recommendation: [illegible]

Signature: ____________ [illegible]

Project Manager: Name ____________

Signature: ____________

Quality Assurance: Name ____________

Response: ____________

Signature: ____________

Project Manager: Name ____________

Report Filed: ____________

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Distribution List of Copies: ____________

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Briar Hydro- Contoocook River Eel Nighttime Visual Eel Survey Summary

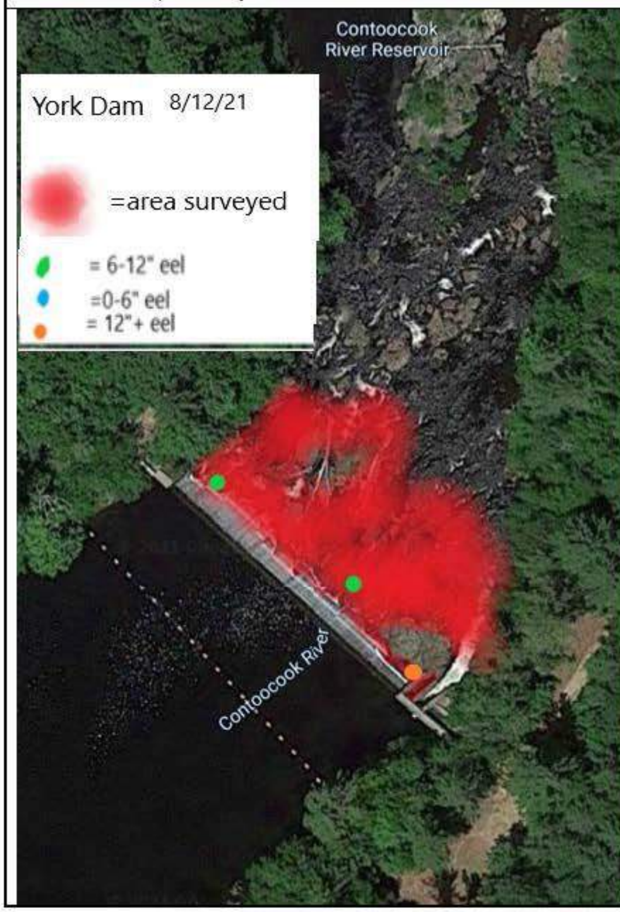
Search Summary for: *Briar Hydro- Contoocook River*

Search Date: 8/12/21

York Dam

Conditions: Weather today was partly cloudy. High temperature was 92. Moon was a waxing crescent with new moon on 8/8/21. 17% lunar illumination. Short heavy rain prior to survey. All normal survey areas were accessible as in previous surveys. TP, JC

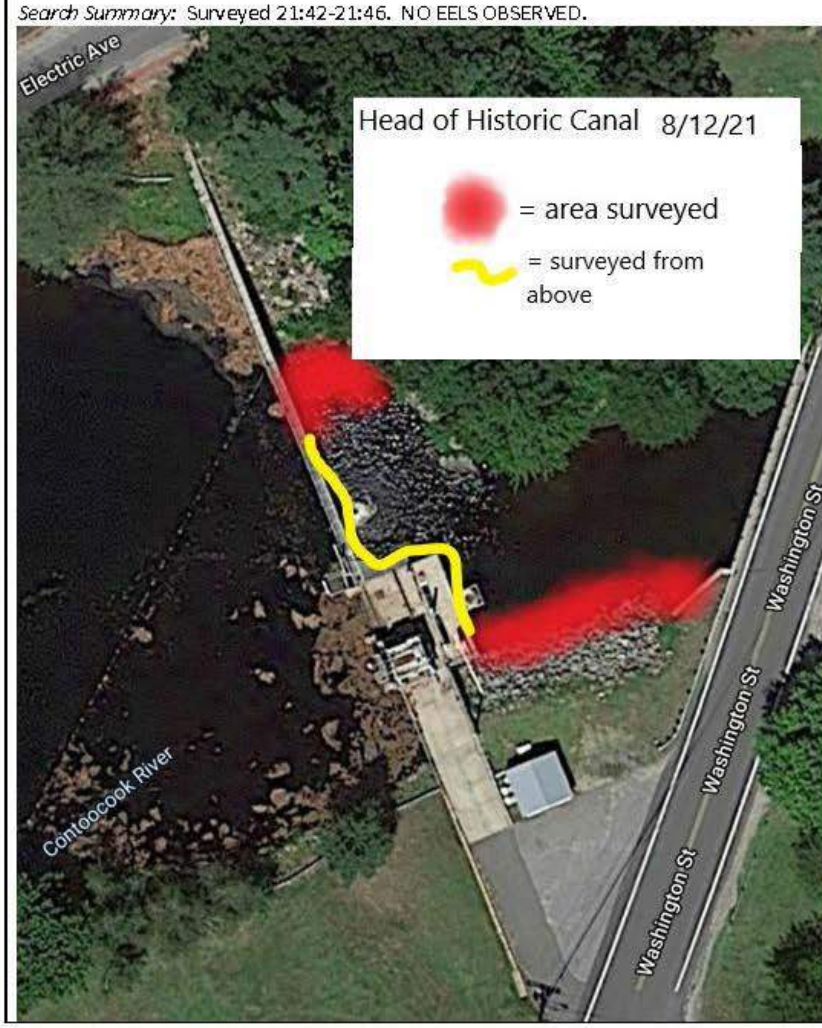
Search Summary: Surveyed 20:55-21:38:15. 3 EELS OBSERVED. One 12"+, and two 6-12"



Head of Historic Canal

Conditions: Weather today was partly cloudy. High temperature was 92. Moon was a waxing crescent with new moon on 8/8/21. 17% lunar illumination. Short heavy rain prior to survey. All normal survey areas were accessible as in previous surveys. TP, JC

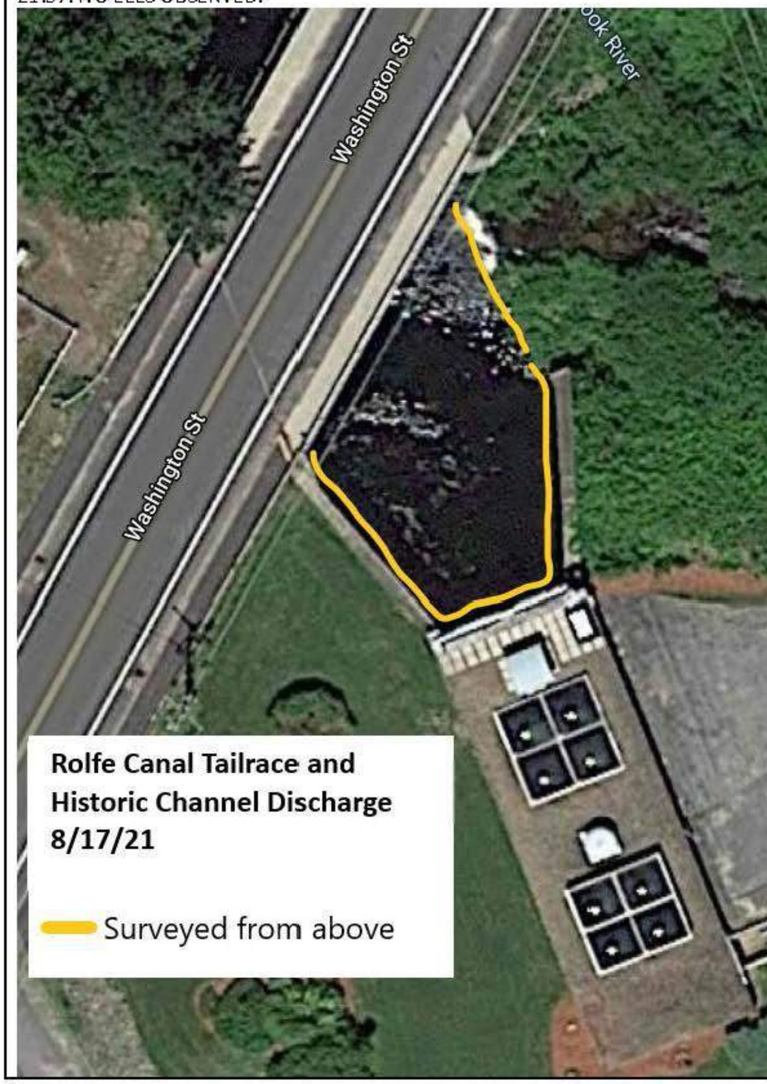
Search Summary: Surveyed 21:42-21:46. NO EELS OBSERVED.



Rolfe Canal Tailrace and Historic Channel Discharge

Conditions: Weather today was partly cloudy with high temps in the low 80s. Moon was a waning gibbous with 71% Illumination. TP, JC

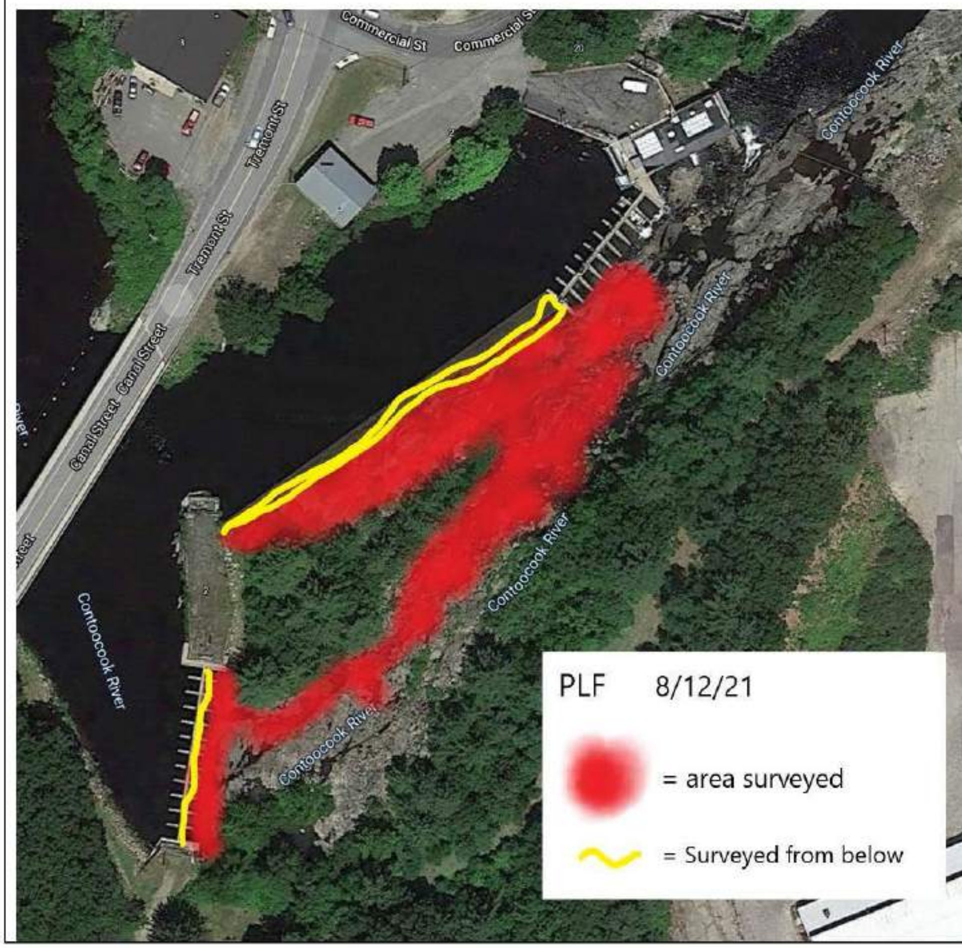
Search Summary: 4th and final Rolfe Canal Tailrace survey occurred on 8/17/21. Surveyed from 21:51 – 21:57. NO EELS OBSERVED.



PLF Diversion Spillway, Auxiliary Spillway, Main Spill and Tailrace

Conditions: Weather today was partly cloudy. High temperature was 92. Moon was a waxing crescent with new moon on 8/8/21. 17% lunar illumination. Short heavy rain prior to survey. All normal survey areas were accessible as in previous surveys. TP, JC

Search Summary: Surveyed 21:50-22:23. NO EELS OBSERVED.



Appendix B. Field summary notes from electrofishing effort at Rolfe Canal and PLF during July and August 2021

Briar Hydro- Contoocook River Eel Electrofishing Survey Summary

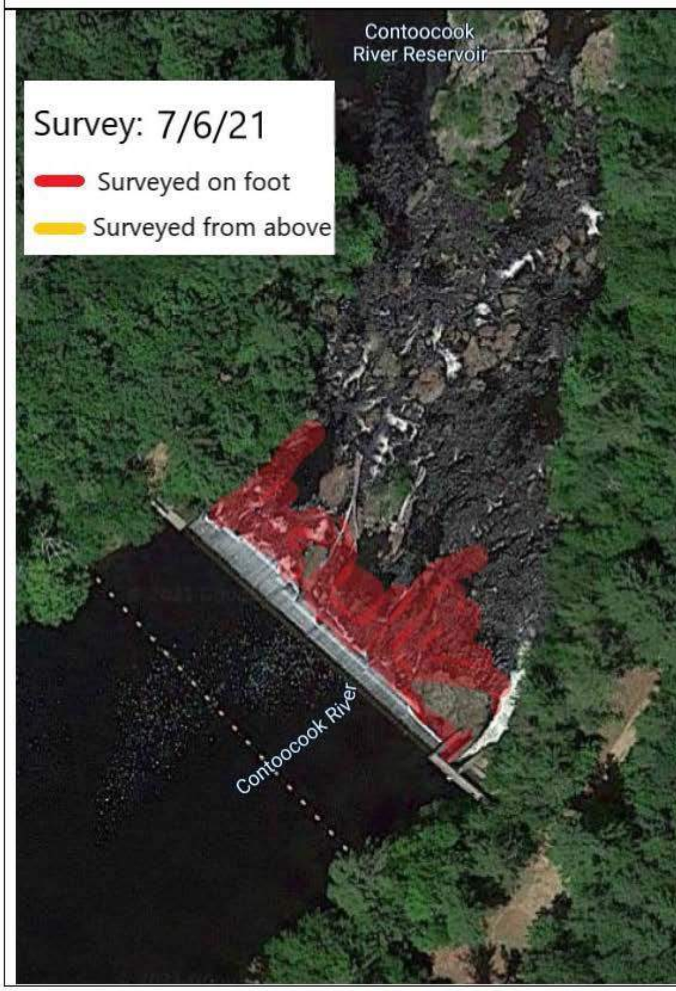
Search Summary for *Briar Hydro- Contoocook River*

Search Date 7/6/21

York Dam

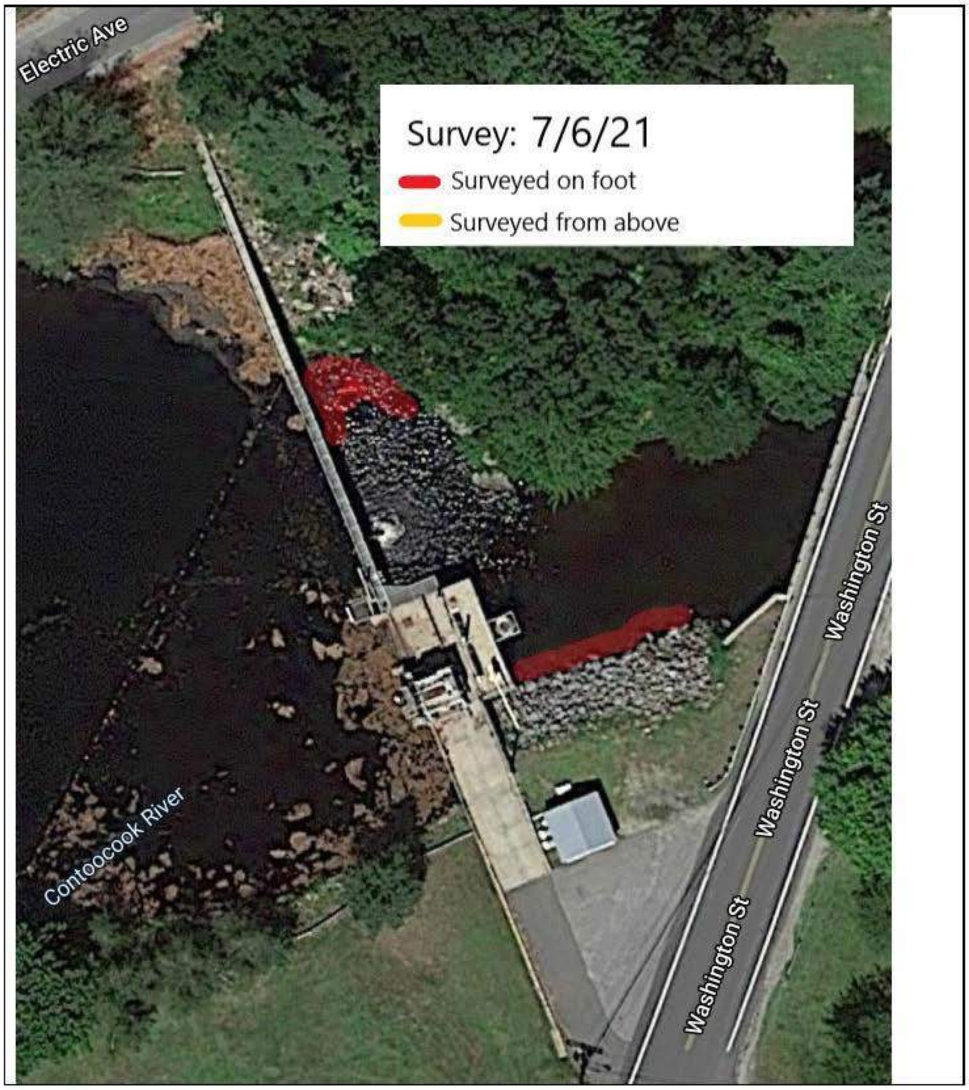
Conditions: Hot and humid. Much less flow as compared to the night surveys preceding this. This is due to the briar running their hydro units. CNG, MJP

Search Summary: Surveyed 10:48-11:12. 525 seconds. 80Hz, 450v. NO EELS OBSERVED.



Head of Historic Canal

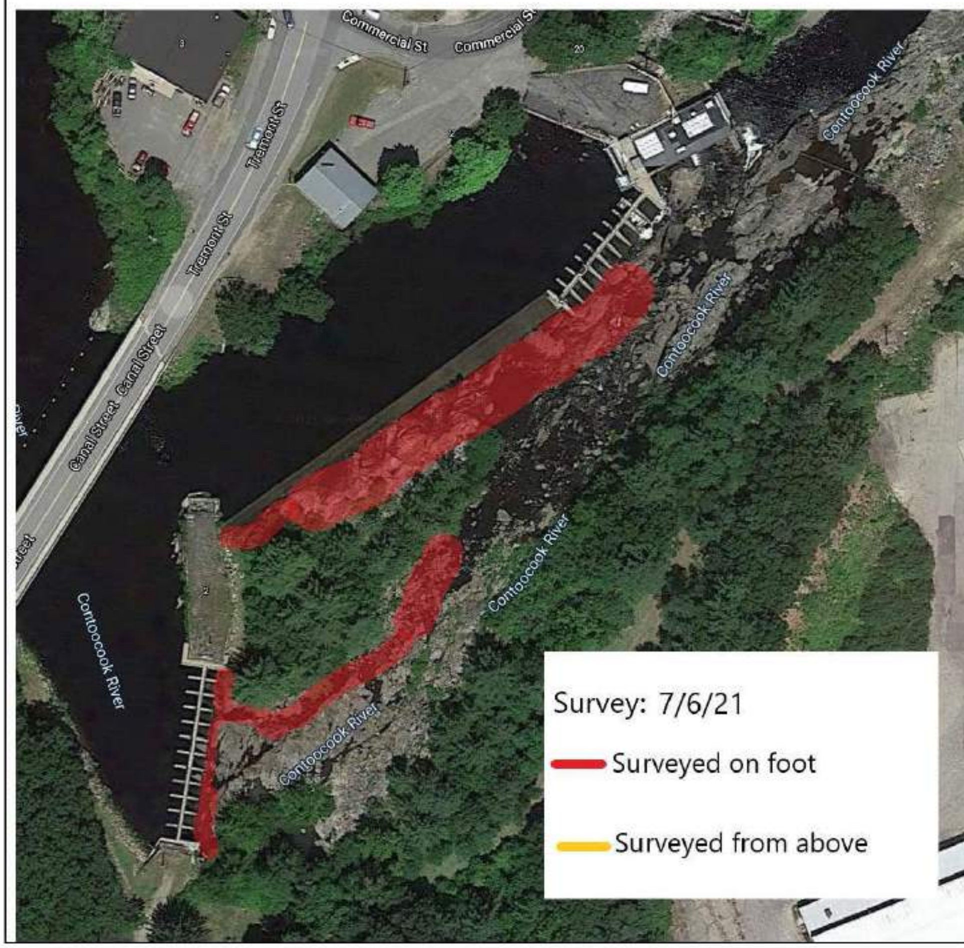
Conditions: Hot and humid. Much less flow as compared to the night surveys preceding this. This is due to the briar running their hydro units. CNG, MJP *Search Summary:* Surveyed 11:24-11:34. 185 seconds. 80Hz, 450v. NO EELS OBSERVED.



PLF Diversion Spillway, Auxiliary Spillway, Main Spill and Tailrace

Conditions: Hot and humid. Much less flow as compared to the night surveys preceding this. This is due to the briar running their hydro units. CNG, MJP

Search Summary: Surveyed 11:50-12:47. 1078 seconds. 80Hz, 450v. NO EELS OBSERVED.



Briar Hydro- Contoocook River Eel Electrofishing Survey Summary

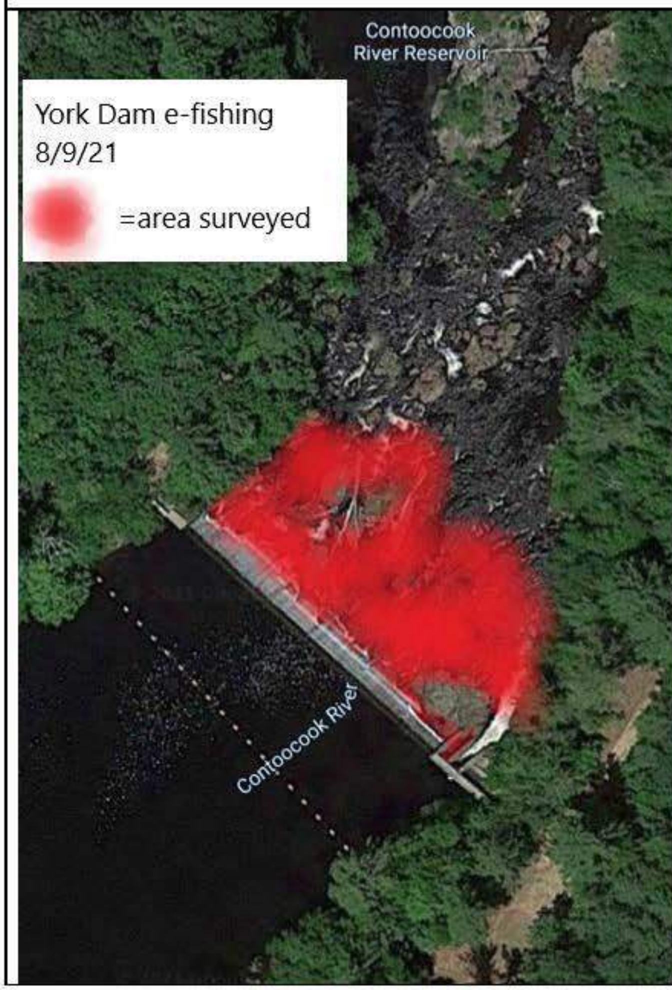
Search Summary for: *Briar Hydro-Contoocook River*

Search Date: 8/9/21

York Dam

Conditions: High of 80 degrees F. Fairly minimal flow over the dam. Plenty of water coming through the waste gate. Entire dam surveyable TP, JC

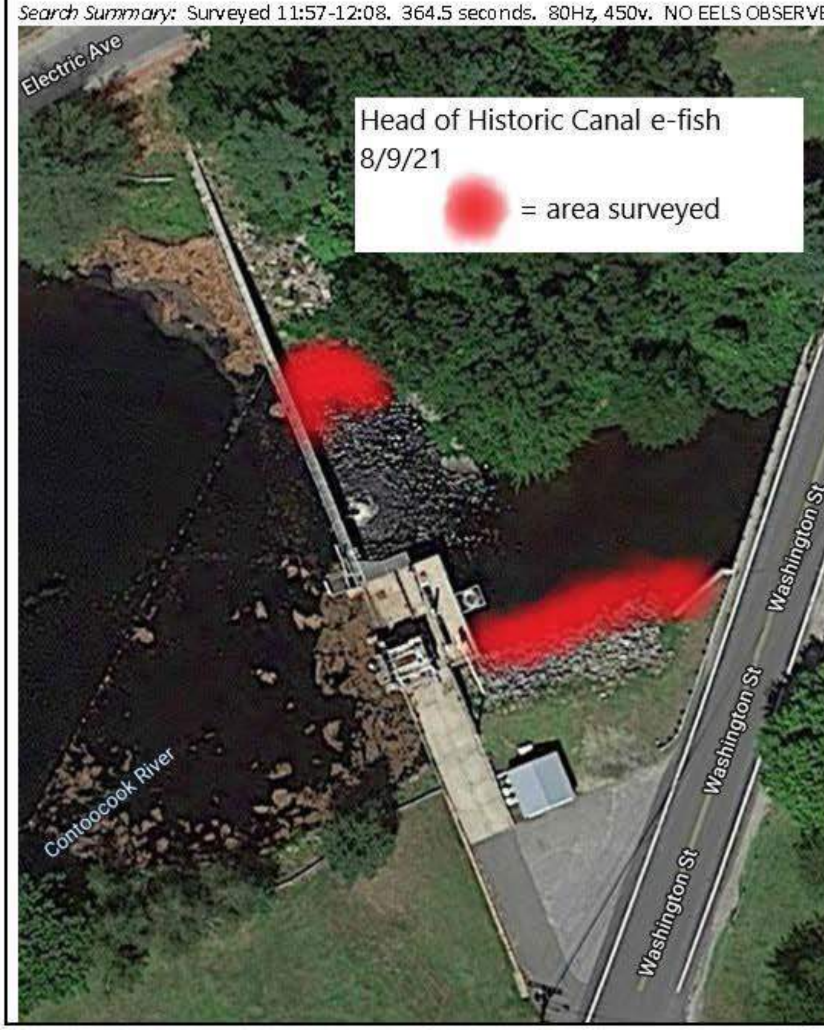
Search Summary: Surveyed 10:45-11:15. 887.9 seconds. 80Hz, 450v. NO EELS OBSERVED.



Head of Historic Canal

Conditions: High of 80 degrees F. Fairly minimal flow. TP, JC

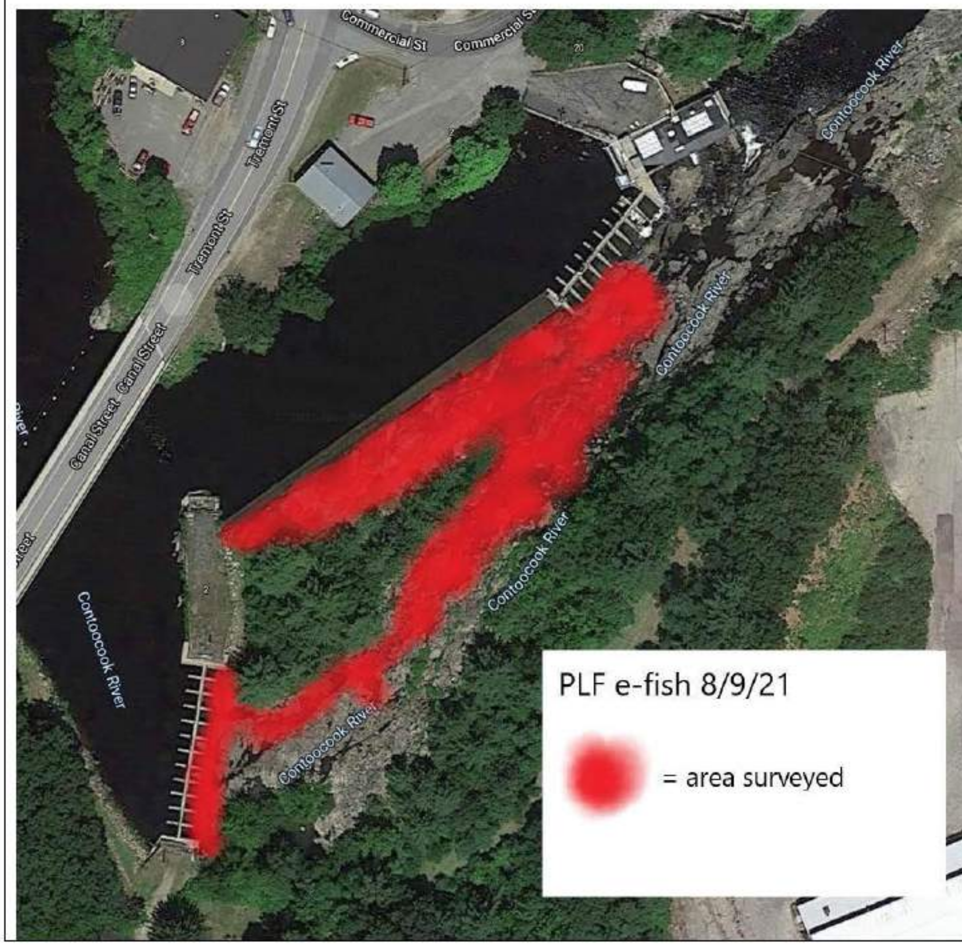
Search Summary: Surveyed 11:57-12:08. 364.5 seconds. 80Hz, 450v. NO EELS OBSERVED.



PLF Diversion Spillway, Auxiliary Spillway, Main Spill and Tailrace

Conditions: High of 80 degrees F. Fairly minimal flow. TP, JC

Search Summary: Surveyed 12:55-13:35. 762.9 seconds. 80Hz, 450v. NO EELS OBSERVED.



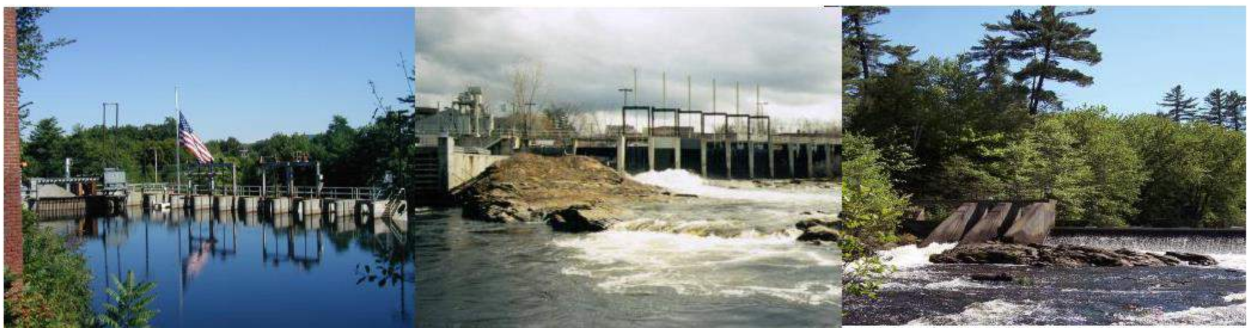
Downstream Fish Passage Survival Study

Briar Hydro Associates

Penacook Lower Falls
Hydroelectric Project
Project No. 3342

Penacook Upper Falls
Hydroelectric Project
Project No. 6689

Rolfe Canal
Hydroelectric Project
Project No. 3240



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NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

March 2022

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1 Introduction and Background

Briar Hydro Associates (Briar Hydro or Licensee) is in the process of relicensing the Rolfe Canal (FERC No. 3240), Penacook Upper Falls (PUF; FERC No. 6689), and Penacook Lower Falls (PLF; FERC No. 3342) Hydroelectric Projects (Project; collectively, Projects) with the Federal Energy Regulatory Commission (FERC or Commission). The Projects are located on the Contoocook River in Boscawen and Concord, New Hampshire. PLF sits at river mile 0 of the Contoocook River, above the confluence with the Merrimack River. The Upper Penacook and Rolfe Canal Projects are located upstream at river miles 1.0 and 2.0, respectively.

The current Project licenses were issued by the Federal Energy Regulatory Commission (FERC or Commission) in accordance with the Commission's delegated authority under the Federal Power Act on November 17, 1982 (PLF) and December 5, 1984 (Rolfe Canal and PUF). By FERC order the original April 17, 2018 license expiration for PLF was extended from October 31, 2022 to November 30, 2024 and matching the expiration for the Rolfe Canal and PUF Projects. Briar Hydro is pursuing a new license for the three Projects through the Commission's Traditional Licensing Process (TLP).

In response to requests provided by the resource agencies as part of the TLP process, Briar Hydro prepared a Preliminary Study Plan (PSP). The intent of the PSP was that the goals, methodology, scope, and schedule would be refined in consultation with interested stakeholders, as necessary. Briar Hydro distributed a copy of the PSP to representatives from the representatives from the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFGD) and the New Hampshire Department of Environmental Services (NHDES) on December 14, 2020. Following receipt and consultation related to comments on the PSP, Briar Hydro prepared a Revised Study Plan (RSP) which was finalized in March 2021 and filed with FERC on July 6, 2021. This Downstream Fish Passage Survival Study was conducted in support of obtaining a new license for the Project.

2 Goals and Objectives

The goal of this study was to estimate project-specific and cumulative effects of the Projects on the survival of emigrating diadromous species that pass through the Projects' turbines.

The objectives of this study were to:

- conduct a desktop turbine survival study for the full suite of diadromous species and life stages through all of the Projects' turbines[1];
- calculate total project survival for each project using empirical or derived routing data and turbine survival model results; and
- calculate cumulative survival through all of the Projects.

3 Study Area

The study area for the Downstream Fish Passage Survival Study included the Rolfe Canal, PUF, and PLF powerhouses and associated structures, including the intake structures.

4 Methodology

This study utilized the Turbine Blade Strike Analysis (TBSA) desktop tool to estimate passage survival/mortality rates for juvenile alosines at the Rolfe Canal, PUF and PLF Projects. The TBSA Tool was developed by the U.S. Fish and Wildlife Service, Region 5 Fish Passage Engineering Group (Towler and Pica 2018). TBSA incorporates the turbine blade strike equations originally developed by the Idaho National Engineering Laboratory (Franke et al. 1997) and allows users to input site-specific information to inform a Monte Carlo simulation that probabilistically models turbine and non-turbine route fish passage mortality.

As part of this effort, TBSA models were developed for each of the three Projects. The full set of potential downstream passage routes at each Project formed the framework for the station-specific passage survival estimates. Potential passage routes at each Project include spill, downstream bypass facilities or a single Kaplan turbine unit. This TBSA analysis focused specifically on the adult and juvenile life stages for American shad and river herring. Available length information from the Merrimack River watershed was used to inform those species models.

For the purposes of this analysis it was assumed that downstream fish passage was distributed among the available passage routes proportional to flow. Seasonal flows and distribution to those passage routes were determined using the flow duration curves provided in the Briar Hydro's Pre-Application Document (PAD). Flows considered as representative for the spring diadromous fish passage period were determined

[1] In their original study requests the USFWS, NMFS, and NHFGD indicated that in the event findings from the American Eel Downstream Passage Study were inconclusive with regards to passage survival then Briar Hydro should incorporate American eel into the Downstream Fish Passage Survival Study. Since field data collected from radio-tagged adult American eels allowed for the direct estimation of project-specific and cumulative passage at the Projects, Briar Hydro did not include eels as a target species of this desktop analysis.

using the flow duration curve for the month of May, whereas flows considered as representative for the fall diadromous fish passage period were determined using the October curve. For both the spring and fall seasons, exceedance flow values of 25%, 50%, and 75% were evaluated. Estimates of passage mortality at all non-turbine downstream passage routes (e.g., spill or downstream bypasses) were obtained based on observations from the spring 2021 adult river herring radio telemetry study. Estimates of passage mortality at Project turbines were calculated directly by the TBSA tool following input of unit-specific values (i.e., type, runner diameter, number blades, runner height, discharge, head, and rotational speed).

Once values related to passage route utilization, turbine characteristics, and estimates of non-turbine passage mortality were entered into the TBSA model, a fish population size (i.e., 10,000 individuals), a value of the mean length of the modeled population, and a value of the standard deviation for the population mean length were identified.

The TBSA simulation resulted in an estimate of turbine strike probability, an estimate of bypass failure, and an estimate of the percentage of the user-specified population which successfully passed downstream of a Project. Taken as a joint probability, these three estimates collectively provided an estimate of cumulative passage survival for the full set of Projects (i.e., downstream passage).

4.1 Required Model Inputs

The following information was required for the development of desktop models to address downstream passage survival for alosine species at Rolfe Canal, PUF, and PLF:

- Mean body length and associated standard deviation for anticipated outmigrating populations of adult river herring, adult American shad, and juvenile alosines;
- Inflow for the downstream passage season for spring (i.e., May) and fall (i.e., October) migrants for the 75%, 50%, and 25% exceedance conditions;
- Set of physical parameter values and estimates for characterizing each of the Kaplan turbine units housed in the three Project powerhouses;
- Calibrated values of lambda for use in the new downstream passage models for adult alosines (calibration to be informed using estimated turbine survival rates obtained during the 2021 field study for adult alosines);
- Proportional distribution among available downstream passage routes; and
- Non-turbine route-specific survival estimates (obtained from the 2021 field study).

5 Results

5.1 Target Species Body Size information

Body size information for the three target fish species/life stages included in this analysis are presented in Table 5-1. Species-specific length ranges were obtained from the recently completed Fish Passage Survival Study for the Lowell Hydroelectric Project (FERC No. 2790) located in the lower Merrimack River watershed[2]. For modeling purposes a normal distribution was assumed and the mid-point of each species-specific range was adopted as the mean value. An associated standard deviation was calculated as 1/3 the value between the mean and upper or lower bound of the range. This ensured that approximately 99% of the overall expected size range for each species or life stage would be considered.

Table 5-1. Size range (i.e., minimum – maximum), average, and associated standard deviation for target diadromous fish species in the Merrimack River watershed

Species	Minimum (inches)	Maximum (inches)	Average (inches)	Std. Dev.
River herring (Adult)	9	13	11	0. 7
American shad (Adult)	15	23	19	1.3
Juvenile Alosine	2	6	4	0.7

5.2 Project Inflow Conditions

In order to model passage survival under low, medium, and high flow conditions, representative monthly flow duration curves were collected from the PAD. The month of May was chosen to represent spring flows, and October was used to represent fall flows. Values for the 25%, 50%, and 75% exceedance conditions were considered as part of this analysis and are presented in Table 2.

Table 5-2. Contoocook River inflow at Rolfe Canal, PUF, and PLF for the 25%, 50%, and 75% exceedance condition during the spring (May) and fall (October) fish passage periods

Percent Exceedance	Spring (cfs)	Fall (cfs)
25	2,200	800
50	1,750	450
75	1,050	250

[2] FERC Accession No. 20211101-5277

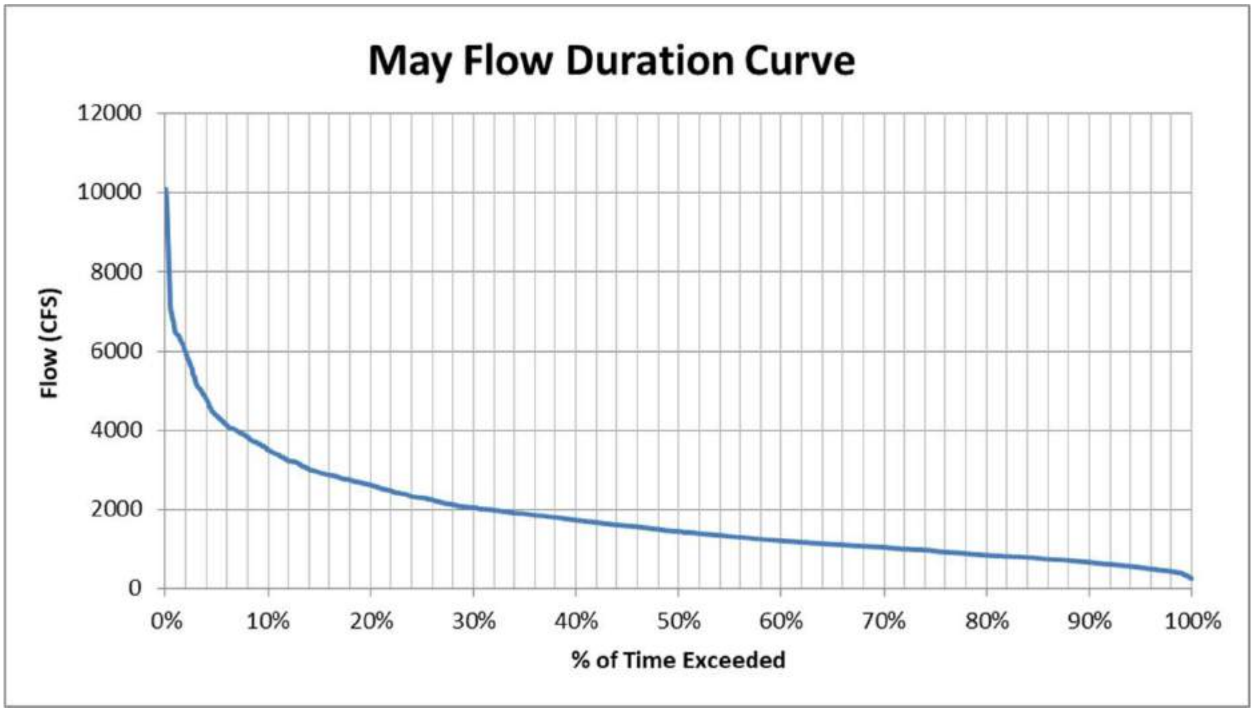


Figure 60-37: Flow duration curve for the month of May on the Contoocook River.

Note: Reproduced from Project PAD

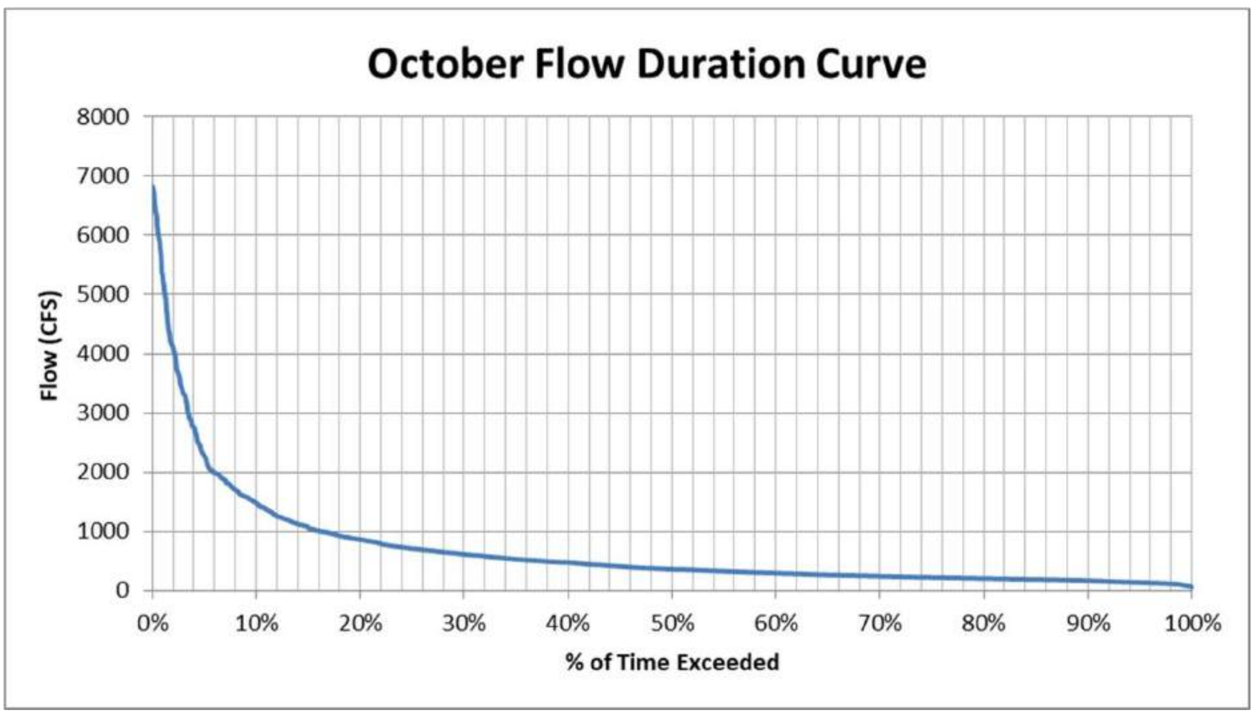


Figure 60-38: Flow duration curve for the month of October on the Contoocook River.

Note: Reproduced from Project PAD

5.3 Project Turbine Parameters

Table 5-3 provides a summary of the descriptive parameters for each of the Kaplan turbines in operation at each of the three Project powerhouses. A single Kaplan style turbine is operated at each to the three Briar Hydro Projects on the Contoocook River. Runner diameter (~9.8 ft), number of blades (n = 5), and maximum discharge are identical among the three stations. Rotational speed varied among Projects (131- 150 rpm). Trash rack spacing at each of the three Projects is 3.5 inches or greater.

Table 5-3. Characteristics of Project turbines in operation at the Rolfe Canal, PUF, and PLF powerhouses

	PLF	PUF	Rolfe Canal
Turbine Type	Kaplan	Kaplan	Kaplan
Runner Diameter (ft)	9.8	9.8	9.8
Number of Blades	5	5	5
Turbine Discharge (cfs)	2,000	2,000	2,000
Discharge at Optimum Efficiency (cfs)	1,300	1,525	1,375
Net Head (ft)	36	24	36
Speed (rpm)	131	138	150
Turbine Efficiency (%)	93.8	92.5	92.4
Trash Rack Clear Spacing (inches)	3.625	3.5	3.5

5.4 Calibration of Lambda

In addition to the turbine parameters described above, the strike mortality correlation factor, lambda (λ) is also required to run simulations of downstream fish passage survival using the USFWS TBSA Tool. Typically, it is recommended that a starting lambda value of 0.2 be used for alosine species, but in this case, lambda was calibrated using the site-specific survival rate obtained during the 2021 adult alosine telemetry study. Although telemetry-based survival data were only collected for adult river herring, these data were also used as a surrogate to calibrate a lambda value to model adult American shad passage survival. Models for juvenile alosines utilized the recommended lambda value of 0.2. To accomplish the lambda calibration with observations from the 2021 field telemetry study for adult herring, multiple simulations were run which held the project-specific turbine parameters and fish population characteristics constant while allowing the correlation factor to vary. These simulations were run until a value of lambda was identified which produced a TBSA estimate of turbine passage survival equivalent (within 1%) to that observed during field study conducted during 2021. The resulting values for lambda used as part of this analysis for PLF, PUF, and Rolfe Canal are presented in Tables 5-4, 5-5, and 5-6, respectively.

Table 5-4. Correlation factor values (λ) used to calibrate turbine passage component of TBSA models for PLF

Fish Species (life stage)	Field-derived Turbine Survival Rate	Correlation Factor (λ)	Resulting TBSA Turbine Survival Rate
River herring (Adult)	71.1% (95% CI = 56.4%-82.4%)	0.6	72.1%
American shad (Adult)	-	0.6Ŧ	-
Juvenile Alosine	-	0.2*	-

Ŧ Calibrated River herring correlation factor was used
*As no field-derived estimate of juvenile alosine survival was available, the standard USFWS value of λ =0.2 was used

Table 5-5. Correlation factor values (λ) used to calibrate turbine passage component of TBSA models for PUF

Fish Species (life stage)	Field-derived Turbine Survival Rate	Correlation Factor (λ)	Resulting TBSA Turbine Survival Rate
River herring (Adult)	82.4% (95% CI = 57.3%-94.2%)	0.35	83.3%
American shad (Adult)	-	0.35Ŧ	-
Juvenile Alosine	-	0.2*	-

Ŧ Calibrated River herring correlation factor was used
*As no field-derived estimate of adult shad or juvenile alosine survival was available, the standard USFWS value of λ =0.2 was used

Table 5-6. Correlation factor values (λ) used to calibrate turbine passage component of TBSA models for Rolfe Canal

Fish Species (life stage)	Field-derived Turbine Survival Rate	Correlation Factor (λ)	Resulting TBSA Turbine Survival Rate
River herring (Adult)	50.0% (95% CI = 20.0%-80.0%)	0.98	49.6%
American shad (Adult)	-	0.98Ŧ	-
Juvenile Alosine	-	0.2*	-

Ŧ Calibrated River herring correlation factor was used
*As no field-derived estimate of adult shad or juvenile alosine survival was available, the standard USFWS value of λ =0.2 was used

5.5 Passage Route Distribution

Downstream passage survival analyses were assembled under the assumption that fish routed among available passage routes proportional to flow. Table 5-7 summarizes the distribution of water at each of the three Projects under each of the seasonal inflow conditions presented in Table 5-2. For PLF and PUF, it was assumed that the bypass was operated normally with 25 cfs passing through, while at the Rolfe Canal, a minimum of 100 cfs was assumed to constantly pass via spill, or through the gate at the York dam. Inflow of up to 2,000 cfs was assumed pass via each of the Projects single Kaplan turbines. Any inflow in excess of the downstream bypass and powerhouse was assumed to pass downstream via spill. Additionally, if inflows did not amount to enough water to operate the turbine unit (i.e., less than 200 cfs), it was assumed that all water was passed via a combination of spill and the downstream bypass, if applicable.

Table 5-7. Distribution of inflow at the three Projects under the 25%, 50%, and 75% exceedance conditions during the spring and fall fish migration periods

	Condition	Inflow (cfs)	Discharge (cfs)			Distribution (%)		
			Turbine	Bypass	Spill	Turbine	Bypass	Spill
PLF	Spring - 25% Exceedance	2,200	2,000	25	175	90.9%	1.1%	8.0%
	Spring - 50% Exceedance	1,750	1,725	25	0	98.6%	1.4%	0.0%
	Spring - 75% Exceedance	1,050	1,025	25	0	97.6%	2.4%	0.0%
	Fall - 25% Exceedance	800	775	25	0	96.9%	3.1%	0.0%
	Fall - 50% Exceedance	450	425	25	0	94.4%	5.6%	0.0%
	Fall - 75% Exceedance	250	225	25		90.0%	10.0%	0.0%
PUF	Spring - 25% Exceedance	2,200	2,000	25	175	90.9%	1.1%	8.0%
	Spring - 50% Exceedance	1,750	1,725	25	0	98.6%	1.4%	0.0%
	Spring - 75% Exceedance	1,050	1,025	25	0	97.6%	2.4%	0.0%
	Fall - 25% Exceedance	800	775	25	0	96.9%	3.1%	0.0%
	Fall - 50% Exceedance	450	425	25	0	94.4%	5.6%	0.0%
	Fall - 75% Exceedance	250	225	25	0	90.0%	10.0%	0.0%
RC	Spring - 25% Exceedance	2,200	2,000	5	195	90.9%	0.2%	8.9%
	Spring - 50% Exceedance	1,750	1,645	5	100	94.0%	0.3%	5.7%
	Spring - 75% Exceedance	1,050	945	5	100	90.0%	0.5%	9.5%
	Fall - 25% Exceedance	800	695	5	100	86.9%	0.6%	12.5%
	Fall - 50% Exceedance	450	345	5	100	76.7%	1.1%	22.2%
	Fall - 75% Exceedance	250	0	5	245	0.0%	2.0%	98.0%

5.6 Non-Turbine Passage Mortality Rates

Estimation of project passage survival for the theoretical populations of adult and juvenile alosines evaluated as part of this study with the USFWS TBSA model required user-defined input to characterize survival of individuals passing downstream via any non-turbine passage routes. To support this analysis, empirical field-derived passage rates for adult river herring were available from the 2021 field evaluation of downstream passage at Rolfe Canal, PUF, and PLF. The bypass and spill survival/mortality rates observed during that study were utilized during TBSA model construction for adult river herring, adult American shad, and juvenile alosines as part of this evaluation. A summary of non-turbine passage mortality rates for adult river herring at Rolfe Canal, PUF, and PLF is provided in Table 5-8.

Table 5-8. Field-derived (adult herring) or assumed (adult shad/juvenile alosine) non-turbine route mortality rates for species/life stages at the three Projects

	Fish Species (life stage)	Bypass	Spill	Notes
PLF	River herring (Adult)	10.5%	1.0%	No fish passed via spill at PLF in telemetry study. Used an average of PUF and RC spill mortality.
	American shad (Adult)	10.5%	1.0%	Used adult river herring rates as surrogate
	Juvenile Alosine	10.5%	1.0%	Used adult river herring rates as surrogate
PUF	River herring (Adult)	4.7%	0.0%	
	American shad (Adult)	4.7%	0.0%	Used adult river herring rates as surrogate
	Juvenile Alosine	4.7%	0.0%	Used adult river herring rates as surrogate
Rolfe Canal	River herring (Adult)	NA	2.0%	
	American shad (Adult)	NA	2.0%	Used adult river herring rates as surrogate
	Juvenile Alosine	NA	2.0%	Used adult river herring rates as surrogate

5.7 TBSA Model Results

Species-specific body size information, turbine parameters, assumed passage route distribution information, and available non-turbine survival rates were combined using the TBSA Tool to generate estimates of passage survival for adult river herring, adult American shad, and juvenile alosines. Estimates were generated for a high flow condition (i.e., 25% exceedance condition), mid flow condition (i.e., 50% exceedance condition) and a low flow condition (i.e., 75% exceedance condition). Results are presented in Tables 5-9 (adult river herring), 5-10 (adult American shad), and 5-11 (juvenile alosines). Cumulative survival reflecting passage at all three Projects is presented in Table 5-12. It is important to note that for adult river herring and adult American shad, only the spring flow conditions were used in the models. For juvenile alosines, only the fall flow conditions were used. These time periods correspond with the biological timing of downstream migration for each of the species and life stages assessed in this analysis. During the lowest flows assessed for the fall time period (i.e., for juvenile alosines), the Rolfe Canal turbine was assumed to be off due to a lack of adequate flow. For all flow conditions assessed for the spring time period (i.e., for adult river herring and adult American shad), all project turbines were assumed to be operating as there would be enough water for the turbines to be on.

At Rolfe Canal, the highest estimate of whole station survival for adult river herring (58.9%) occurred under the mid flow condition (i.e., 50% exceedance condition), whereas the highest estimate of whole station survival for adult shad (29.9%) and juvenile herring (97.8%) occurred under the lowest flow condition (i.e., 75% exceedance condition; Table 5-9). At PUF, the highest estimate of whole station survival for adult river herring (84.9%) and adult shad (75.2%) occurred at the highest flow condition (i.e., 25% exceedance condition) whereas the highest estimate of whole station survival for juvenile alosines (96.7%) occurred at the lowest flow condition (Table 5-10). At PLF, the highest estimate of whole station survival for each species/life stage occurred during the highest flow condition: 73.9%, 61.1% and 96.2% survival for adult river herring, adult shad, and juvenile alosines, respectively (Table 5-11). Overall, the estimates of whole station survival for an individual species or life stage at a single Project did not vary greatly across the set of flow conditions considered during this analysis with the difference in survival remaining within 5%. The higher estimate of survival at Rolfe Canal under the low flow condition is likely attributable to the limited inflow not being great enough to run the turbine (i.e., all fish would pass via spill).

The cumulative survival for adult and juvenile alosines (i.e., the percent survival for a species/life stage passing downstream at Rolfe Canal, PUF, and PLF) is presented in Table 5-11. Under a median flow condition, cumulative survival was estimated at 35.7% for adult river herring (58.9% * 83.3% * 72.7% = 35.7%), 9.4% for adult American shad (23.8% * 71.7% * 55.0% = 9.4%) and 89.5% for juvenile alosines (96.9% * 96.1% * 96.1% = 89.5%).

Table 5-9: TBSA estimated rates for turbine strike, bypass failure, and passage survival for adult river herring under a high, mid, and low flow condition at the three Briar Hydro Projects

	Condition	Turbine Strikes	Bypass Failures	Survival
PLF	Spring - 25% Exceedance	26.0%	0.1%	73.9%
	Spring - 50% Exceedance	27.3%	0.0%	72.7%
	Spring - 75% Exceedance	27.0%	0.2%	72.8%
PUF	Spring - 25% Exceedance	15.0%	0.1%	84.9%
	Spring - 50% Exceedance	16.8%	0.0%	83.3%
	Spring - 75% Exceedance	16.3%	0.2%	83.6%

	Condition	Turbine Strikes	Bypass Failures	Survival
Rolfe Canal	Spring - 25% Exceedance	43.8%	0.2%	56.1%
	Spring - 50% Exceedance	40.9%	0.2%	58.9%
	Spring - 75% Exceedance	41.6%	0.1%	58.3%

Table 5-10: TBSA estimated rates for turbine strike, bypass failure, and passage survival for adult American shad under a high, mid, and low flow condition at the three Briar Hydro Projects

	Condition	Turbine Strikes	Bypass Failures	Survival
PLF	Spring - 25% Exceedance	38.7%	0.2%	61.1%
	Spring - 50% Exceedance	44.9%	0.1%	55.0%
	Spring - 75% Exceedance	41.8%	0.2%	58.0%
PUF	Spring - 25% Exceedance	24.7%	0.1%	75.2%
	Spring - 50% Exceedance	28.3%	0.0%	71.7%
	Spring - 75% Exceedance	26.1%	0.0%	73.8%
Rolfe Canal	Spring - 25% Exceedance	73.1%	0.4%	26.5%
	Spring - 50% Exceedance	76.0%	0.2%	23.8%
	Spring - 75% Exceedance	70.0%	0.1%	29.9%

Table 5-11: TBSA estimated rates for turbine strike, bypass failure, and passage survival for juvenile alosines under a high, mid, and low flow condition at the three Briar Hydro Projects

	Condition	Turbine Strikes	Bypass Failures	Survival
PLF	Fall - 25% Exceedance	3.3%	0.4%	96.2%
	Fall - 50% Exceedance	3.8%	0.1%	96.1%
	Fall - 75% Exceedance	2.9%	1.4%	95.8%
PUF	Fall - 25% Exceedance	3.5%	0.1%	96.4%
	Fall - 50% Exceedance	3.0%	0.9%	96.1%
	Fall - 75% Exceedance	2.1%	1.2%	96.7%
Rolfe Canal	Fall - 25% Exceedance	3.1%	0.3%	96.7%
	Fall - 50% Exceedance	2.6%	0.5%	96.9%
	Fall - 75% Exceedance	0.0%	2.2%	97.8%

Table 5-12: TBSA estimated cumulative survival for adult and juvenile alosines

Species	Condition	Cumulative Survival
Adult river herring	Spring - 25% Exceedance	35.2%
	Spring - 50% Exceedance	35.7%
	Spring - 75% Exceedance	35.5%
Adult American shad	Spring - 25% Exceedance	12.2%
	Spring - 50% Exceedance	9.4%

Species	Condition	Cumulative Survival
	Spring - 75% Exceedance	12.8%
Juvenile alosines	Fall - 25% Exceedance	89.7%
	Fall - 50% Exceedance	89.5%
	Fall - 75% Exceedance	90.6%

6 Summary

A desktop-based evaluation of downstream passage success for adult river herring, adult American shad, and juvenile alosines was conducted in support of the FERC relicensing of the Rolfe Canal, PUF, and PLF Projects. Passage success was evaluated using the TBSA Tool developed by the U.S. Fish and Wildlife Service, Region 5 Fish Passage Engineering Group (Towler and Pica 2018). This TBSA analysis incorporated the turbine blade strike equations originally developed by the Idaho National Engineering Laboratory (Franke et al. 1997) as well site-specific information pertaining to the three Briar Hydro Projects to inform a Monte Carlo simulation that probabilistically modeled turbine and non-turbine route fish passage mortality. Additionally, in this analysis, the field derived survival rates for turbine passage of adult river herring were used to calibrate the correlation coefficient (lambda) to more specifically tailor the results to each specific Project turbine.

Three different flow conditions were assessed for project survival for adult and juvenile alosines. High flow (i.e., 25% exceedance), mid flow (i.e., 50% exceedance) and low flow (i.e., 75% exceedance) conditions were selected from a May flow duration to be representative for the spring outmigration period (i.e., adult river herring and American shad) and from October to be representative for the fall outmigration period (i.e., juvenile alosines). These months reflect the potential flow conditions expected during the time period that each species/ life stage is known to migrate downstream. Available inflow was also used to determine how discharge and fish would distribute to the available passage routes at each Project. Survival rates were estimated for each species at each of the flow conditions at all three Projects. These estimated survival rates were then used to determine a rate of cumulative passage success across all three Projects combined.

Estimated survival rates for adult river herring ranged from 72.7% to 73.9% at PLF, 83.3% to 84.9% at PUF, and 56.1% to 58.9% at Rolfe Canal. These desktop estimates are comparable for adult herring passage at PLF (75.9% [95% CI = 65.8-83.7%]) PUF (91.8% [95% CI = 82.9-96.3%]). However, the desktop estimate for adult river herring at Rolfe Canal (58.9% under a median flow condition) was much lower than observed during the field study which was estimated at 91.4% (95% CI = 80.9-96.4%). Operational conditions during the 2021 field study at Rolfe Canal resulted in a period of time where the station turbine was offline for a large percentage of the passage period which resulted in a significant portion of adult herring passing downstream via the York Dam bypass. Turbine passage survival was estimated for radio tagged adult river herring at Rolfe Canal at 50% providing support for the lower desktop evaluation estimate which assumed a higher percentage of adult herring would attempt downstream passage via the Rolfe Canal turbine. Additionally, the field derived adult river herring survival rate of 50% through the Rolfe Canal turbine was based on a limited sample size (n = 8) which increases the uncertainty for the estimate. For American shad, depending on flow, estimated survival rates ranged from 55.0% to 61.1% at PLF, 71.7% to 75.2% at PUF, and 23.8% to 29.9% at Rolfe Canal. For juvenile alosines, depending on flow, estimated survival rates ranged from 95.8% to 96.9% at PLF, 96.1% to 96.7% at PUF, and 96.7% to 97.8% at Rolfe Canal. These passage survival rates then translate to a cumulative three Project rate ranging from 35.2% to 35.7% for adult river herring, 9.4% to 12.8% for American shad, and 89.5% to 90.6% for juvenile alosines.

A full summary of the methodology and results from the adult silver-phase American eel study conducted during the fall of 2021 is provided in the *American Eel Downstream Passage Study Report*. Project-specific estimates of passage survival for American eels were 92.1% (95% CI = 82.3-96.7%) for Rolfe Canal, 84.8% (95% CI = 75.1-91.2%) for PUF, and 90.9% (95% CI = 82.9-95.4%) for PLF. This resulted in a cumulative estimated downstream passage survival of 71.0% (95% CI = 60.8-80.4%).

7 Variances from Approved Study Plan

The Downstream Fish Passage Survival Study was conducted following the methods described in the RSP which was finalized in March 2021 and filed with FERC on July 6, 2021.

8 References

Franke, G. F., D. R. Webb, R. K. Fisher, Jr., D. Mathur, P. N. Hopping, P. A. March, M. R. Headrick, I. T. Laczo, Y. Ventikos, and F. Sotiropoulos. 1997. Development of environmentally advanced hydropower turbine system design concepts. Prepared for U.S. Department of Energy, Idaho Operations Office.

Towler, B., J. Pica. 2018. Turbine Blade Strike Analysis freeware. Downloaded from: https://www.fws.gov/northeast/fisheries/fishpassageengineering.html

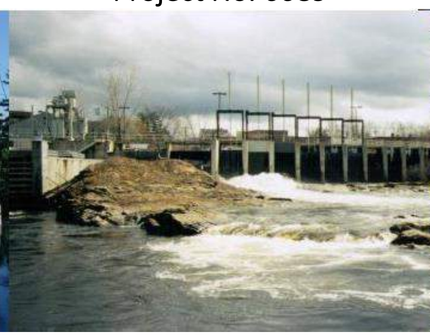
Mussel Survey Study

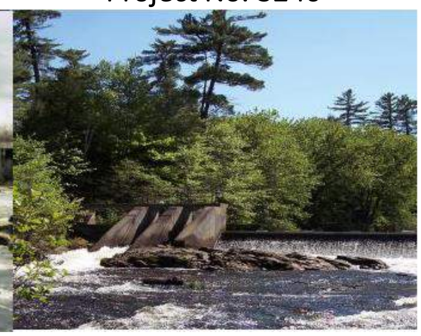
Briar Hydro Associates

Penacook Lower Falls
Hydroelectric Project
Project No. 3342

Penacook Upper Falls
Hydroelectric Project
Project No. 6689

Rolfe Canal
Hydroelectric Project
Project No. 3240





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NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

March 2022

Table of Contents

1 Introduction and Background

Briar Hydro Associates (Briar Hydro or Licensee) is in the process of relicensing the Rolfe Canal (FERC No. 3240), Penacook Upper Falls (PUF; FERC No. 6689), and Penacook Lower Falls (PLF; FERC No. 3342) Hydroelectric Projects (Project; collectively, Projects) with the Federal Energy Regulatory Commission (FERC or Commission). The Projects are located on the Contoocook River in Boscawen and Concord, New Hampshire. PLF sits at river mile 0 of the Contoocook River, above the confluence with the Merrimack River. The Upper Penacook and Rolfe Canal Projects are located upstream at river miles 1.0 and 2.0, respectively (Figure 1-1).

The current Project licenses were issued by the Federal Energy Regulatory Commission (FERC or Commission) in accordance with the Commission's delegated authority under the Federal Power Act on November 17, 1982 (PLF) and December 5, 1984 (Rolfe Canal and PUF). By FERC order the original April 17, 2018 license expiration for PLF was extended from October 31, 2022 to November 30, 2024 and matching the expiration for the Rolfe Canal and PUF Projects. Briar Hydro is pursuing a new license for the three Projects through the Commission's Traditional Licensing Process (TLP).

In response to requests provided by the resource agencies as part of the TLP process, Briar Hydro prepared a Preliminary Study Plan (PSP). The intent of the PSP was that the goals, methodology, scope, and schedule would be refined in consultation with interested stakeholders, as necessary. Briar Hydro distributed a copy of the PSP to representatives from the representatives from the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFGD) and the New Hampshire Department of Environmental Services (NHDES) on December 14, 2020. Following receipt and consultation related to comments on the PSP, Briar Hydro prepared a Revised Study Plan (RSP) which was finalized in March 2021 and filed with FERC on July 6, 2021. This report describes the Freshwater Mussel Study conducted in support of obtaining a new license for the Project.

19. Goals and Objectives

The goal of this study was to characterize the existing freshwater habitat and assess the presence and relative distribution freshwater mussels (unionids) in the Rolfe Canal, PUF and PLF Project areas. The specific objective for this study was to survey the Project areas for suitable mussel habitat as well as determine relative species composition, relative distribution and abundance of freshwater mussel species.

20. Study Area

Between September 13 and September 15, 2021, Normandeau Associates Inc. (Normandeau) conducted a qualitative freshwater mussel survey of the Rolfe Canal, PUF and PLF impoundments, the York Dam bypass reach, and a section of the Contoocook River immediately downstream of PLF (Figure 3-1). The Contoocook River is a major tributary to the Merrimack River and has a total drainage area of approximately 765 square miles. Table 3-1 provides a list of the survey reaches, their total distance and maximum number of survey sites within each. Survey sites were selected at representative locations within a particular Project area reach. Several study variances to the study design described in the RSP occurred such that Transects 3, 6 and 8 were not surveyed due to unsuitable habitat or steep contours along the river margins in these sections of the river (see Section 7). Transect locations were adjusted to assess the representative habitat observed in each project reach.

Table 3–48. Freshwater Mussel Survey Sites for Rolfe Canal, PUF, and PLF Project Areas.

• Reach	• Reach Length (Miles)	• No. Survey Reaches
Downstream of PLF	0.2	2
PUF to PLF	0.4	2
Rolfe Canal to PUF	0.6	0
York Dam Bypass Reach	0.8	3
Rolfe Canal Impoundment	9.0	12
Total Reach	11.0	19

21. Methodology

The mussel survey was conducted following the RSP and the survey plan submitted to NHFGD on September 3, 2021 (Appendix A). Normandeau malacologist Joseph Snavely led the field survey as permitted under a New Hampshire Scientific Collectors Permit, dated September 8, 2021 and included in Appendix B. A total of 19 survey locations were established no more than five meters from the shorelines of the impoundment margins in water depths up to five feet. At each survey site a transect was placed, 50 m in length and oriented parallel to the shoreline with focus on the area's most likely to be affected by water level fluctuation. Each transect was divided into five consecutive 10 m long segments (i.e., segment 1, segment 2, segment 3, segment 4, and segment 5). Transects were surveyed in a downstream to upstream fashion and segments were labeled accordingly. Segment 1 was positioned at the most downstream point and segment 5 at the upstream limit.

Normandeau surveyors used visual and tactile search methods to survey the river bottom substrate in each 10 m segment. More survey time was spent in high quality habitats and less in poor quality habitat. Surveyors assessed the available substrate habitat at each transect location as well as searched for evidence of live mussel populations. The width of each 50-meter segment depended on river contours and bathymetry (maximum width of 5 meters). Live mussels were collected from the substrate surface for identification and processing (e.g., rare or state-listed species). Substrate was hand-swept to approximately 1-2 inches depth to locate semi-burrowed individuals. Given the amount of ledge and bedrock habitat, shoreline locations were selected in the field based on the likelihood to support mussels.

Representative photographs of all live species observed were recorded. Any state-listed species were measured (shell length) and photographed. Common species such as the eastern elliptio (*Elliptio complanata*) were identified and counted at depth but not measured. Relative abundances were recorded in areas of highly dense mussel communities. No quantitative sampling or excavations were conducted during the survey effort. The mussels captured during the surveys were kept in mesh dive bags in free-flowing river water until they were identified and processed. Out of water and holding times were minimized to reduce stress to the mussels prior to returning them to their transect segment. The mussels found in the survey area were placed back into river bottom substrate, anterior end down in the approximate areas where they were collected.

Data recorded from the survey included total time searched in each transect; substrate composition (visual percentage based on Wentworth scale); water depth (nearest foot); and other notable features. Field data sheets are provided in Appendix C. Photographs of the survey transects are provided in Appendix D. The resume of Joseph Snavely, who prepared the survey plan, oversaw the survey, and prepared this report, is provided in Appendix E.

22. Results

The freshwater mussel survey occurred September 13-15, 2021. During the survey, the weather was sunny to partly cloudy. Air temperatures ranged from 66-78 ^{o}F. Water temperatures ranged between 63-64 ^{o}F. Water clarity was suitable for surveying for freshwater mussels, with visibility reaching up to two meters (m). Flows (as measured at USGS gage 01085500) were generally consistent, ranging between 1,030-1,290 cubic feet per second (cfs) over the course of the survey effort.

In general, the habitat conditions present in the impoundment and downstream in the tailwaters of the Project areas are conducive to mussels. Overall, the 19 transects surveyed displayed a wide range in mussel assemblages present in the project operation area. After approximately 17.4 hours of search effort, a total of 2,738 live freshwater mussels were collected, comprised of four live species and one species observed as shell material only (Table 5-1). The dominant species, eastern elliptio (*Elliptio complanata),* represented approximately 97.8% of the total catch (Table 5-1). A total of 53 live brook floater (*Alasmidonta varicosa)*, a New Hampshire state endangered species, were observed during this effort from three locations. However, it is likely that they are present at other locations. A. *varicosa* represented approximately 1.9% of the total catch. The triangle floater (*Alasmidonta undulata*; n=5) and eastern floater (*Pyganodon cataracta*; n=3) represented 0.3% of the total catch combined. Shell material of eastern lampmussel (*Lampsilis radiata)* was observed throughout the Rolfe Canal Impoundment but no live individuals were observed during the survey. The overall Catch Per Unit Effort (CPUE) for this survey was calculated at 157.4 mussels per hour of search effort (Table 5-1).

5.1 Habitat

Habitat varied throughout the survey areas, but most transects provided ideal burrowable substrates for mussels. Some areas of these reaches were deeply incised and suitable habitat for freshwater mussels along the shallow river margins was not likely to be affected by water level fluctuation.

5.1.1 Downstream of Penacook Lower Falls

Two transects were placed downstream of PLF; Transect 1 and Transect 2. Substrate at these locations was dominated by gravel, cobble and boulder (Figure 5-1; Table 5-2). Boulder was present on Transect 2 in segments 1 through 4. Silt was only present on Transect 2, segment 5. Sand was present throughout Transects 1 and 2.

5.1.2 Penacook Upper Falls to Penacook Lower Falls

The RSP identified three transects within the reach between PLF and PUF: Transect 3, Transect 4, and Transect 5. Transect 3 was not surveyed due to the lack of appropriate habitat. This area was deeply incised and not likely to be affected by changes in water level. Substrate at Transect 4 consisted of silt, sand, gravel and cobble in each transect segment. Transect 5 contained similar substrates, such as cobble, gravel, sand and silt. Substrate in segment 5 was comprised of 100 percent silt whereas segment 4 was almost entirely cobble. No silt was observed in segments 1 or 2 (Figure 5-1; Table 5-2).

5.1.3 Rolfe Canal to Penacook Upper Falls

Two transects, Transect 6 and Transect 8, were identified in the RSP for the section of the Contoocook River between PUF and Rolfe Canal. Based on visual observations in the field, neither location was surveyed due to the lack of appropriate habitat. These areas were deeply incised and provided little to no suitable freshwater mussel habitat along the river margins.

5.1.4 York Dam Bypass Reach

The RSP identified three transects within the York Dam bypass reach: Transect 7, Transect 9, and Transect 10. Transect 7 was characterized as containing a mix of boulder, cobble, gravel, sand, and silt substrates. The presence of silt was limited to segment 4 (Figure 5-1; Table 5-2). Transect 9 was dominated by cobble with areas of gravel and sand observed in segments 1 and 2. Boulder and some bedrock substrate was observed in all five segments of Transect 9. Transect 10 contained a similar mix of substrate types to that observed in Transect 9 but contained a larger percentage of bedrock.

5.1.5 Rolfe Canal Impoundment

Transects 11 through 22 were positioned within the Rolfe Canal impoundment with Transect 11 located just upstream of the channel split to the Rolfe Canal gatehouse and York Dam bypass reach. Transect 22 was located at the upstream end of the impoundment, just downstream of the Penacook Road Bridge (Figure 3-1). Diversity of substrate types was greater for transects located towards the downstream end of the Rolfe Canal impoundment. Transects 11, 13, 15, and 16 were characterized with a mix of substrate types ranging from boulder to silt (Figure 5-1; Table 5-2). With the exception of Transect 21, at which some limited gravel substrate was observed, the transects in the upper half of the Rolfe Canal impoundment (i.e., Transects 17 to 22) were primarily silt substrate with some areas of sand (Figure 5-1; Table 5-2).

5.2 Unionid Community

Over 17.4 hours of survey effort were expended over 950 square meters of river bottom. During this time, a total of 2,738 live mussels were observed (Table 5-1) The CPUE was calculated at greater than 100 mussels observed per hour for over half the transects evaluated during this study (11 out of the 19 transects) indicating a robust mussel community (Table 5-3). The highest values of CPUE were recorded in the Rolfe Canal impoundment stations (Transect 10 through Transect 21). The average CPUE across all transects surveyed during this study was 157.4 mussels per hour of search effort (Table 5-3). Transect CPUE and mussel counts are graphically presented in Figures 5-2 and 5-3, respectively.

5.2.1 Downstream of Penacook Lower Falls

A total of 67 live mussels representing a single species (*E. complanata*) were observed at Transects 1 and 2 located in the section of the Contoocook River downstream of PLF (Table 5-4). The CPUE at survey transects downstream of PLF ranged between 38.8-40.0 mussels per hour of search time (Table 5-3).

5.2.2 Penacook Upper Falls to Penacook Lower Falls

Survey effort at Transects 4 and 5 yielded a total of 70 live mussels representing two species. Most live individuals (68 of the 70) were *E. complanata* with the remainder identified as *A. varicosa* (Table 5-4). An additional weathered *A. varicosa* shell was collected along Transect 4. CPUE was 4.0 mussels per hour at Transect 4 and 90.0 mussels per hour at Transect 5 (Table 5-3).

5.2.3 Rolfe Canal to Penacook Upper Falls

As noted above in Section 5.1.3, Transects 6 and 8 were not surveyed due to a lack of suitable freshwater mussel habitat along the channel margins in this section of the Project area.

5.2.4 York Dam Bypass Reach

A total of 160 live mussels representing four species were observed at Transects 7, 9, and 10 located within the York Dam bypass reach (Table 5-4). The majority of live mussels from that section of the Project areas were *E. complanata* (n = 104) and *A. varicosa* (n = 51). A limited number of live *A. undulata* (n = 4) and *P. cataracta* (n = 1) were also observed. All four species were observed at Transect 10 whereas observations at Transects 7 and 9 were limited to only *E. complanata*. The CPUE was higher at Transect 10 (111.8 mussels per hour) than at Transects 7 and 9 located towards the lower part of the York Dam bypass reach (3.8-30.9 mussels per hour; Table 5-3). The CPUE for Transect 10 was the highest for all sites located downstream of the Rolfe Canal impoundment.

5.2.5 Rolfe Canal Impoundment

A total of 2,438 live mussels representing three species were observed among the 12 transects located within the Rolfe Canal impoundment (Table 5-4). The majority (2,438 out of 2,441) of the live mussels were identified as *E. complanata.* A limited number of live *A. undulata* (n = 1) and *P. cataracta* (n = 2) were also observed. In addition to live specimens, a total of four freshly dead and five weathered *L. radiata* shells were observed along with limited numbers of weathered *A. undulata* (n = 1) and *P. cataracta* (n = 1). Live *E. complanata* was observed at each of the twelve transects ranging from a high of 530 individuals at Transect 17 to a low of one individual at Transect 22. Live specimens of *A. undulata* were observed at Transects 17 and 19 and of *P. cataracta* at Transect 19. When all live specimens are considered, CPUE was greater than 100 mussels per hour for each transect in the Rolfe Canal with the exception of Transects 19 and 22 (Table 5-3). Trends in CPUE were driven by the abundance of *E. complanata.*

23. Summary

Populations of unionid mussels exist in the shallow river margins throughout the surveyed reach which are likely to be affected by Project operations that result in a change in water surface elevation. Dense mussel beds were observed between one foot and five feet of water depth within 15 feet of the shoreline. Whereas most mussels observed were common species such as the eastern elliptio (*E. complanata*), several populations of the New Hampshire state endangered brook floater (*A. varicosa)* exist between the York Dam Bypass and the Penacook Upper Falls facilities.

One of the main trends observed during this survey was that CPUE was generally higher upstream of the Rolfe Canal where it ranged between 1.8 (Transect 22) and 572.9 (Transect 14) individuals per hour of search effort. Downstream of the York Dam Bypass, CPUE ranged from 3.8 (Transect 9) to 111.8 (Transect 10). Species richness was generally lower throughout the upstream impoundment. Species richness was highest at Transect 10 (four species) and Transect 19 (three species).

Based on observations during this survey, it is possible that habitat conditions within the York Dam bypass reach from the York Dam downstream to the confluence of the bypass reach and the Rolfe Canal tailwater channel replicate natural riverine conditions preferred by *A. varicosa* and its host fish[8]. Ideal conditions for *A. varicosa* are generally found in low to moderate flows with coarser substrates, but they can be observed in flow refuges in fast flowing streams (Nedeau 2008). The population of *A. varicosa* observed at Transect 10 was robust and healthy with several age classes observed. At Transect 10, the population of *A. varicosa* matched that of *E. complanata* in numbers, despite its being the dominant species in this river system. It is likely that conditions at Transect 10 are more favorable to *A. varicosa* than any other species in this reach. Individuals were also collected downstream at Transect 5 and it is likely that *A. varicosa* occupies this reach. Further surveys may help identify the extent of the *A. varicosa* population within these reaches.

A. undulata was detected in low numbers at Transect 10 and Transect 19, similarly to *P. cataracta*. *P. cataracta* was also observed during this survey in low numbers upstream of Rolfe Canal at Transects 17

[8] Host fish species for the brook floater include blacknose dace, longnose dace, golden shiner, pumpkinseed, slimy sculpin, yellow perch, and margined madtom.

and 19, as well as immediately downstream of the York Dam at Transect 10. These species likely exist in low numbers in these reaches. No live *L. radiata* were collected during this survey. Assemblages of *E. complanata* appeared healthy and prolific throughout the survey areas.

Project operations may potentially impact mussel populations that inhabit the shallow water (one to five foot) margins of the Contoocook River, including the state endangered brook floater. However, with the healthy mussel community of *A. varicosa*, observed within the York Dam bypass reach, these populations appear to have established themselves in a suitable habitat scenario. Deviations from the current operation of these facilities could have a potential impact on these populations.

24. Variances from Approved Study Plan

In the RSP, Normandeau proposed to survey a total of 22 sites along the Contoocook River. During the field survey effort, suitable habitat along the margins was not present at three locations. This led to the removal of Transect 3 from the PUF to PLF reach, Transect 6 and Transect 8 from the Rolfe Canal reach because of the steep shorelines and lack of evidence that suggests that mussels would be adversely effected in these reaches. Several sites were relocated due to access issues as well as the lack of suitable habitat while other site locations were adjusted due to the presence of dense assemblages of the state listed *A. varicosa*.

25. References

Survey Protocol for Assessment of Endangered Freshwater Mussels in the Allegheny River, Pennsylvania (Smith, et al. 2001)

Nedeau, E. J.2008. Freshwater Mussels and the Connecticut River Watershed. Connecticut River Watershed Council, Greenfield, Massachusetts. xvii+132 pp.

26. Appendices

Appendix A. NHFGD Scientific Collectors Permit

New Hampshire
Fish and Game Department

11 Hazen Drive, Concord, NH 03301-6500
Headquarters: (603) 271-3421
Website: www.WildNH.com

TDD Access: Relay NH 1-800-735-2964
Fax: (603) 271-1438
Email: info@wildlife.nh.gov

Scott R. Mason
Executive Director

September 8, 2021

TO WHOM IT MAY CONCERN:

Under the authority contained in RSA 214:29, permission is hereby granted to **Joseph C. Snavely**, Normandeau Associates Inc, 400 Old Reading Pike, Bldg A, Suite 101, Stowe, PA 19464 to temporarily possess all species of freshwater mussels from the Contoocook River and bypass channels as part of species documentation surveys for the Briar Hydro Associates FERC relicensing as described in the 'Application for Scientific License' dated August 30, 2021 and supporting documentation dated September 3, 2021.

* Mussels will be hand-captured and placed in mesh dive bags that are held in flowing river water until they are measured and photographed. No tissue samples will be collected. All mussels will be placed back in the sediment at the capture location following measurements and photographs.

* It is the responsibility of the permittee to obtain any additional state, federal and/or local permits and/or permissions necessary for the work described under this permit.

Subpermittees: Alan Frizzel, Erik Rydbek, Erik Feldotto, Chris Baker, Mike Mettler, Christian Gagne, Bryan Lees, Rich Bistline, Mike Polchlopek, Ben Griffith, Jamie O'Brien, Dillon McNulty

This permit, or a copy, shall be carried with the permittee while engaged in any activity allowed under this permit and shall be displayed to any New Hampshire Fish and Game Department Conservation Officer or employee upon request

This permit shall expire December 31, 2021, unless sooner revoked or rescinded. Under the transactions of this permit, the permittee shall submit a report documenting the disposition of all permitted animals to the Executive Director by January 31, 2022.

Scott R Mason

Scott R. Mason
Executive Director

SRM/bjc

cc: Law Enforcement
Nongame

Appendix B. Survey Plan.

NORMANDEAU ASSOCIATES
Environmental Consultants

September 3, 2021

Melissa Doperalski
Nongame and Endangered Wildlife Program
NH Fish and Game Department
11 Hazen Drive, Concord, NH 03301
603-271-0463

VIA EMAIL: Melissa.Doperalski@wildlife.nh.gov

Re: Briar Hydro Associates Facility FERC Relicensing –Mussel Survey
Contoocook River, Merrimack County, New Hampshire

Dear Ms. Doperalski:

Normandeau Associates, Inc. (Normandeau) is submitting this proposed freshwater mussel survey plan on behalf of Briar Hydro Associates in regard to the mussel surveys on the Contoocook River in Merrimack County, NH. These surveys were requested by USFWS and NHFGD as part of Briar Hydro Associates FERC Relicensing requirements for the Penacook Lower Falls, Penacook Upper Falls and Rolfe Canal Hydroelectric Projects (**Figure 1**). This study plan was prepared in order to seek your approval to conduct this survey on behalf of Briar Hydro. The survey sites are shown in greater detail on **Figure 2.** Normandeau was contracted by Briar Hydro Associates to conduct this mussel survey.

USFWS and NHFGD have indicated a concern that freshwater mussels may be impacted by plant maintenance operations on the Contoocook River and has requested that Briar Hydro Associates conduct a mussel survey within the impoundments to identify suitable mussel habitat as well as determine species composition, distribution and abundance of freshwater mussel species and to evaluate potential project effects on any present freshwater mussels.

This Survey Plan was developed following guidance provided in the Survey Protocol for Assessment of Endangered Freshwater Mussels in the Allegheny River, Pennsylvania (Smith, et al. 2001) and "Smith Protocols" (2001 and 2003). This Survey Plan was prepared by Joseph Snavely, a NHFGD and U.S. Fish and Wildlife Service (USFWS) qualified mussel surveyor in New Hampshire. Mr. Snavely will lead the field efforts and will be responsible for all mussel identification. It is anticipated that the mussel survey will be conducted in Summer/Fall of 2021.

The objectives of this survey are to:

- Identify whether any mussel (unionid) habitat and individuals are present in the survey sites;
- Assess the condition of available habit (e.g., substrate characteristics, water depth, unionid presence or absence); and
- Evaluate potential impacts to unionid communities.

Qualitative assessment methods will be used to evaluate the presence or absence and distribution of unionids, as well as substrate characteristics within the project area described in this survey plan.

METHODS

Normandeau proposes to conduct a qualitative freshwater mussel survey of the Rolfe Canal, PUF, and PLF impoundments, York Dam bypass reach, and section of the Contoocook River immediately downstream of PLF. The survey will be conducted between the dates of May 1 and September 30 and will consist of visual surveys of the river bottom by several biologists using mask and snorkel. Although the majority of the survey work is anticipated in shallow water (4 feet or less), the survey crew will be prepared to dive selected areas, if necessary.

Divers will use visual and tactile search methods to survey the stream bottom substrate. More survey time will be spent in high quality habitat and less in poor quality habitat. Live mussels will be collected from the substrate surface, with some substrate swept away to approximately 1-2 inches depth in order to locate semi-burrowed individuals.

Table 1 provides a list of the survey reaches, their total distance and the proposed maximum number of survey sites within each. Survey sites will be selected at representative locations within a particular Project area reach. Each survey site will be 50 meters in length and oriented parallel to the shoreline with focus on the area's most likely to be affected by water level fluctuations. Given the amount of ledge and bedrock habitat, shoreline location will be selected in the field based on the likelihood to support mussels. Project staff will survey each search location to assess habitat as well as search for evidence of live mussel populations. Mussel searches will be conducted using both visual and tactile search methods. The width of each 50 meter segment will depend on river contours and bathymetry (maximum width of 5 meters).

Table 1. Proposed Freshwater Mussel Survey Sites for Rolfe Canal, PUF, and PLF Project Areas

Reach	Reach Length (Miles)	No. Survey Reaches
Rolfe Canal Impoundment	9.0	12
York Dam Bypass Reach	0.8	2
Rolfe Canal to PUF[1]	0.6	3
PUF1 to PLF[2]	0.4	3
Downstream of PLF[2]	0.2	2
Total Reach	11.0	22

PUF[1] – Penacook Upper Falls
PLF[2] – Penacook Lower Falls

At each survey site, the crew will identify all live mussels observed and return them to the river bottom. Representative photographs of all live species observed will be recorded. Any state-listed species will be measured (shell length) and photographed. Common species such as the eastern elliptio (*Elliptio complanata*) will not be measured. Relative abundances will be recorded in areas of highly dense mussel communities. No quantitative sampling is proposed at this time.

The mussels found during the surveys will be kept in mesh dive bags in free flowing stream water until they are processed. Out of water and holding times will be minimized to reduce stress to the mussels and enhance survival. The mussels found in the survey area will be placed back into stream bottom substrate, anterior end down in the approximate areas where they were collected where they were collected.

Normandeau will prepare a draft and, subsequent to receipt of draft review comments, final reports describing the results of the surveys. This report will include a description of methodology, the survey conditions, substrate characteristics, and the data associated with the observed mussels. The following data will be collected for each survey reach and summarized in the survey report:

- Photographs of the survey sites;
- A minimum of one representative photo of each mussel species encountered will be taken for verification purposes;
- Time for each mussel search effort;
- Substrate composition of each survey site (visual percentage based on Wentworth scale;
- Estimate of aquatic vegetation;
- Water depth (meters);
- Water clarity;
- Mussel species, individual size (Federal or NH -listed species only - length, height, and width;
- to the nearest millimeter), sex (where applicable), and age (external annuli count);
- Mussel shells (classified as fresh dead, weathered dead, or relic shell);
- GPS locations of survey cell corners and mussel aggregation limits; and
- Other notable features.

If state or federal-listed species are detected during a portion of the survey effort, Normandeau will stop work and notify Briar Hydro, NHFGD and USFWS immediately.

If there are any questions, comments or concerns, please call me at (267) 644-8928.

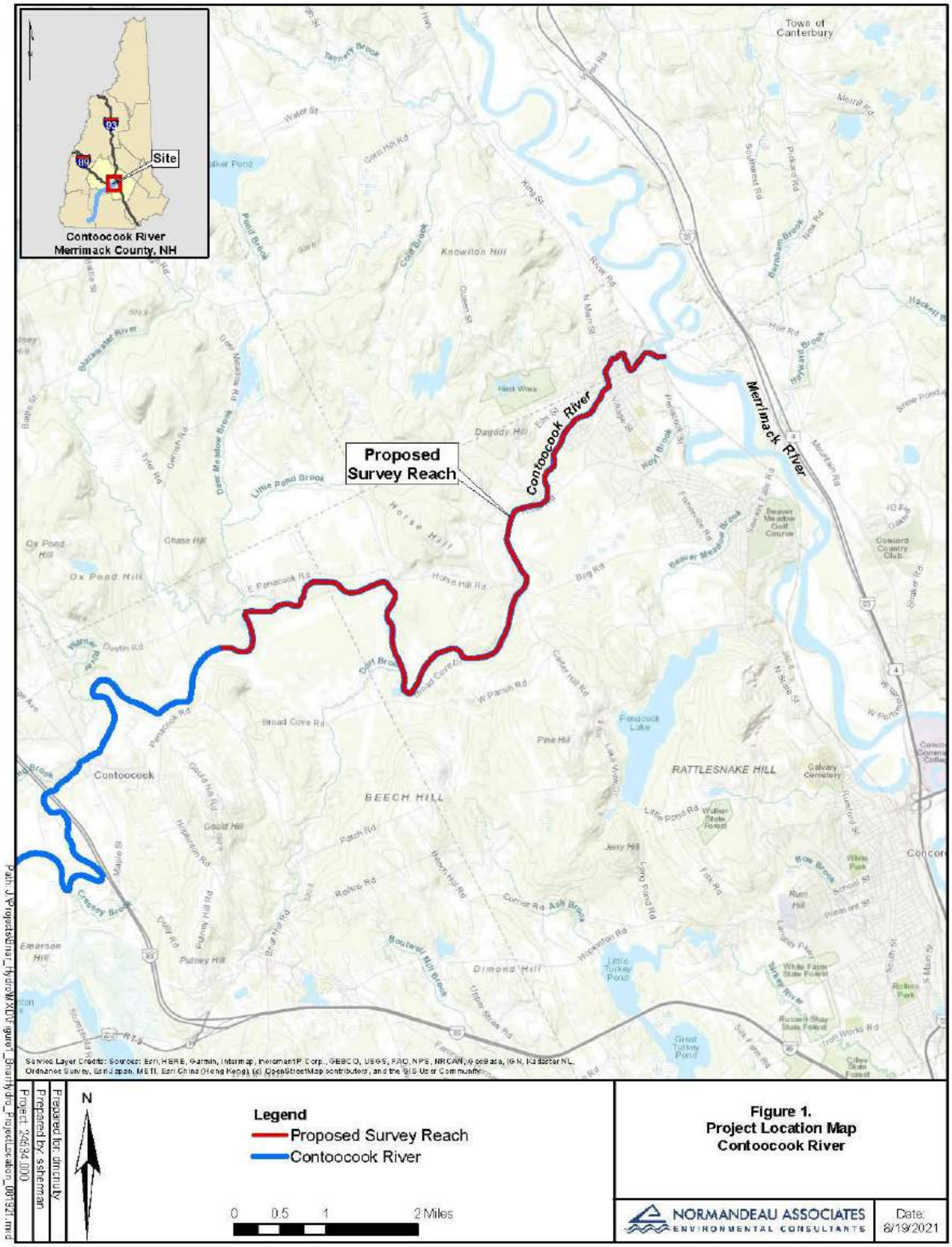
Sincerely,

Joseph C. Snavely
Task Manager

Attachments (3)

REFERENCES

Survey Protocol for Assessment of Endangered Freshwater Mussels in the Allegheny River, Pennsylvania (Smith, et al. 2001)


Contoocook River
Merrimack County, NH
Site
Proposed
Survey Reach
Contoocook River
Merrimack River
Legend
Proposed Survey Reach
Contoocook River
0 0.5 1 2 Miles
N
Figure 1.
Project Location Map
Contoocook River
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date:
8/19/2021
Prepared for: dmcnulty
Prepared by: ssherman
Project: 24834.000

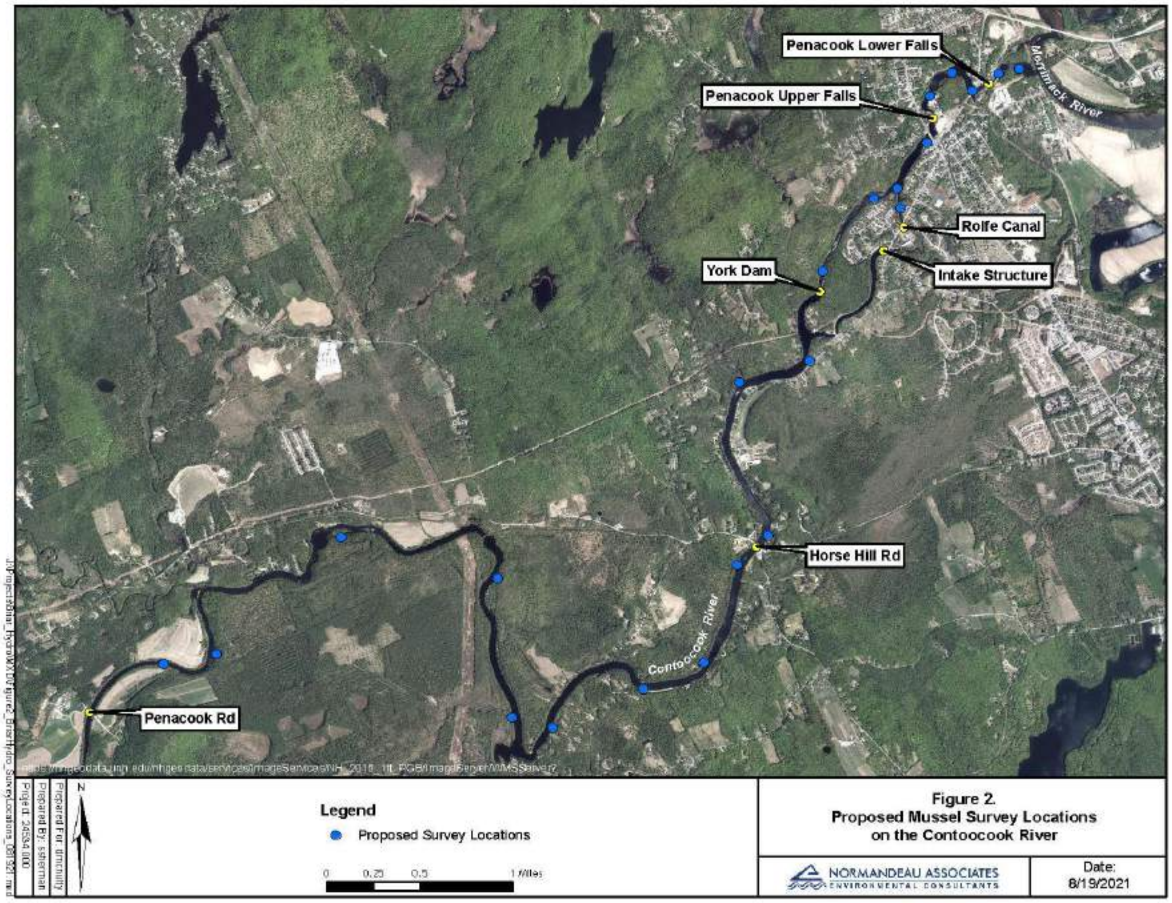


Figure 2.
Proposed Mussel Survey Locations
on the Contoocook River

Appendix C. Data Sheets

Date 13 Sept 2021

Project Name/No.: Briar Hydro 24534.000

Freshwater Mussel Data Sheet

Page 1 of 2

Crew: JCS, DMG, MP

River/Stream Name Contoocook State NH County

County River Mile Location/Town

Weather

Water Quality (T, pH, Flow, Cond, DO) Air Temp: 66-78°F

Survey Type (Semi-quan/Qual/Quan/Reconn): Water - 63-64°F

Comments Visibility ideal 2+ meters

	T/Q/Site[A]	Rep[B] X	Rep[B] Y	Species	L	A/J	Age	L/H/W	FD	WD	SF	Depth	Br	Bo	Cb	Gr	Sd	St	Cl	Other
1	T	1	1	ELCo	18	A/J		—				3'			40	40	20		10%	
2																			Algae	
3												Time 1040-1104 x2								
4															All Transect.					
5	T	1	2	ELCo	8	AJ		—				3			70	20	10		80%	
6	T	1	3	ELCo	3	AJ		—				3			40	40	20		Algae	
7	T	1	4	ELCo	2	A		—				3			60	30	10			
8	T	1	5	No Live	0	—		—				3								
9																				
10												Time 1240 - 1317 x2 = 74 Min								
11	T11	1		ELCo	27	AJ						4.5			60	30	10		70% SAV	
12		11	2	ELCO	18	AJ						4.5			30	50	20			
13				A. undulata	0	—		—		/										
14		11	3	ELCo	28	AJ						4.5			30	50	20			
15		11	4	ELCo	30	AJ						4.5			30	40	30			
16		11	5	ELCo	35	AJ.						4.5		20	30	20	30			
17																				
18								Time 1340 - 1410 x2 = 60 Min												
19	T12	1		ELCO	62	AJ						4.0					40	60	60% SAV	
20		12	2	ELCo	47	AJ						↓					40	60	60% SAV	
21		12	3	ELCo	11	AJ						↓					20	80	100% SAV	
22		12	4	ELCo	16	AJ						↓						100	20 LWD	
23		12	5	ELCo	24	AJ						↓							20 SWD	
24																		100	20 LWD	
25	T13	1		ELCo	26	AJ						4.5		15	10	35	20	20		
26		13	2	ELCO	94	AJ								25	25	20	20	10	20% LWD	
27				L. Radiata	0	—		—	/					35	30	25	10		~LWD	
28		13	3	ELCo	45	AJ														
29		13	4	ELCo	17	AJ								60		15	10	15	2-LWD	
30		13	5	ELCo	51	AJ								20	40	20	10	10		

Photo Log Notes

GPS Log Notes

A = Transect Number, Quadrat Number or Site ID B = Replicate or Quadrant

Freshwater Mussel Data Sheet

Date 13 Sept 2021
Project Name/No.: Briar Hydro 24534.000
Page 2 of 2
Crew: JCS, DMC, MP
River/Stream Name Contoocook State NH County
County River Mile Location/Town
Weather
Water Quality (T, pH, Flow, Cond, DO) Air Temp: water 63-64
Survey Type (Semi-quan/Qual/Quan/Reconn):
Comments

Time 1521-15:52

	T/Q/Site[A]	Rep[B] X	Rep[B] Y	Species	L	A/J	Age	L/H/W	FD	WD	SF	Depth	Br	Bo	Cb	Gr	Sd	St	Cl	Other
1	T-14-1			ELCO	63	AJ						3					60	40	40% SAV	
2																				
3		14-2		ELCO	74	AJ											60	40	50 SAV	
4		14-3		ELCO	26	AJ											60	40	60 SWD " "	
5				LARA	0	—	—		—	—	|						6			
6		14-4		ELCO	45	AJ											60	40	50 SAV	
7		14-5		ELCO	88	AJ											60	40	60 SWD 50 SAV	
8																				
9	T 15-1			ELCO	24	AJ						4.5		50	30		10			
10		15-2		ELCO	45	AJ						↓		30	30	20	10	10		
11		15-3		ELCO	83	AJ								10	50	30	10			
12				LARA	—	—		—	—	2										
13		15-4		ELCO											30	20	20	30	50 SWD	
14		15-5		ELCO	7	AJ						↓			20	20	20	40		
15																				
16																				
17																				
18																				
19																				
20																				
21																				
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				

Photo Log Notes

GPS Log Notes

A = Transect Number, Quadrat Number or Site ID B = Replicate or Quadrant

Date 14 September 2021

Project Name/No.: Briar Hydro 24534.000

Freshwater Mussel Data Sheet

Page 1 of 3

Crew: JCS, DML, MP

River/Stream Name Contoocook

State NH

County

River Mile

Location/Town

Weather

Air Temp:

Water Quality (T, pH, Flow, Cond, DO)

Survey Type (Semi-quan/Qual/Quan/Reconn):

Comments T-17 ~ 5m offshore

Many mussels Burrowed @ T-16

	T/Q/Site^A	Rep^B X	Rep^B Y	Species	L	A/J	Age	L/H/W	FD	WD	SF	Depth	Br	Bo	Cb	Gr	Sd	St	Cl	Other
1	T16-1			Time 850-922 x 2 = 64 min																
2		16-1		ELCO	10	AJ						4.5		40	30	15	10	5	10 SWD	
3		16-2		ELCO	18	↓						↓		40	25	15	20			
4		16-3		ELCO	50	↓						↓		10	20	20	15	35	20 SWD 20 SAV	
5		16-4		ELCO	94	↓						↓			10	10	20	60		
6		16-5		ELCO	15	↓						↓			5	5	10	80		
7																				
8	T-17-1			Time 0947-1019 x 2 = 64 min																
9		T17-1		ELCO	44	AJ						3.0					30	70		
10		17-2		ELCO	126	AJ						↓						100		
11				P. cataracta	1	J	4	65—				↓							40% SAV	
12		17-3		ELCO	126	AJ						↓						100	88 organic	
13		17-4		ELCO	101	AJ						↓						100	80% organic	
14		17-5		ELCO	133	AJ						↓						100	80% org	
15																			75% SAV	
16	T 18			Time 1027-1059 x 2 = 64 min																
17		18-1		ELCO	59	AJ						3.5					10	90	90% organic	
18		18-2		ELCO	69	AJ														
19				LARA	—	—		—			1						10	90		
20		18-3		ELCO	75	AJ											10	90		
21				LARA	—	—			—	2	—									
22		18-4		ELCO	125	AJ											10	90		
23				LARA	—	—		—	1	2	3									
24				PYCA	—	—		—		1										
25		18-5		ELCO	56	AJ														
26																				
27																				
28																				
29																				
30																				

Photo Log Notes

GPS Log Notes

A = Transect Number, Quadrat Number or Site ID B = Replicate or Quadrant

Date 14 Sept. 2021
Project Name/No.: Briar Hydro 24534.000

Freshwater Mussel Data Sheet

Page 2 of 3
Crew: JCS, DMC, MP

River/Stream Name Contoocook State NH County
County River Mile Location/Town
Weather Air Temp:
Water Quality (T, pH, Flow, Cond, DO)
Survey Type (Semi-quan/Qual/Quan/Reconn):
Comments

	T/Q/Site[A]	Rep[B] X	Rep[B] Y	Species	Unionid Data L	A/J	Age	L/H/W	FD	WD	SF	Hab/Substrate (%) Depth	Br	Bo	Cb	Gr	Sd	St	Cl	Other
1	T	19		Time 1132-1200 x 2 = 56 min																
2		19	1	ELCO	26	AJ						4.0					100			40 SWD
3		19	2	ELCO	22	AJ											100			
4				A. undulata	1			41,25,20												
5		19	3	ELCO	1												100			
6		19	4	ELCO	2															
7				PYCA	1			62 —									100			70% LWD
8		19	5	No Live mussels													100			
9																				
10	T	20		Time 1226-1248 x 2 = 44 min																
11		20	1	ELCO	46	AJ						4.0						100		20% SAV
12		20	2	ELCO	34															30% SAV
13		20	3	ELCO	20															80 org
14				LARA	—			—		1										60% SAV
15		20	4	ELCO	22	AJ														
16		20	5	ELCO	14	AJ														60% SAV
17																				
18	T	21		Time 1316-1337 x 2 = 41 min																
19		21	1	ELCO	31	AJ						5.0					100			
20		21	2	ELCO	8												100			
21		21	3	ELCO	58											35	45	20		
22		21	4	ELCO	50											60	40			
23		21	5	ELCO	31											40	40		20	
24																				
25	T	22		Time 1355-1412 x 2 = 34 min																
26		22	1	No Live	—						—							100	100% organic	
27		22	2	No Live	—					—										
28		22	3	ELCO	1	A				—										
29		22	4	No Live	—					—										
30		22	5	No Live	—					—										

Photo Log Notes

GPS Log Notes

A = Transect Number, Quadrat Number or Site ID B = Replicate or Quadrant

Freshwater Mussel Data Sheet

Date 14 Sep 2021
Project Name/No.: Briar Hydro 24534.000
Page 3 of
Crew: JCS, DMC, MD

River/Stream Name Contoocook
State NH
County
County
River Mile
Location/Town
Weather
Air Temp:
Water Quality (T, pH, Flow, Cond, DO)
Survey Type (Semi-quan/Qual/Quan/Reconn):
Comments T-10 see Add'l sheets for measurements

	T/Q/Site[A]	Rep[B] X	Rep[B] Y	Species	L	A/J	Age	L/H/W	FD	WD	SF	Depth	Br	Bo	Cb	Gr	Sd	St	Cl	Other
1	T	10		Time 1558-1631 x 2 = 66 min								2.5	10	50	15	10	15			
2		10-1		ELCO	6	AJ														
3				A. varicosa	9															
4		10-2		ELCO	23	AJ							10	50	15	10	15			
5				ALUN	2	J														
6				ALVA	26	AJ														
7				PYCA	1	J														
8		10-3		ELCO	8	A								Same as previous						
9				ALVA	2	A														
10		10-4		ELCO	10	AJ									Same —					
11				ALUN	2	A														
12				ALVA	13	AJ														
13		10-5		ELCO	20	AJ									Same —					
14				ALVA	11	AJ														
15																				
16																				
17																				
18																				
19																				
20																				
21																				
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				

Photo Log Notes

GPS Log Notes

A = Transect Number, Quadrat Number or Site ID B = Replicate or Quadrant

Date 15 Sept 2021

Project Name/No.: Briar Hydro 24534.000

Freshwater Mussel Data Sheet

Page 1 of

Crew: JWS, DML, MP

River/Stream Name Contoocook State NH County

County River Mile Location/Town

Weather

Water Quality (T, pH, Flow, Cond, DO) Air Temp:

Survey Type (Semi-quan/Qual/Quan/Reconn):

Comments T-9 very swift Flows and coarse substrate Flow ~ ≥ 2.0 fps

	T/Q/Site[A]	Rep[B] X	Rep[B] Y	Species	Unionid Data L	A/J	Age	L/H/W	FD	WD	SF	Depth	Hab/Substrate (%) Br	Bo	Cb	Gr	Sd	St	Cl	Other
1	T	9		Time 0824 - 0840 x 2 = 32 min								1.5		30	60	5	5			
2		9-1		ELCO	1	A														
3		9-2		~~ELCO~~ No Live										30	60	5	5			
4		9-3		~~ELCO~~ NO Live										30	60	10				
5		9-4		ELCO	1	A								30	60	10				
6		9-5		No Live										30	60	10				
7																				
8	T	7		Time 0854 - 0928 = 68 min								4.0								
9		7-1		ELCO	3	A								20	50	20	10			
10		7-2		ELCO	17	AJ								20	40	15	15			
11		7-3		ELCO	4	A								5	25	40	30			10 LWD
12		7-4		ELCO	2	A								5	15	30	30	20		20 LWD
13		7-5		ELCO	9	A								20	30	30	20			10% LWD
14																				
15																				
16	T	8		No Survey Due To Steep Near vertical Banks																
17																				
18																				
19																				
20																				
21	T	5		Time 1010 - 1032 x 2 = 44 min								5								
22		5-1		ELCO	12	AJ														
23				ALVA	1	A		43, 25, 17						30	50	20				90 Attached Algae
24		5-2		ELCO	17															
25				ALVA	1	A		50 28, 19						30	50	20				
26		5-3		ELCO	~~4~~	A								30	20	10	40			100% SAV
27		5-4		ELCO	11	A								90			10			
28		5-5		ELCO	20	AJ								[illegible]			100			10% LWD
29																				
30																				

Photo Log Notes

GPS Log Notes

A = Transect Number, Quadrat Number or Site ID B = Replicate or Quadrant

Date 15 Sept 2021

Project Name/No.: Briar Hydro 24534,000

Freshwater Mussel Data Sheet

Page 2 of

Crew: JLJ, DMC, MP

River/Stream Name Contoocook State NH County

County River Mile Location/Town

Weather

Air Temp:

Water Quality (T, pH, Flow, Cond, DO)

Survey Type (Semi-quan/Qual/Quan/Reconn):

Comments

	T/Q/Site[A]	Rep[B] X	Rep[B] Y	Species	Unionid Data L	A/J	Age	L/H/W	FD	WD	SF	Depth	Hab/Substrate (%) Br	Bo	Cb	Gr	Sd	St	Cl	Other
1	T	4		Time 1140-1210 x2 = 60 min																
2		4	-1	ELCO	2							3.5			30	10		60		40% SAV
3		4	-2	ALWA	—	—	—		—	1	—				30	20	20	30		20% SAV
4		4	-3	ELCO	2							↓			30	20	10	40		
5		4	-4	No Live								↓			30	20	10	40		
6		4	-5	No Live								↓			20	40		30		40% SAV
7																				
8																				
9	T	6		No surveys Steep Banks + Drop offs.																
10	T	3																		
11																				
12																				
13																				
14	T	2		Time 1349-1446 x2 = 54 min																
15		2	-1	~~ELCO~~ No Live	—	—						4.5		30	40	25	5			
16		2	-2	ELCO	1	A								30	40	25	5			
17		2	-3	ELCO	4	A								30	40	25	5			
18		2	-4	ELCO	1	A								10	60	20	10			
19		2	-5	ELCO	30	A								[illegible]	40	40	10	10		
20																				
21																				
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				

Photo Log Notes

GPS Log Notes

A = Transect Number, Quadrat Number or Site ID B = Replicate or Quadrant

Date 9/14/21
Project Name/No.:

Freshwater Mussel Data Sheet

Page 2 of 2
Crew:

River/Stream Name Contoocook River State NH County
County River Mile Location/Town
Weather
Air Temp:
Water Quality (T, pH, Flow, Cond, DO)
Survey Type (Semi-quan/Qual/Quan/Reconn):
Comments
Station 10

	T/Q/Site^A	Rep^B X	Rep^B Y	Species	Length A/J	Age	L/H/W	FD	WD	SF	Depth	Br	Bo	Cb	Gr	Sd	St	Cl	Other
1				A. varicosa	38														
2					44														
3					42														
4					46														
5					48														
6					51														
7					42														
8					42														
9					36														
10					39														
11					52														
12					54														
13					42														
14					40														
15					41														
16					55														
17					45														
18					41														
19					38														
20					35														
21					48														
22							2 Relic Shells	|	|										
23																			
24				Alun	22														
25					53														
26					55														
27					45														
28																			
29																			
30																			

Photo Log Notes

GPS Log Notes

A = Transect Number, Quadrat Number or Site ID B = Replicate or Quadrant

Date 9/14/21
Project Name/No.:

Freshwater Mussel Data Sheet

Page 1 of 2
Crew:

River/Stream Name Contoocook River State NH County
County River Mile Location/Town
Weather Air Temp:
Water Quality (T, pH, Flow, Cond, DO)
Survey Type (Semi-quan/Qual/Quan/Reconn):
Comments

Station 10

	T/Q/Site[A]	Rep[B] X	Y	Species	Length	A/J	Age	L/H/W	FD	WD	SF	Depth	Br	Bo	Cb	Gr	Sd	St	Cl	Other
1				A. varicosa	55															
2					42															
3					45															
4					51															
5					51															
6					46															
7					52															
8					48															
9					36															
10					38															
11					40															
12					25															
13					28															
14					28															
15					23															
16					42															
17					32															
18					53															
19					40															
20					39															
21					45															
22					55															
23					43															
24					40															
25					30															
26					47															
27					54															
28					45															
29				↓	35															
30					46															

Photo Log Notes

GPS Log Notes

A = Transect Number, Quadrat Number or Site ID B = Replicate or Quadrant

Appendix D. Project Photographs

Photo # 1 Looking upstream from Transect 1.
Date: 09/13/2021

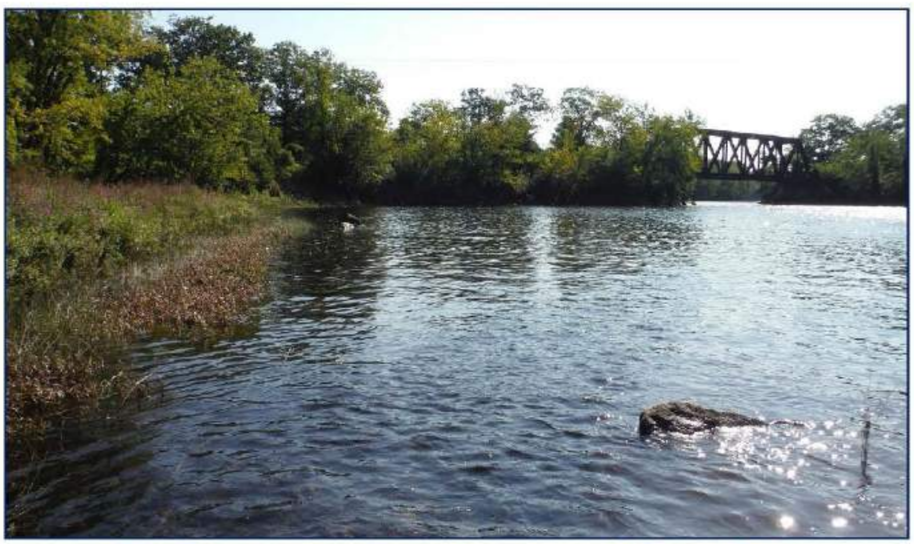


Photo # 2 Looking downstream from Transect 1 towards the confluence with the Merrimack River.
Date: 09/13/2021

NORMANDEAU ASSOCIATES
Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 3 Looking upstream at Transect 2.
Date: 09/15/2021

Photo # 4 Looking downstream from Transect 2.
Date: 09/15/2021

NORMANDEAU ASSOCIATES
Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 5 Looking upstream from Transect 4.
Date: 09/15/2021

Photo # 6 Looking upstream from Transect 5.
Date: 09/15/2021

NORMANDEAU ASSOCIATES
Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 7 Looking downstream from Transect 5.
Date: 09/15/2021

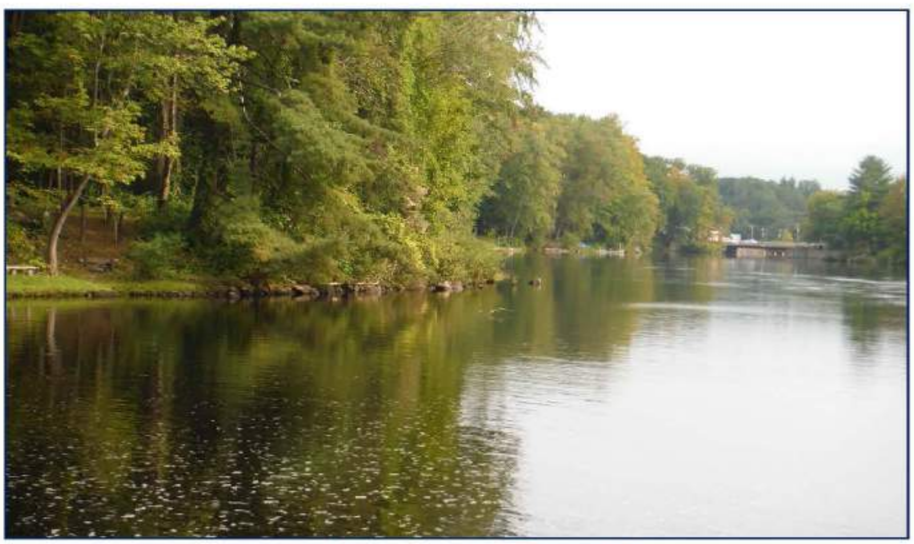


Photo # 8 Looking downstream at Transect 7.
Date: 09/15/2021

NORMANDEAU ASSOCIATES
Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 9 Looking upstream at Transect 8.
Date: 09/14/2021

Photo # 10 Looking upstream from Transect 9.
Date: 09/15/2021

NORMANDEAU ASSOCIATES
Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 11 Looking downstream from Transect 9.
Date: 09/15/2021

Photo # 12 Looking upstream from Transect 10.
Date: 09/14/2021

NORMANDEAU ASSOCIATES
Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 13 Looking downstream from Transect 10.
Date: 09/14/2021

Photo # 14 Representative photo of substrates at Transect 10.
Date: 09/14/2021

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Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 1 Looking upstream from Transect 11.
Date: 09/13/2021

Photo # 16 Looking upstream from Transect 12.
Date: 09/13/2021

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Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 17 Looking upstream from Transect 13.
Date: 09/13/2021

Photo # 18 Looking upstream from Transect 14.
Date: 09/13/2021

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Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 19 Looking downstream from Transect 14.
Date: 09/13/2021

Photo # 20 Looking upstream from Transect 15.
Date: 09/13/2021

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Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 21 Looking upstream from Transect 16.
Date: 09/14/2021

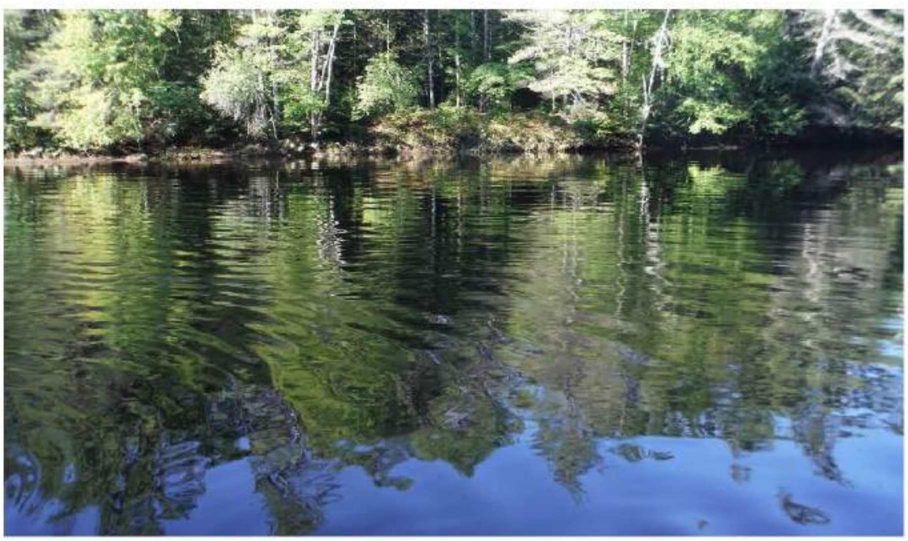

Photo # 22 Looking laterally across the river from Transect 16.
Date: 09/14/2021

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Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 23 Looking downstream from Transect 16.
Date: 09/14/2021

Photo # 24 Looking downstream from Transect 17.
Date: 09/14/2021

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Environmental Consultants

Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

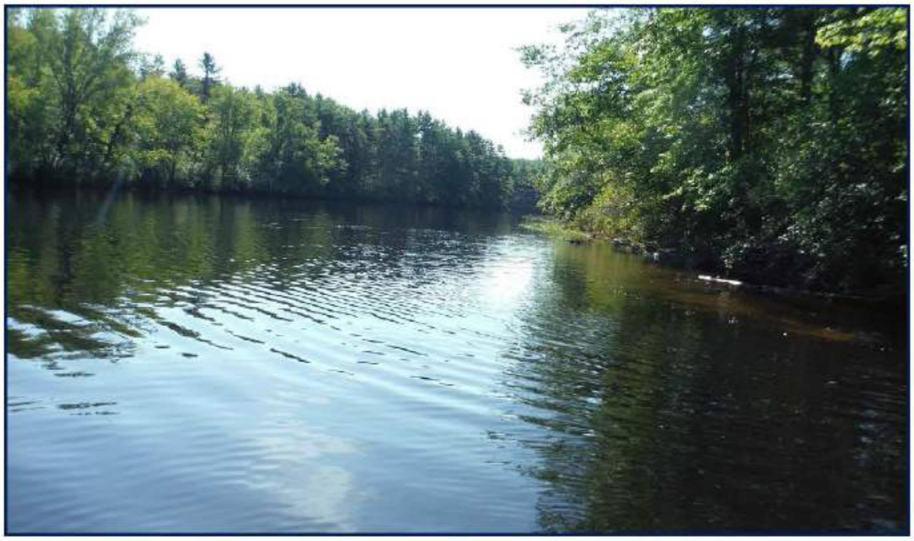

Photo # 25 Looking upstream from Transect 18.
Date: 09/14/2021

Photo # 26 Looking upstream from Transect 19.
Date: 09/14/2021

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Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 27 Looking downstream from Transect 20.
Date: 09/14/2021

Photo # 28 Looking downstream from Transect 22.
Date: 09/14/2021

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Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 29 Representative photo of *Elliptio complanata* (eastern elliptio), lateral view.
Date: 09/14/2021

Photo # 30 Representative photo of eastern elliptio, dorsal view.
Date: 09/14/2021

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Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 31 Representative photo of *Pyganodon cataracta* (eastern floater), lateral view.
Date: 09/14/2021

Photo # 32 Representative photo of eastern floater, dorsal view.
Date: 09/14/2021

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Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 33 Representative photo of *Alasmidonta undulata* (triangle floater), lateral view.
Date: 09/14/2021

Photo # 34 Representative photo of triangle floater, dorsal view.
Date: 09/14/2021

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Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 35 Representative photo of *Alasmidonta varicosa* (brook floater), lateral view.
Date: 09/14/2021

Photo # 36 Representative photo of brook floater, dorsal view.
Date: 09/14/2021

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Project No. 24534.000
Date: 09/13/2021-09/15/2021
Name: Briar Hydro Mussel Survey

Photo # 37 Representative photo of typical brook floater catch.

Date: 09/14/2021

Photo # 38 Representative photo of eastern lampmussel *(Lampsilis radiata)* shell, dorsal view.

Date: 09/14/2021

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Project No. 24534.000

Date: 09/13/2021-09/15/2021

Name: Briar Hydro Mussel Survey

Appendix E. Resume

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

JOSEPH C. SNAVELY
Principal Scientist

Mr. Snavely has over 20 years of multidisciplinary project experience focused on project management, agency coordination, strategic planning, dive operations management, site safety, wetland identification/ delineation and functional evaluation of wetland systems, evaluation of aquatic ecosystems, stream and river classification, assisting in the completion of Environmental Impact Statements (EIS), and the completion of Joint Permit Applications for oil and gas, transportation, infrastructure, commercial, legal testimony and residential development projects in Pennsylvania, Maryland, New Jersey, Delaware, and Virginia. He has delineated several thousand wetland systems throughout his career including large transportation, land development, oil and gas, and utility projects.

Mr. Snavely is involved in the study and evaluation of aquatic ecosystems, specifically, lotic systems. Evaluations include assessment of the physiochemical, aquatic habitat, and the aquatic biota conditions. He has extensive experience in aquatic habitat surveys/evaluations and aquatic ecology using methods and protocol outlined in EPA's Rapid BioAssessment Protocol for Use in Wadeable Streams and Rivers for Benthic Macroinvertebrates and Fish (1999), multihabitat assessment protocols from the Maryland Biological Stream Surveys for fish and macroinvertebrates, Pennsylvania multihabitat and macroinvertebrate protocols, Virginia Save Our Streams, and North Carolina DENR Bioassessments for State 401 Water Quality Certification. Mr. Snavely has over 15 years of experience in surveying for freshwater mussels for species from the Atlantic Slope and Interior Basins.

Mr. Snavely has also provided 8 years of assistance in Phase I and Phase II Bog Turtle Habitat Evaluations in Pennsylvania and Maryland. Mr. Snavely has conducted sensitive plant species surveys in Pennsylvania and Virginia including assistance with monitoring for the Federal Endangered Northeastern Bulrush (*Scirpus ancistrocheatus*). Mr. Snavely has five years of experience in performing forest stand delineations in accordance with the State of Maryland Reforestation Act (1991), Roadside Tree Law, and Reforestation Law within the State of Maryland. Mr. Snavely has completed and submitted forest conservation plans necessary for the acquisition of land development permits in Anne Arundel, and Frederick County, Maryland.

EDUCATION

B.S. Environmental Health & Biology, Indiana University of PA,

PROFESSIONAL EXPERIENCE

2016-Present	Normandeau Associates
2011-2016	AECOM
2000-2011	Skelly and Loy, Inc.

PROFESSIONAL CERTIFICATIONS

- Qualified Professional Forest Stand Delineator, 2007
- Pennsylvania &U.S. Fish and Wildlife Service Qualified Northeastern Bulrush (Scirpus ancistrocheatus) Surveyor, 2015
- U.S. Fish and Wildlife Service, PA, NJ, NY, & New England Qualified Dwarf Wedgemussel Surveyor, 2012
- U.S. Fish and Wildlife Service Qualified Surveyor Region 3 and Region 5
- New York Qualified Freshwater Mussel Surveyor, 2014
- Ohio Qualified Surveyor
- West Virginia Qualified Surveyor
- Virginia Qualified Surveyor
- Maryland Qualified Freshwater Mussel Surveyor, 2011
- SCUBA certified – Divemaster - Drysuit
- DAN Oxygen, CPR, and First Aid
- Shell Safelands Safety Training
- AECOM Certified Project Manager
- AECOM Dive Board 2017

PROFESSIONAL AFFILIATIONS

- Mid-Atlantic Water Pollution Biologists (2000-2016)
- Freshwater Mollusk Conservation Society
- PA Biological Society – Mollusk Technical Sub-group (2015-2017)
- Chesapeake Bay Freshwater Mussel Workgroup (2010-2016)
- Ohio River Valley Mussel Group (2016-2017)
- Entomological Society of Pennsylvania (2003-2009)
- MBSS Macroinvertebrate Training (2000-2004, 2008-2012)
- MBSS Fish Training (2002-2004, 2008-2011)
- Natural Stream Channel Design Summit (2001-2002)

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REPRESENTATIVE PROJECT EXPERIENCE

Lancaster-Guildhall US Route 2 Bridge Replacement Project, Dwarf Wedgemussel Section 7 Consultation (2016-Present). In coordination with the project consultant team, NHDOT, and FHWA, Mr. Snavely prepared and submitted a mussel survey plan, developed salvage strategies, and conducted agency negotiations for the development of a Biological Opinion to collect and relocate federally endangered Dwarf Wedgemussel (*A. heterodon*) from the area of direct impact prior to construction activities. This project required a multi-phase salvage approach over multiple years based on the construction schedule and duration of project disturbances. One of the largest relocation efforts for the species, over 35,000 mussels have been relocated including over 500 Dwarf Wedgemussel. Task Manager, USFWS Qualified Surveyor Region 5.

Great River Hydro Dwarf Wedgemussel FERC Relicensing Project, Section 7 Consultation, Connecticut River, Multiple Counties, NH (2019-Present). In coordination with the project team, Mr. Snavely served as the qualified malacologist for the preparation of a biological assessment for potential effects to the Dwarf Wedgemussel at three hydropower operations on the Connecticut River. The biological assessment covers 120 miles of the Connecticut River that encompass two discrete populations of Dwarf Wedgemussel. Project activities included review of the FERC study plans and documents, habitat and population impact assessments and agency negotiation support for the development of a Biological Opinion. Presently, Normandeau is supporting additional agency coordination for the project. Project Manager, USFWS Qualified Surveyor.

Headquarters Road Bridge over Tinicum Creek, River Condition Assessment, PADOT District 6, Bucks County, PA (2020-Present). In coordination with the project team, Mr. Snavely oversaw the evaluation of existing aquatic habitat conditions from Tinicum Creek. Completion of the Pennsylvania Riverine Condition Level 2 Rapid Assessment was required in support of the project Joint Permit Application and mitigation coordination. Project activities included review of the Categorical Exclusion Evaluation, project area assessment and riparian and floodway habitat evaluations. Mr. Snavely was responsible technical reporting and project and agency coordination. Project Manager.

French Creek Mussel Community Assessment, French Creek, Venango County, PA (2019). Mr. Snavely served as the natural resource coordinator and qualified malacologist for a mussel survey in French Creek, Pennsylvania. As part of field crew training on several regional project, Mr. Snavely led species surveys for identification training of field staff. Over 20 species of mussels were observed including five federal endangered species: Rayed Bean (*Villosa fabilis*), Northern Riffleshell (*Epioblasma t. rangiana*), Clubshell (*Pluerobema clava*), Rabbitsfoot (*Theliderma cylindrica*) and Snuffbox (*Epioblasma triquetra*). Lead Malacologist, USFWS Qualified Surveyor.

Freshwater Mussel, Macroinvertebrate Survey and Mitigation Support, Allegheny County Sanitary Authority (ALCOSAN) Outfall and Riverwall Project, Allegheny County, PA (2017-Present). Mr. Snavely coordinated and led freshwater mussel survey, macroinvertebrate, and fish evaluation efforts in support of Environmental Assessments associated with a Joint Permit Application submission for riverwall and outfall construction in the Ohio River. ALCOSAN combines over 50 municipalities from the greater Pittsburgh, Pennsylvania area into a one million gallons per day discharge. Mr. Snavely participated in agency negotiation efforts with PADEP, USACE, PFBC, and USFWS associated with the proposed impacts to aquatic communities from the proposed riverwall and outfalls. He also assisted with the proposed conceptual mitigation package for the Joint Permit Application. Project Manager, USFWS Qualified Mussel Surveyor.

New York State Route 430 Bridge Replacement Project, NYSDOT Region 5, Dewittville Creek, Chautauqua County, PA (2019-Present). Mr. Snavely served as the natural resource coordinator and qualified malacologist for mussel survey on the Dewittville Creek in Cautauqua County, New York. Activities included mussel survey and salvage plan negotiation, visual and tactile searches (Smith et. al 2000, 2001, and 2006 and West Virginia protocols), timed searches, assessment of available habitat, and species distribution. Presently, Normandeau is supporting additional PFBC coordination for the project. Project Manager, USFWS Qualified Surveyor.

Allegheny Riverfront Development Project, Allegheny River (RM 1.9), Allegheny County, PA (2018-Present). Mr. Snavely served as the natural resource coordinator and qualified malacologist for mussel survey in Pool 4 of the Allegheny River, Pennsylvania. Activities included mussel survey and survey plan negotiation, visual and tactile searches (Smith et. al 2000, 2001, and 2006 and West Virginia protocols), timed searches, habitat assess, quadrat excavations and species distribution. Project activities involved the survey targeting Rayed Bean (*Villosa fabilis*). A total of five live species were observed during this survey. Normandeau was successful in obtaining agency clearance from the PFBC and USFWS in support of this project. Project Manager, USFWS Qualified Surveyor.

Electra Pipeline Intake Project, Allegheny River Pool 4 (RM 17.0), Allegheny County, PA (2018-Present). Mr. Snavely served as the natural resource coordinator and qualified malacologist for mussel survey in Pool 4 of the Allegheny River, Pennsylvania. Activities included mussel survey and survey plan negotiation, visual and tactile searches (Smith et. al 2000, 2001, and 2006 and West Virginia protocols), timed searches, habitat assessment, quadrat excavations and species distribution. Project activities involved the survey targeting Rayed Bean (*Villosa fabilis*). A total of four live species were observed during this survey. Normandeau was successful in obtaining agency clearance from the PFBC and USFWS in support of this project. Project Manager, USFWS Qualified Surveyor.

Kanawha River Capping Project, Kanawha River (RM 30 to 42), Putnam County, PA (2018-Present). Mr. Snavely served as the natural resource coordinator and qualified malacologist for mussel survey across a large portion of the Kanawha River. Activities included mussel survey and survey plan negotiation, visual and tactile searches (Smith et. al 2000, 2001, and 2006 and West Virginia protocols), timed searches, habitat assessment, and species distribution. Over 170 transects were surveyed across five separate capping sites comprising nearly 15 acres of direct impact area. This project involved multiple dive crews and operations teams. A total of 23 species were observed during this survey including the first record of the federal endangered Pink Mucket (*Lampsilis abrupta*) in this section of the Kanawha River. Normandeau supported the completion of the biological assessment and agency negotiations. Project Manager, WV/USFWS Qualified Surveyor.

Confidential FERC Pipeline Project, Multiple Sites Allegheny River Watershed, McKean and Potter Counties, PA (2018-Present). Mr. Snavely served as the qualified malacologist for mussel survey operations at multiple pipeline crossing locations in McKean and Potter Counties in Pennsylvania. Activities included mussel survey and survey plan negotiation, visual and tactile searches (Smith et. al 2000, 2001, and 2006 and West Virginia protocols), timed searches, assessment of available habitat, and species distribution. Target species included the salamander mussel (*Simposonias ambigua*) and the Rayed Bean (*Villosa fabilis*). Nearly 20 mussel species were observed including seven PA listed species of concern. Presently, Normandeau is supporting additional PFBC and USFWS coordination for the project. Project Manager, USFWS Qualified Surveyor.

Conneaut Lake Shoreline Development Project, Conneaut Lake, Crawford County, PA (2019-Present). Mr. Snavely served as the natural resource coordinator and qualified malacologist for mussel survey and salvage for the project. Activities included mussel survey and survey plan negotiation, visual and tactile searches (Smith et. al 2000, 2001, and 2006 and West Virginia protocols), timed searches, assessment of available habitat, and species distribution. Normandeau successfully obtained clearance from PFBC in support of this project. Project Manager, USFWS Qualified Surveyor.

Wolf Bridge Replacement Project, PennDOT District 8-0, Conodoguinet Creek, Cumberland County, PA (2016-Present). Mr. Snavely served as the natural resource coordinator and qualified malacologist for mussel survey and salvage operations on the Conodoguinet Creek in Cumberland Count, Pennsylvania. Activities

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included mussel survey and salvage plan negotiation, visual and tactile searches (Smith et. al 2000, 2001, and 2006 and West Virginia protocols), timed searches, assessment of available habitat, and species distribution. Project activities involved the relocation of over 200 live mussels (multiple species) to a PFBC approved location. Presently, Normandeau is supporting additional PFBC coordination for the project. Project Manager, USFWS Qualified Surveyor.

AECOM – PQS, NTC Pipeyard Freshwater Mussel Survey and Section 7 Consultation Oil Creek, Venango County, PA (2017-Present). In coordination with the project consultant team, AECOM and Shell, Mr. Snavely prepared and submitted a mussel survey plan, developed salvage strategies, and conducted agency negotiations for the survey of the federally endangered Northern Riffleshell (*E. torulosa rangiana*) and the state rare Wavy-rayed Lampmussel (*L. fasciola*). A total of nine mussel species were identified within the study area, including the Northern Riffleshell and Wavy-rayed Lampmussel. Formal Section 7 consultation and subsequent Biological Assessment has been initiated to address the effect of the proposed shoreline improvements to federal endangered mussel species. Project Manager, USFWS Qualified Surveyor Region 5.

AECOM – Pennzoil Quaker State Refinery, Plant II Freshwater Mussel Survey and Section 7 Consultation Oil Creek, Venango County, PA (2017-Present). In coordination with the project consultant team, AECOM and Shell, Mr. Snavely prepared and submitted a mussel survey plan, developed salvage strategies, and conducted agency negotiations for the survey of the federally endangered Northern Riffleshell (*E. torulosa rangiana*) and the state rare Wavy-rayed Lampmussel (*L. fasciola*). A total of eight mussel species were identified within the study area including, the Northern Riffleshell and Wavy-rayed Lampmussel. Formal Section 7 consultation and subsequent Biological Assessment has been initiated to address the effect of the proposed shoreline improvements to federal endangered mussel species. Project Manager, USFWS Qualified Surveyor Region 5.

Allegheny River Discharge Reporting Review, Confidential Client, Venango County, PA (2017). Mr. Snavely provided an independent technical review of PA DEP water quality and species survey reporting for potential effects of an existing outfall to federal endangered mussel species located in proximity to the existing outfall. The desktop review include reviews for the federal endangered Norther Riffleshell (*E. torulosa rangiana*) and Clubshell (*P. clava*) among other species. Task Manager.

Shell Northeast Ethane Pipeline (Falcon Pipeline) OH and PA (2015 and 2016). Mr. Snavely served as the task lead for mussel survey efforts across numerous drainages throughout the proposed pipeline. This project involved agency coordination and habitat assessments for numerous crossing locations along eastern Ohio and western Pennsylvania. Survey efforts were designed and reported using the Ohio Mussel Survey Protocol for presence/absence surveys and habitat assessments. USFWS Qualified Surveyor Region 3 and Ohio DNR Approved Surveyor.

Shell Proposed Petrochemical Facility, Beaver County, PA (2013-2016). Mr. Snavely oversaw all wetland delineations, aquatic assessments, mitigation evaluations, and coordinated Section 404 and Chapter 105 permitting for all natural resources associated with the proposed Gas to Liquids facility in Beaver County, PA. Project activities for the 750-acre site included wetland and watercourse delineations (approximately five acres of jurisdictional wetlands and approximately 40,000 feet of jurisdictional watercourse), benthic evaluations, freshwater mussel surveys, T&E species evaluation, multi-agency coordination, mitigation site planning, impact assessments as part of the feasibility study. A preliminary jurisdictional determination of the identified aquatic resources was completed for the project with representatives of the U.S. Army Corps of Engineers, Pittsburgh District, PADEP, and U.S. EPA. Permitting and Natural Resource Lead.

Shell Petrochemical Facility Marine Services, Beaver County, PA (2013). Mr. Snavely served as the site safety officer, natural resource lead and co-taxonomist for a mussel survey operation on the Ohio River in Pennsylvania. Mr. Snavely prepared and submitted mussel survey plans for approval by the PFBC and USFWS and led the project survey efforts as designed by the approved survey plan requirements. Mr. Snavely served as the lead agency coordinator for the mussel survey effort to present survey designs and results. This project involved visual and tactile searches using the West Virginia Mussel Sample (Clayton 2013) and Smith et. al 2000, 2001, and 2006 protocols. Both transect and timed searches were employed along with an assessment of river substrate, available habitat, and species distribution. Project activities involved the translocation of several mussel species to a USFWS and PFBC approved location. A total of 190 live mussels, including 8 live species, were encountered including Pink Heelsplitter (*P. alatus*), Mapleleaf (*Q. quadrula*), Threehorn Wartyback (*O. reflexa*), White Heelsplitter (*L. complanata*), Flat Floater (*A. suborbiculata*), Fat Mucket (*L. siliquoidea*), and Black Sandshell (*L. recta*). Mr. Snavely was responsible for daily safety briefings, daily site checks, coordination with lock and dams, float plans, and project safety reporting. Site Safety Officer and Natural Resource Lead.

Cornish-Windsor Covered Bridge 25067, Dwarf Wedgemussel Survey, Connecticut River, Sullivan County, NH (2017-Present). In coordination with the project consultant team, NHDOT, and FHWA, Mr. Snavely prepared and submitted a mussel survey plan, developed salvage strategies, and conducted agency negotiations for the development of a Biological Opinion to complete a survey for federally endangered Dwarf Wedgemussel (*A. heterodon*). As designed, this survey effort required diving and the use of fixed area timed cell survey strategies. Over 1,500 live unionids were observed representing three live species including Dwarf Wedgemussel. Task Manager, USFWS Qualified Surveyor Region 5.

Cresson Covered Bridge 23737 Replacement Project, Dwarf Wedgemussel Section 7 Consultation, Ashuelot River, Cheshire County, NH (2016-Present). In coordination with the project consultant team, NHDOT, and FHWA, Mr. Snavely prepared and submitted a mussel survey plan, developed salvage strategies, and conducted agency negotiations for the development of a Biological Assessment and Biological Opinion to collect and relocate federally endangered Dwarf Wedgemussel (*A. heterodon*) from the area of direct impact prior to construction activities. In total, over 8,000 live mussels were relocated including seven species. A total of 68 federal endangered Dwarf Wedgemussels were captured, tagged, and relocated to a USFWS approved location. One-month survivorship and monitoring studies were conducted relocated Dwarf Wedgemussels and reported to the USFWS. Task Manager, USFWS Qualified Surveyor Region 5.

National Park Service Chesapeake and Ohio Canal National Historic Park, McMahons Mill Towpath Reconstruction and River Wall Restoration Freshwater Mussel and SAV Survey (2016-2017). The National Park Service (NPS) plans to rehabilitate an existing historic stone retaining wall and re-establish the historic towpath along an approximate 0.9-mile stretch in the Chesapeake and Ohio Canal National Historical Park between McMahon's Mill and Lock 42 in Washington County Maryland, bounded by Chesapeake and Ohio Canal (Canal) mileposts 88.0 and 89.0.

NPS also requested that Normandeau conduct a freshwater mussel presence and submerged aquatic vegetation (SAV) survey along the Potomac River littoral zone proposed for construction. Normandeau evaluated the presence and distribution of species with special protection status in proximity to the existing towpath wall and incorporate these sensitive areas into the preliminary design alternatives to develop appropriate avoidance and minimization measures.

A total of 863 live individuals representing five (5) species was observed within the survey area. The state rare Atlantic spike (*Elliptio producta*) represented nearly 98 percent of the total catch. The state endangered green floater (*Lasmigona subviridis*) was the next abundant comprising nearly one (1) percent of the total catch. The remaining approximate one (1) percent of the total catch comprised the eastern elliptio (*Elliptio complanata*, 0.5%), pocketbook (*Lampsilis cardium*, 0.3%), and paper pondshell (*Utterbackia imbecillis*, 0.3%).

Longview Property Aquatic Resource Characterization, Confidential Client, Chester County, PA (2016-Present). In coordination with the property owner and project counsel on behalf of its client, Mr. Snavely

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evaluated existing aquatic habitat conditions from three drainages. Physical habitat, biological and water quality data were used to determine points of first use and determine boundaries between ephemeral, intermittent and perennial stream channels within the subject property. Macroinvertebrate samples were collected using the PA Index of Biotic Integrity (IBI) protocols and analyzed as part of this evaluation. Mr. Snavely was responsible for survey design, sample analysis, technical reporting and project and agency coordination. Project Manager.

Pennsylvania Fish and Boat Commission Federal Endangered Mussel PIT Tagging Pilot Study, Allegheny River and Conowingo Creek, Warren County, PA (2014). Mr. Snavely assisted the PFBC with the PIT tagging, processing, and relocation of the federal endangered Clubshell (*Pleurabema clava*) and Northern Riffleshell (*Epioblasma torulosa rangiana*). A total of 90 individuals from each species were PIT tagged and translocated to the Conowingo Creek to assess mark recapture efficiency and species survivorship.

Chemours Shoreline Access Mussel Relocation, Ohio River Parkersburg, WV (2015). Mr. Snavely served as the project manager associated with the required mussel relocation efforts associated with temporary barge spudding and shoreline improvement projects. West Virginia Department of Natural Resources required that all live mussels be relocated from the direct impact area prior to construction. Species were relocated to an approved location on Blennerhasset Island. Project Manager - USFWS Qualified Surveyor and West Virginia Approved Surveyor.

Freshwater Mussel Survey, Matrix Realty Outfall Project, Delaware River, Burlington County, NJ (2016-2017). Mr. Snavely performed freshwater mussel survey efforts as previously designed, assisted with Impact Avoidance Plans, and conducted agency coordination efforts. Over 2,300 live mussels including four live species were encountered: Eastern elliptio (*E. complanata*), Eastern Floater (*P. cataracta*), Tidewater Mucket (*L. ochracea*), and Eastern Pondmussel (*L. nasuta*). Mr. Snavely led agency negotiation efforts for reduction in relocation efforts and assisted with the Impact Avoidance Plan for submittal to the NJDEP. USFWS Qualified Dwarf Wedgemussel Surveyor.

FERC Relicensing Project, Attean Pond Freshwater Mussel Survey, Brookfield Energy, Somerset County, ME (2016-Present). Mr. Snavely performed freshwater mussel survey efforts as previously designed. Over 14,000 live mussels including three live species were encountered: Eastern Elliptio (*E. complanata*), Eastern Floater (*P. cataracta*), and Triangle Floater (*A. undulata*). Mr. Snavely provided agency negotiation support and prepared the final report documents for submittal to the state agency. Project Manager - USFWS Qualified Dwarf Wedgemussel Surveyor.

Route 94 Bridge Repair Project, New Jersey Department of Transportation, Paulins Kill River, Warren County, NJ (2017-Present). Mr. Snavely prepared and submitted a mussel survey plan and led agency negotiations for freshwater mussel survey services targeting the federally endangered Dwarf Wedgemussel (*A. heterodon*). Survey work was completed in the 2017 survey season. Over 2,000 live mussels were identified during the Phase 1 survey activities including the state threatened Eastern Lampmussel (*Lampsillis radiata*). Evaluations of the direct and indirect project impacts were summarized to determine applicable avoidance and minimization measures for the bridge repair project. Project Manager - USFWS Qualified Dwarf Wedgemussel Surveyor.

Interstate 81 Bridge Improvement Project, MD State Highway Administration, Potomac River, Washington County, MD (2016-2017). Mr. Snavely developed and submitted a river wide survey and salvage plan for this bridge project. The salvage plan was approved and implemented by Maryland DNR and the consultant team for the detection and relocation of inhabitant mussel species. Project Manager, USFWS Qualified Surveyor.

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Dwarf Wedge Mussel Survey, Delaware River, City of Port Jervis Whitewater Park, Pike County, PA and Sullivan County, NY (2014-2017). Mr. Snavely prepared and submitted a mussel survey plan and led the project survey efforts as designed. Over 1,000 live mussels of five live species were encountered: Eastern elliptio (*E. complanata*), Alewife Floater (*A. implicata*), Eastern Floater (*P. cataracta*), Creep (*S. undulatus*), and Yellow Lampmussel (*L. cariosa*). Project Manager - USFWS Qualified Dwarf Wedgemussel Surveyor.

Schoharie Creek Freshwater Mussel Survey, Schoharie Creek, NY (2014). Mr. Snavely prepared and submitted a mussel survey plan and led the project survey efforts as designed. This project included the survey and relocation of State listed species associated with the placement of a temporary water intake structure. Five live species were encountered: Giant Floater (*P. grandis*), Creeper (*S. undulatus*), Fluted Shell (*L. costata*), Elktoe (*A. marginata*) and Yellow Lampmussel (*L. cariosa*). Project Manager - USFWS Qualified Dwarf Wedgemussel Surveyor.

Delaware River Pipeline Repair Project, Warren County, NJ (2014-2015). Mr. Snavely served as the project manager and natural resource coordinator for a mussel survey operation on the Delaware River in New Jersey. As the USFWS Qualified Surveyor Mr. Snavely prepared and submitted a mussel survey plan for approval by the NJDEP and USFWS and led the project survey efforts as designed by the approved survey plan requirements. This project involved visual and tactile searches using the Smith et. al 2000, 2001, and 2006 protocols. Both transect and timed searches were employed along with an assessment of river substrate, available habitat, and species distribution. Project activities involved the translocation of several mussel species to a USFWS and NJDEP approved location to facilitate the dig, lift, repair of an existing transmission line. Over 1,500 live mussels including 5 live species were encountered including Eastern Elliptio (*E. complanata*), Alewife Floater (*A. implicata*), Eastern Floater (*P. cataracta*), Triangle Floater (*A. undulata*), and Yellow Lampmussel (*L. cariosa*). Project Manager, Natural Resource Coordinator.

Big Darby Creek, S.R. 245 Bridge Replacement Project, Union County, OH (2014). Mr. Snavely assisted in the qualitative survey of freshwater mussels within the Big Darby Creek (West Virginia Mussel Sampling Protocols; Smith, et al. 2000). This project involved surveying approximately 300 meters of Big Darby Creek (250m downstream and 150m upstream) for unionids prior to the replacement of an existing bridge structure. This project involved midden searches, visual and tactile surveys, viewing buckets, SCUBA, and periodic excavation. Several species of live mussels were encountered including the Fat Mucket (*L. siliquoidea*), Cylindrical Papershell (*A. ferussacianus*), Spike (*E. dilitata*), Wabash Pigtoe (*F. flava*), Creek Heelsplitter (*L. compressa*), and Giant Floater (*P. grandis*). Qualified Surveyor.

Conodoguinet Creek Aquatic Characterization S.R. 4021 Bridge Replacement Project, Cumberland County, PA (2002). Mr. Snavely assisted in the qualitative survey of freshwater mussels within the Conodoguinet Creek (Smith, et al. 2000). This project involved surveying 500 meters of Conodoguinet Creek (300m downstream and 200m upstream) for the historically documented Green Floater (*L. subviridis*) prior to the replacement of an existing bridge structure. This project involved midden searches, visual and tactile surveys, viewing buckets, and periodic excavation. A total of 1,102 live mussels were encountered including two unionid species; the Atlantic Spike (*E. complanata*) and Creeper (*S.undulatus*). Senior Biologist.

North Branch Susquehanna River – Mifflinville Sewer Force Main Project, Columbia County, PA (2003). This project involved a survey for the Yellow Lampmussel (*L. cariosa*) and the Green Floater (*L. subviridis*) for the placement of a sewer force main across the North Branch Susquehanna River. Survey protocols were coordinated with the Pennsylvania Fish and Boat Commission (Smith, et al. 2000; Strayer and Smith, 2003). The project involved surveying 300 meters of the North Branch (200m downstream and 100m upstream) including midden searches, visual and tactile searches, snorkeling, SCUBA, viewing buckets, and periodic excavation. A total of 60 live mussels were encountered including six unionid species; the Yellow Lampmussel (*L. cariosa*), Green Floater (*L. subviridis*), Elktoe (*A. marginata*), Creeper (*S. undulatus*), Eastern Floater (*P. cataracta*), and Triangle Floater (*A. undulata*) within the zone of direct and indirect effects of the proposed project. Task Manager.

S.R. 0035 Juniata River Bridge Replacement Project, Juniata County, PA (2004). Mr. Snavely assisted the Pennsylvania Fish and Boat Commission (Jeff Schmid) in the collection and relocation of freshwater mussels located within the zone of direct and indirect effects of the proposed bridge structure and causeway. A total of 45 live mussels were encountered including three unionid species; the Eastern Spike (*E. complanata*), Yellow Lampmussel (*L. cariosa*), and Rainbow (*V. iris*). In addition, two other relect unionid species were also detected, the Triangle Floater (*A. undulata*) and Elktoe (*A. marginata*). Captured live individuals were relocated upstream of the existing vehicular bridge in a suitable substrate habitat where live individuals were previously detected. Task Manager.

Maryland Route 5 Roadway Improvement Project, St. Mary's County, MD (2008). This project involved coordination with the Maryland Department of Natural Resources (MD DNR) for potential effects on the Dwarf Wedgemussel (*A. heterodon*) from proposed MD 5 roadway improvements within the McIntosh Run watershed. The project area is located in the lower reaches of McIntosh Run (Leonardtown) and the zone of tidal influence and therefore, detail mussel surveys were not required by MD DNR. Project Manager.

Natural Gas Pipeline Wetland and Watercourse Delineations, Williams Midstream, LLC., PA (2011-2015). Responsible for coordinating and conducting delineation efforts on approximately seven miles of new natural gas transmission pipeline in Susquehanna County, PA. Efforts included coordination with project land agents, GPS (Trimble Geo- XH) survey, and the project team. Responsible for effective communication project conditions for the purposes of submitting necessary reporting and permitting requirements. Senior Biologist – Field Crew Leader.

Natural Gas Pipeline Post-Construction Impact Assessment, Williams Midstream, LLC., PA (2014). Responsible for post-construction evaluation and delineation of existing, new, and/or impacted wetlands and watercourses over approximately 44 miles of constructed pipeline for after- the-fact permit negotiations with regulatory agencies. Efforts included the evaluation of all resources along the constructed pipeline and a determination between existing permitted, newly created, and recently impacted wetland and watercourse features under disturbed conditions. Senior Biologist – Field Crew Leader.

Kinder Morgan Saw Palmetto Pipeline, Sumter National Forest, Long Cane District (2014). Interstate environmental assessment and 404 permitting project. AECOM. FL, GA, SC RTE Project lead, including websters salamander, federally endangered Carolina heel splitter, Georgia aster, Oglethorpe oak, relict trillium, and other plant and tree species within the Sumter National Forest. Project activities included agency negotiation, field surveys with multiple protocols and multiple seasons. Threatened and Endangered Species Lead/Task Manager.

Seneca Owls Nest Seismic Testing, Forest and Elk Counties, PA (2011). Responsible for natural resource surveys regarding wetlands, watercourses, threatened and endangered species, invasive species avoidances, and sensitive areas for seismic testing for a 51-square mile tract in the Allegheny National Forest, Pennsylvania. Sensitive species surveys included birds, raptor nesting areas, rattlesnakes, and sensitive plant communities. Senior Biologist/Field Leader.

Southwestern Energy, PA (2011-2013). Responsible for wetland delineation, GPS survey, T&E species evaluation, permitting coordination, and project scheduling for nine miles of water supply and gathering line rights-of-way, impoundment locations, well pads, and water in-take structures. Conducted sensitive plant species surveys for soft-leaved sedge and marsh bedstraw. Responsible for effective communication project

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conditions for the purposes of submitting necessary reporting and permitting requirements. Senior Biologist – Task Manager/Field Crew Leader.

Chesapeake Energy Corporation, PA (2011-2014). Responsible for conducting aquatic surveys of macroinvertebrate and fish communities within watersheds in proximity to existing well pad locations. Responsible for evaluating temporal and community effects on biological communities following the placement of well pad structures within the Towanda Creek watershed. Principal taxonomist responsible for the identification of macroinvertebrates and laboratory quality control procedures. Evaluations included community metric calculations and Index of Biotic Integrity (IBI) as outlined in the Pennsylvania Department of Environmental Protection (PADEP) protocols. Senior Aquatic Biologist – Project Manager.

El Paso Northeast Passage Natural Gas Transmission Line Project, Pennsylvania Section. Coordinated and conducted wetland delineations and aquatic assessments of surface water resources associated with the proposed natural gas transmission line of approximately 130 miles throughout south-central and northeastern Pennsylvania. Senior Biologist.

Specialty Granules Inc., Adams County, PA (2011-2015). Mr. Snavely conducted wetland delineations, aquatic assessments, natural resource assessments associated with the proposed expansion of a greenstone quarry in Adams County, PA. Project activities included wetland and watercourse delineations, benthic evaluations, watershed assessments, and multi T&E species evaluation as part of the feasibility study. Rare plant surveys were conducted for Nodding Trillium and Northeastern Bulrush. Coordination with site construction personnel to avoid rare plant populations was performed in conjunction with the PA Department of Conservation of Natural Resources. Natural Resource Lead.

Crystal Springs Land Development Project, Fulton County, PA (2006). Mr. Snavely led wetland delineations and aquatic assessments of all surface water resources associated with the proposed residential development of approximately 550 acres in Crystal Springs, Fulton County, PA. The wetland and watercourse investigations for the proposed project resulted in the identification and delineation of approximately 15 acres of jurisdictional wetland and approximately 15,000 feet of jurisdictional watercourse. A preliminary jurisdictional determination of the identified aquatic resources was completed for the project with representatives of the U.S. Army Corps of Engineers, Baltimore District. Section 404 and Chapter 105 permit authorizations were successfully acquired for the project. Project Biologist.

Vulcan Quarries Planning Project, Loudon County, VA (2005-2007). Mr. Snavely conducted wetland delineations, aquatic assessments, assisted with sensitive plant species surveys associated with the proposed siting of a new quarry location in Loudon County, VA. Project activities included wetland and watercourse delineations, benthic evaluations, headwater stream evaluations, and rare plant species/community evaluations as part of the feasibility study. Rare plant surveys were conducted for Narrowed-Leaved Mountain-Mint, Stiff Goldenrod and the Piedmont Prairie community. Natural Resource Lead.

Liberty Land Development Project, Adams County, PA (2007). Assisted with the coordination of wetland delineations and aquatic assessments of all surface water resources associated with the proposed residential development of approximately 744 acres in Liberty Township, Adams County. The wetland and watercourse investigations for the proposed project resulted in the identification and delineation of approximately 124 acres of jurisdictional wetland and approximately 21, 500 feet of jurisdictional watercourse. A preliminary jurisdictional determination of the identified aquatic resources was completed for the project with representatives of the U.S. Army Corps of Engineers, Baltimore District. Staff Biologist.

Aquatic Resource Monitor and Wetland Delineator – US 220 Roadway Improvement Project, Blair and Center Counties, PA (2001-2011). Principal aquatic biologist responsible for permanent surface water monitoring throughout the South Bald Eagle Creek, North Bald Eagle Creek, and Buffalo Run watersheds. Monitoring includes evaluations of stream flow, ambient water quality, aquatic biota, and fluvial geomorphologic conditions in place for over ten years. Mr. Snavely is currently responsible for the collection and evaluation of physiochemical, biological, and physical habitat data throughout the project for compliance with the state issued CWA 401 Water Quality Certification. He is the principal biologist responsible for the identification and evaluation of the benthologic communities throughout the project watersheds. Senior Biologist.

Wetland Delineator, and Water Quality/Aquatic Resources Assistant, Route 322-B02, Corridor O Project, Centre and Clearfield County, PA (2002-2004). Responsible for the identification and delineation of wetlands and the evaluation of aquatic resources throughout the approximate 12,000 -acre project area. Mr. Snavely was also responsible for the identification and classification of aquatic communities based on their inhabitant benthologic and finfish communities. Staff Biologist.

Wetland Delineator, and Water Quality/Aquatic Resources – Keyser's Ridge NPDES Treatment Systems, Garrett County, MD (2001-2011). Responsible for the delineation of wetlands and watercourses for upgrades and improvements to an active groundwater treatment system in Garrett County, Maryland. This project involved weekly water quality monitoring and calibration within the treatment system and quarterly monitoring along two unnamed tributaries to Lake Louise. This treatment system and long-term monitoring program was designed and retrofitted to transition from passive to active treatment and to re-establish trout communities within Lake Louise and its larger tributaries. This project involved ensuring compliance with permitted NPDES discharge requirement and reporting. Senior Biologist – Task Manager.

Wetland Delineator, Aquatic Resources, and Forest Stand Professional – MD 5 Leonardtown Roadway Improvements Project, St. Mary's County, MD (2008). Responsible for the delineation of wetlands and watercourses along a 1.8 mile stretch of Maryland Route 5 from Maryland Route 243 to Hollywood Drive north of Leonardtown, Maryland. This project also involved assessment of Nontidal Wetlands of Special State Concern along with the land cover within the project study corridor for impacts to adjacent forest stand and roadside trees within the jurisdiction Roadside Tree and Reforestation Laws of Maryland as well as the Forest Conservation Laws of St. Mary's County. Assessment of seven watercourses, including McIntosh Run, using MD DNR MBSS protocols was conducted as part of this project. Senior Biologist – Task Manager.

Water Quality and Aquatic Resources Professional – Intercounty Connector Project Contract C, Montgomery and Prince Georges County, MD (2009-2011). Responsible for the deployment of solar powered continuous water quality stations for pre-, active, and post- construction monitoring in the Little Paint Branch and Indian Creek Watersheds. The project involved management of routine water quality station maintenance and calibration. Responsible for collection, identification, and relocation of freshwater fish during channel dewatering and relocation efforts. This effort required a MD DNR collectors permit. Also assisted with Box Turtle translocation efforts using visual, tactile, and canine detection methods. Senior Biologist – Task Manager.

Interstate 81 Widening Mitigation Site Evaluation, Washington County, MD (2005-2008). Project manager responsible for the identification of potential wetland and stream mitigation sites within the Conococheague watershed for inclusion in the Maryland State Highway Administration's Conceptual Mitigation Design Package. This project involved the coordination and over-site of field staff, land owner consultation, and coordination with the US Army Corps of Engineers, US Fish and Wildlife Service, Maryland State Highway Administration, and Maryland Department of the Environment. Successfully attained interagency approval for the mitigation alternatives. Senior Biologist.

Wetland Delineator and Forest Stand Professional – Boyer's Mill Road, Frederick County, MD (2009). Project manager responsible for the delineation of wetlands and watercourses along 4.4 miles of Boyer's Mill

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Road from Gas House Pike to Old National Pike. This project also involved assessment of the land cover within the project study corridor for impacts to adjacent forest stand and roadside trees within the jurisdiction Roadside Tree and Reforestation Laws of Maryland as well as the Forest Conservation Laws of Frederick County. Detailed agency coordination with the ACOE, MDE, and Frederick County was required to address future mitigation strategies. Senior Biologist – Project Manager.

Wetland Delineator and Forest Stand Professional – Maryland State Highway Administration (MDSHA) (2007-2011). Project manager responsible for the delineation of wetlands and watercourses on numerous MD SHA projects in Districts 3, 4, 5, 6, and 7. These projects involved completion of delineation reports for inclusion in Maryland Joint Permit application. Agency coordination with the ACOE and MDE was conducted to present resource boundaries and conduct impact assessments. Senior Biologist – Project Manager.

Broadneck Road Stream Restoration Project, Anne Arundel County, MD (2009-2010). Task manager responsible for the coordination and completion of wetland and watercourse delineations and forest stand delineations. This inventory was conducted for the completion of an Environmental Assessment and associated permitting requisites for stream restoration. The delineation of the approximate 1.6-mile project area was conducted to facilitate the planning and design of stream restoration efforts on behalf of the Anne Arundel County Department of Public Works. Senior Biologist – Task Manager.

SPECIAL TRAINING

Detailed species experience from 2013 to present is extensive available upon request

West Virginia Freshwater Mussel Taxonomy Class, Janet Clayton (WVDNR) 2020

Ohio Freshwater Mussel Taxonomy Class Tom Watters, FMCS 2017

North Carolina Freshwater Mussel Taxonomy North Carolina Tim Savidge, American Fisheries Society 2017

Freshwater Mussel Taxonomy Workshop, Art Bogan, Mid- Atlantic Water Pollution Biologists Workshop (2008)

Freshwater Mussel Taxonomy Workshop, Janet Clayton (WVDNR), Mid-Atlantic Water Pollution Biologists Workshop (2002-2003)

Attachment 1. Tables

Table 5-1. Summary of Unionid Species Observed in the Contoocook River, NH September 13-15, 2021.

Species	Total Live by Species	Rel. Ab. (%)
Elliptio complanata	2,677	97.8
Alasmidonta varicosa	53	1.9
Alasmidonta undulata	5	0.2
Pyganodon cataracta	3	0.1
Lampsilis radiata	0	0.0
Species Richness Total	5	
Species Richness Live	4	
Total Live Relocated [2]	0	
Total Unionids	2,738	
Survey Effort - hr(min)	17.4 (1044)	
Total Search Area (m^2)	950	
Overall CPUE (no./hour)[1]	157.4	

[1] CPUE = number live per work person hour (no. live / (Tot time/60 min)

[2] No mussels were relocated as part of this effort

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Table 5.2. (cont.) Maximum Depth, Number of Live Unionids, and Substrate Composition in the Contoocook River, NH, September 13-15, 2021.

			Average Substrate Composition (%)[1]						
Survey Location/Distance	**Maximum Depth (ft.)**	**Live Unionids**	**BR**	**BO**	**CB**	**GR**	**SD**	**ST**	**CL**
T1-1 (0-10 m)	3	18	0	0	40	40	20	0	0
T1-2 (10-20 m)	3	8	0	0	70	20	10	0	0
T1-3 (20-30 M)	3	3	0	0	40	40	20	0	0
T1-4 (30-40 m)	3	2	0	0	60	30	10	0	0
T1-5 (40-50 m)	3	0	0	0	60	30	10	0	0
T2-1 (0-10 m)	4.5	0	0	30	40	25	5	0	0
T2-2 (10-20 m)	4.5	1	0	30	40	25	5	0	0
T2-3 (20-30 M)	4.5	4	0	30	40	25	5	0	0
T2-4 (30-40 m)	4.5	1	0	10	60	20	10	0	0
T2-5 (40-50 m)	4.5	30	0	0	40	40	10	10	0
T3[a]	-	-	-	-	-	-	-	-	-
T4-1 (0-10 m)	3.5	2	0	0	30	10	0	60	0
T4-2 (10-20 m)	3.5	0	0	0	30	20	20	30	0
T4-3 (20-30 M)	3.5	2	0	0	30	20	10	40	0
T4-4 (30-40 m)	3.5	0	0	0	30	20	10	40	0
T4-5 (40-50 m)	3.5	0	0	0	20	40	10	30	0
T5-1 (0-10 m)	5	13	0	0	30	50	20	0	0
T5-2 (10-20 m)	5	18	0	0	30	50	20	0	0
T5-3 (20-30 M)	5	4	0	0	30	20	10	40	0
T5-4 (30-40 m)	5	11	0	0	90	0	0	10	0
T5-5 (40-50 m)	5	20	0	0	0	0	0	100	0
T6[a]	-	-	-	-	-	-	-	-	
T7-1 (0-10 m)	4	3	0	20	50	20	10	0	0
T7-2 (10-20 m)	4	17	0	20	45	20	15	0	0
T7-3 (20-30 M)	4	4	0	5	25	40	30	0	0
T7-4 (30-40 m)	4	2	0	5	15	30	30	20	0
T7-5 (40-50 m)	4	9	0	20	30	30	20	0	0
T8[a]	-	-	-	-	-	-	-	-	-
T9-1 (0-10 m)	1.5	1	0	30	60	5	5	0	0
T9-2 (10-20 m)	1.5	0	0	30	60	5	5	0	0
T9-3 (20-30 M)	1.5	0	0	30	60	10	0	0	0
T9-4 (30-40 m)	1.5	1	0	30	60	10	0	0	0
T9-5 (40-50 m)	1.5	0	0	30	60	10	0	0	0
T10-1 (0-10 m)	2.5	12	10	50	15	10	15	0	0
T10-2 (10-20 m)	2.5	50	10	50	15	10	15	0	0
T10-3 (20-30 M)	2.5	10	10	50	15	10	15	0	0
T10-4 (30-40 m)	2.5	23	10	50	15	10	15	0	0
T10-5 (40-50 m)	2.5	28	10	50	15	10	15	0	0
T11-1 (0-10 m)	4.5	27	0	0	60	30	10	0	0
T11-2 (10-20 m)	4.5	18	0	0	30	50	20	0	0
T11-3 (20-30 M)	4.5	28	0	0	30	50	20	0	0
T11-4 (30-40 m)	4.5	30	0	0	30	50	20	0	0
T11-5 (40-50 m)	4.5	35	0	20	30	20	30	0	0
T12-1 (0-10 m)	4	62	0	0	0	0	40	60	0
T12-2 (10-20 m)	4	47	0	0	0	0	40	60	0
T12-3 (20-30 M)	4	11	0	0	0	0	20	80	0
T12-4 (30-40 m)	4	16	0	0	0	0	0	100	0
T12-5 (40-50 m)	4	24	0	0	0	0	0	100	0
T13-1 (0-10 m)	4.5	26	0	15	10	35	20	20	0
T13-2 (10-20 m)	4.5	94	0	25	25	20	20	10	0
T13-3 (20-30 M)	4.5	45	0	35	30	25	10	0	0
T13-4 (30-40 m)	4.5	17	0	60	0	15	10	15	0

Table 5-2.(cont.) Maximum Depth, Number of Live Unionids, and Substrate Composition in the Contoocook River, NH, September 13-15, 2021.

			Average Substrate Composition (%)[1]						
T13-5 (40-50 m)	4.5	41	0	20	40	20	10	10	0
T14-1 (0-10 m)	3	63	0	0	0	0	60	40	0
T14-2 (10-20 m)	3	74	0	0	0	0	60	40	0
T14-3 (20-30 M)	3	26	0	0	0	0	60	40	0
T14-4 (30-40 m)	3	45	0	0	0	0	60	40	0
T14-5 (40-50 m)	3	88	0	0	0	0	60	40	0
T15-1 (0-10 m)	4.5	24	0	50	30	5	15	0	0
T15-2 (10-20 m)	4.5	45	0	30	30	20	10	10	0
T15-3 (20-30 M)	4.5	83	0	10	50	30	10	0	0
T15-4 (30-40 m)	4.5		0	0	30	20	20	30	0
T15-5 (40-50 m)	4.5	7	0	0	20	20	20	40	0
T16-1 (0-10 m)	4.5	10	0	40	30	15	10	5	0
T16-2 (10-20 m)	4.5	18	0	40	25	15	20	0	0
T16-3 (20-30 M)	4.5	50	0	10	20	20	15	35	0
T16-4 (30-40 m)	4.5	94	0	0	10	10	20	60	0
T16-5 (40-50 m)	4.5	15	0	0	5	5	10	80	0
T17-1 (0-10 m)	3	44	0	0	0	0	30	70	0
T17-2 (10-20 m)	3	127	0	0	0	0	0	100	0
T17-3 (20-30 M)	3	126	0	0	0	0	0	100	0
T17-4 (30-40 m)	3	101	0	0	0	0	0	100	0
T17-5 (40-50 m)	3	133	0	0	0	0	0	100	0
T18-1 (0-10 m)	3.5	54	0	0	0	0	10	90	0
T18-2 (10-20 m)	3.5	69	0	0	0	0	10	90	0
T18-3 (20-30 M)	3.5	75	0	0	0	0	10	90	0
T18-4 (30-40 m)	3.5	125	0	0	0	0	10	90	0
T18-5 (40-50 m)	3.5	56	0	0	0	0	10	90	0
T19-1 (0-10 m)	4	26	0	0	0	0	100	0	0
T19-2 (10-20 m)	4	23	0	0	0	0	100	0	0
T19-3 (20-30 M)	4	1	0	0	0	0	100	0	0
T19-4 (30-40 m)	4	3	0	0	0	0	100	0	0
T19-5 (40-50 m)	4	0	0	0	0	0	100	0	0
T20-1 (0-10 m)	4	46	0	0	0	0	0	100	0
T20-2 (10-20 m)	4	34	0	0	0	0	0	100	0
T20-3 (20-30 M)	4	20	0	0	0	0	0	100	0
T20-4 (30-40 m)	4	22	0	0	0	0	0	100	0
T20-5 (40-50 m)	4	14	0	0	0	0	0	100	0
T21-1 (0-10 m)	5	31	0	0	0	0	100	0	0
T21-2 (10-20 m)	5	8	0	0	0	0	100	0	0
T21-3 (20-30 M)	5	58	0	0	0	35	45	20	0
T21-4 (30-40 m)	5	50	0	0	0	60	40	0	0
T21-5 (40-50 m)	5	31	0	0	0	40	40	0	20
T22-1 (0-10 m)	4	0	0	0	0	0	0	100	0
T22-2 (10-20 m)	4	0	0	0	0	0	0	100	0
T22-3 (20-30 M)	4	1	0	0	0	0	0	100	0
T22-4 (30-40 m)	4	0	0	0	0	0	0	100	0
T22-5 (40-50 m)	4	0	0	0	0	0	0	100	0

[1] Wentworth scale (Wentworth 1922)
BR = bed rock, BO = boulder, CB = cobble, GR = gravel, SD = sand, ST = silt, CL = clay, Other = shell material, detritus etc.
[2] no survey due to steep margins

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Table 5-3. Summary of Live Unionids, and CPUE per Transect in the Contoocook River, NH, September 13-15, 2021.

Transect Segment	Number Live Mussels	Survey Time (minutes)	[1]CPUE (no./hour) - Total	Search Area (m^2)
T1	31	48	38.8	50
T2	36	54	40.0	50
T3 [a]	-	-	-	-
T4	4	60	4.0	50
T5	66	44	90.0	50
T6 [a]	-	-	-	-
T7	35	68	30.9	50
T8 [a]	-	-	-	-
T9	2	32	3.8	50
T10	123	66	111.8	50
T11	138	74	111.9	50
T12	160	60	160.0	50
T13	223	60	223.0	50
T14	296	31	572.9	50
T15	159	80	119.3	50
T16	187	64	175.3	50
T17	531	64	497.8	50
T18	379	64	355.3	50
T19	53	56	56.8	50
T20	136	44	185.5	50
T21	178	41	260.5	50
T22	1	34	1.8	50
Grand Total/Average	2,738	1,044	157.4	950

[a] no survey due to steep margins

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Table 5-4. Summary of Unionid Species Observed in the in the Contoocook River, NH, September 13-15, 2021.

Survey Location/Species	Live	FD	WD	SF
T1				
T1-1 (0-10 m)				
Elliptio complanata	18	0	0	0
T1-2 (10-20 m)				
Elliptio complanata	8	0	0	0
T1-3 (20-30 m)				
Elliptio complanata	3	0	0	0
T1-4 (30-40 m)				
Elliptio complanata	2	0	0	0
T1-5 (40-50 m)				
No live mussels or shells	0	0	0	0
Subtotal	31	0	0	0
T2				
T2-1 (0-10 m)				
No live mussels or shells	0	0	0	0
T2-2 (10-20 m)				
Elliptio complanata	1	0	0	0
T2-3 (20-30 m)				
Elliptio complanata	4	0	0	0
T2-4 (30-40 m)				
Elliptio complanata	1	0	0	0
T2-5 (40-50 m)				
Elliptio complanata	30	0	0	0
Subtotal	36	0	0	0
T3 [a]	-	-	-	-
T4				
T4-1 (0-10 m)				
Elliptio complanata	2	0	0	0
T4-2 (10-20 m)				
Alasmidonta varicosa	0	0	1	0
T4-3 (20-30 m)				
Elliptio complanata	2	0	0	0
T4-4 (30-40 m)				
No live mussels or shells	0	0	0	0
T4-5 (40-50 m)				
No live mussels or shells	0	0	0	0
Subtotal	4	0	1	0
T5				
T5-1 (0-10 m)				
Alasmidonta varicosa	1	0	0	0
Elliptio complanata	12	0	0	0

Table 5-4. (cont.) Summary of Unionid Species Observed in the in the Contoocook River, NH, September 13-15, 2021.

Survey Location/Species	Live	FD	WD	SF
T5-2 (10-20 m)				
Alasmidonta varicosa	1	0	0	0
Elliptio complanata	17	0	0	0
T5-3 (20-30 m)				
Elliptio complanata	4	0	0	0
T5-4 (30-40 m)				
Elliptio complanata	11	0	0	0
T5-5 (40-50 m)				
Elliptio complanata	20	0	0	0
Subtotal	66	0	0	0
T6 [a]	-	-	-	-
T7				
T7-1 (0-10 m)				
Elliptio complanata	3	0	0	0
T7-2 (10-20 m)				
Elliptio complanata	17	0	0	0
T7-3 (20-30 m)				
Elliptio complanata	4	0	0	0
T7-4 (30-40 m)				
Elliptio complanata	2	0	0	0
T7-5 (40-50 m)				
Elliptio complanata	9	0	0	0
Subtotal	35	0	0	0
T8 [a]	-	-	-	-
T9				
T9-1 (0-10 m)				
Elliptio complanata	1	0	0	0
T9-2 (10-20 m)				
No live mussels or shells	0	0	0	0
T9-3 (20-30 m)				
No live mussels or shells	0	0	0	0
T9-4 (30-40 m)				
Elliptio complanata	1	0	0	0
T9-5 (40-50 m)				
No live mussels or shells	0	0	0	0
Subtotal	2	0	0	0
T10				
T10-1 (0-10 m)				
Alasmidonta varicosa	6	0	0	0
Elliptio complanata	6	0	0	0

Table 5-4. (cont.) Summary of Unionid Species Observed in the in the Contoocook River, NH, September 13-15, 2021.

Survey Location/Species	Live	FD	WD	SF
T10-2 (10-20 m)				
Alasmidonta undulata	2	0	0	0
Alasmidonta varicosa	24	0	0	0
Elliptio complanata	23	0	0	0
Pyganodon cataracta	1	0	0	0
T10-3 (20-30 m)				
Alasmidonta varicosa	2	0	0	0
Elliptio complanata	8	0	0	0
T10-4 (30-40 m)				
Alasmidonta undulata	2	0	0	0
Alasmidonta varicosa	11	0	0	0
Elliptio complanata	10	0	0	0
T10-5 (40-50 m)				
Alasmidonta varicosa	8	0	0	0
Elliptio complanata	20	0	0	0
Subtotal	123	0	0	0
T11				
T11-1 (0-10 m)				
Elliptio complanata	27	0	0	0
T11-2 (10-20 m)				
Alasmidonta undulata	0	0	1	0
Elliptio complanata	18	0	0	0
T11-3 (20-30 m)				
Elliptio complanata	28	0	0	0
T11-4 (30-40 m)				
Elliptio complanata	30	0	0	0
T11-5 (40-50 m)				
Elliptio complanata	35	0	0	0
Subtotal	138	0	1	0
T12				
T12-1 (0-10 m)				
Elliptio complanata	62	0	0	0
T12-2 (10-20 m)				
Elliptio complanata	47	0	0	0
T12-4 (20-30 m)				
Elliptio complanata	11	0	0	0
T13-4 (30-40 m)				
Elliptio complanata	16	0	0	0
T14-5 (40-50 m)				
Elliptio complanata	24	0	0	0
Subtotal	160	0	0	0
T13				

Table 5-4. (cont.) Summary of Unionid Species Observed in the in the Contoocook River, NH, September 13-15, 2021.

Survey Location/Species	Live	FD	WD	SF
T13-1 (0-10 m)				
Elliptio complanata	26	0	0	0
T13-2 (10-20 m)				
Elliptio complanata	94	0	0	0
Lampsilis radiata	0	1	0	0
T13-3 (20-30 m)				
Elliptio complanata	45	0	0	0
T13-4 (30-40 m)				
Elliptio complanata	17	0	0	0
T13-5 (40-50 m)				
Elliptio complanata	41	0	0	0
Subtotal	223	1	0	0
T14				
T14-1 (0-10 m)				
Elliptio complanata	63	0	0	0
T14-2 (10-20 m)				
Elliptio complanata	74	0	0	0
T14-(20-30 m)				
Elliptio complanata	26	0	0	0
Lampsilis radiata	0	0	0	1
T14-4 (30-40 m)				
Elliptio complanata	45	0	0	0
T14-5 (40-50 m)				
Elliptio complanata	88	0	0	0
Subtotal	296	0	0	1
T15				
T15-1 (0-10 m)				
Elliptio complanata	24	0	0	0
T15-2 (10-20 m)				
Elliptio complanata	45	0	0	0
T15-3 (20-30 m)				
Elliptio complanata	83	0	0	0
Lampsilis radiata	0	2	0	0
T15-4 (30-40 m)				
No live mussels or shells	0	0	0	0
T15-5 (40-50 m)				
Elliptio complanata	7	0	0	0
Subtotal	159	2	0	0
T16				
T16-1 (0-10 m)				
Elliptio complanata	10	0	0	0
T16-2 (10-20 m)				

Table 5-4. (cont.) Summary of Unionid Species Observed in the in the Contoocook River, NH, September 13-15, 2021.

Survey Location/Species	Live	FD	WD	SF
Elliptio complanata	18	0	0	0
T16-3 (20-30 m)				
Elliptio complanata	50	0	0	0
T16-4 (30-40 m)				
Elliptio complanata	94	0	0	0
T16-5 (40-50 m)				
Elliptio complanata	15	0	0	0
Subtotal	187	0	0	0
T17				
T17-1 (0-10 m)				
Elliptio complanata	44	0	0	0
T17-2 (10-20 m)				
Elliptio complanata	126	0	0	0
Pyganodon cataracta	1	0	0	0
T17-3 (20-30 m)				
Elliptio complanata	126	0	0	0
T17-4 (30-40 m)				
Elliptio complanata	101	0	0	0
T17-5 (40-50 m)				
Elliptio complanata	133	0	0	0
Subtotal	531	0	0	0
T18				
T18-1 (0-10 m)				
Elliptio complanata	54	0	0	0
T18-2 (10-20 m)				
Elliptio complanata	69	0	0	0
Lampsilis radiata	0	0	0	1
T18-3 (20-30 m)				
Elliptio complanata	75	0	0	0
Lampsilis radiata	0	0	2	0
T18-4 (30-40 m)				
Elliptio complanata	125	0	0	0
Lampsilis radiata	0	1	2	3
Pyganodon cataracta	0	0	1	0
T18-5 (40-50 m)				
Elliptio complanata	56	0	0	0
Subtotal	379	1	5	4
T19				
T19-1 (0-10 m)				
Elliptio complanata	26	0	0	0
T19-2 (10-20 m)				
Alasmidonta undulata	1	0	0	0

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Table 5-4. (cont.) Summary of Unionid Species Observed in the in the Contoocook River, NH, September 13-15, 2021.

Survey Location/Species	Live	FD	WD	SF
Elliptio complanata	22	0	0	0
T19-3 (20-30 m)				
Elliptio complanata	1	0	0	0
T19-4 (30-40 m)				
Elliptio complanata	2	0	0	0
Pyganodon cataracta	1	0	0	0
T19-5 (40-50 m)				
No live mussels or shells	0	0	0	0
Subtotal	53	0	0	0
T20				
T20-1 (0-10 m)				
Elliptio complanata	46	0	0	0
T20-2 (10-20 m)				
Elliptio complanata	34	0	0	0
T20-3 (20-30				
Elliptio complanata	20	0	0	0
Lampsilis radiata	0	0	1	0
T20-4 (30-40 m)				
Elliptio complanata	22	0	0	0
T20-5 (40-50 m)				
Elliptio complanata	14	0	0	0
Subtotal	136	0	1	0
T21				
T21-1 (0-10 m)				
Elliptio complanata	31	0	0	0
T21-2 (10-20 m)				
Elliptio complanata	8	0	0	0
T21-3 (20-30 m)				
Elliptio complanata	58	0	0	0
T21-4 (30-40 m)				
Elliptio complanata	50	0	0	0
T21-5 (40-50 m)				
Elliptio complanata	31	0	0	0
Subtotal	178	0	0	0
T22				
T22-1 (0-10 m)				
No live mussels or shells	0	0	0	0
T22-2 (10-20 m)				
No live mussels or shells	0	0	0	0
T22-3 (20-30 m)				
Elliptio complanata	1	0	0	0
T22-4 (30-40 m)				

Table 5-4. (cont.) Summary of Unionid Species Observed in the in the Contoocook River, NH, September 13-15, 2021.

Survey Location/Species	Live	FD	WD	SF
No live mussels or shells	0	0	0	0
T22-5 (40-50 m)				
No live mussels or shells	0	0	0	0
Subtotal	1	0	0	0

[1] no survey due to steep bank

Attachment 2. Figures

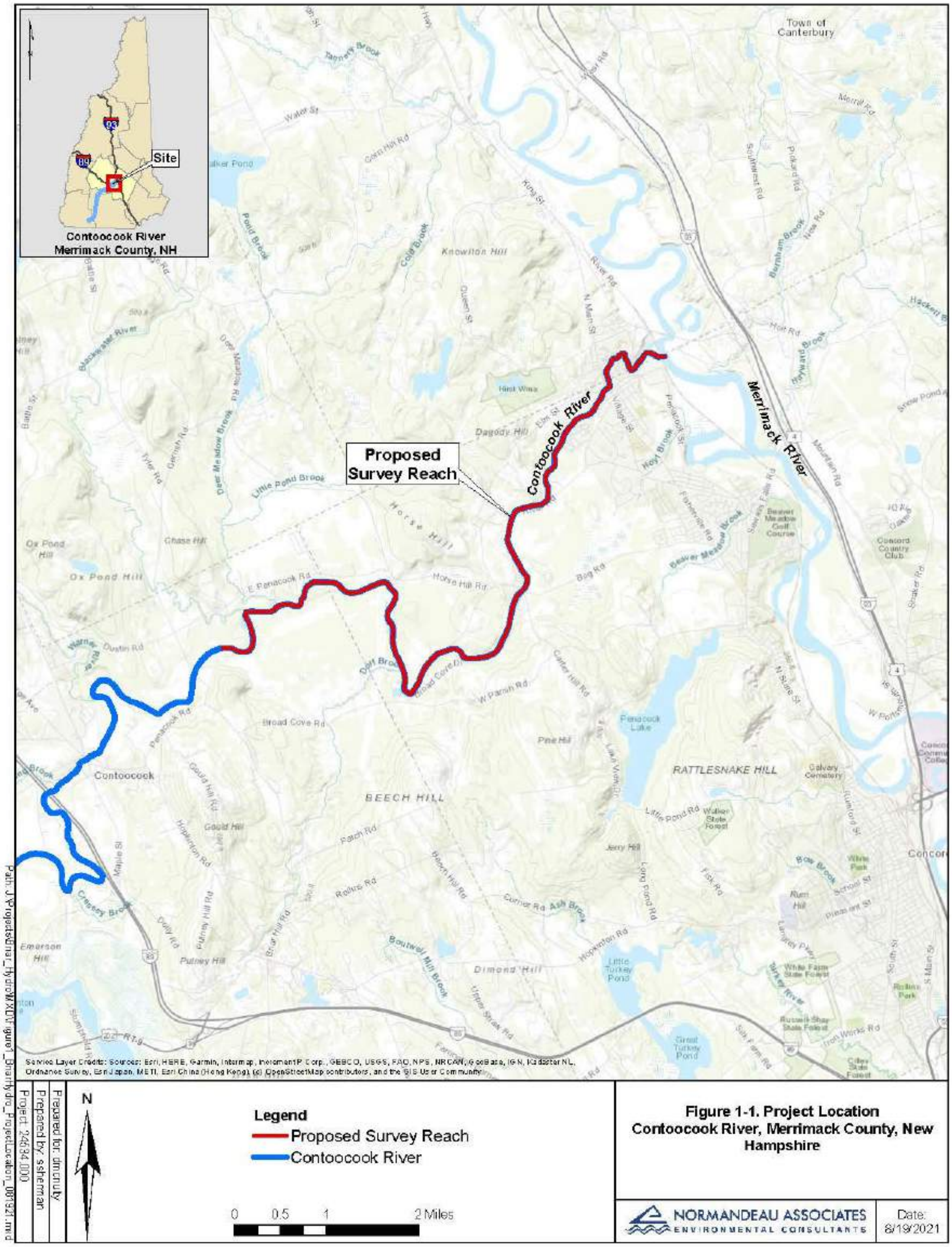

Figure 1-1. Project Location Contoocook River, Merrimack County, New Hampshire

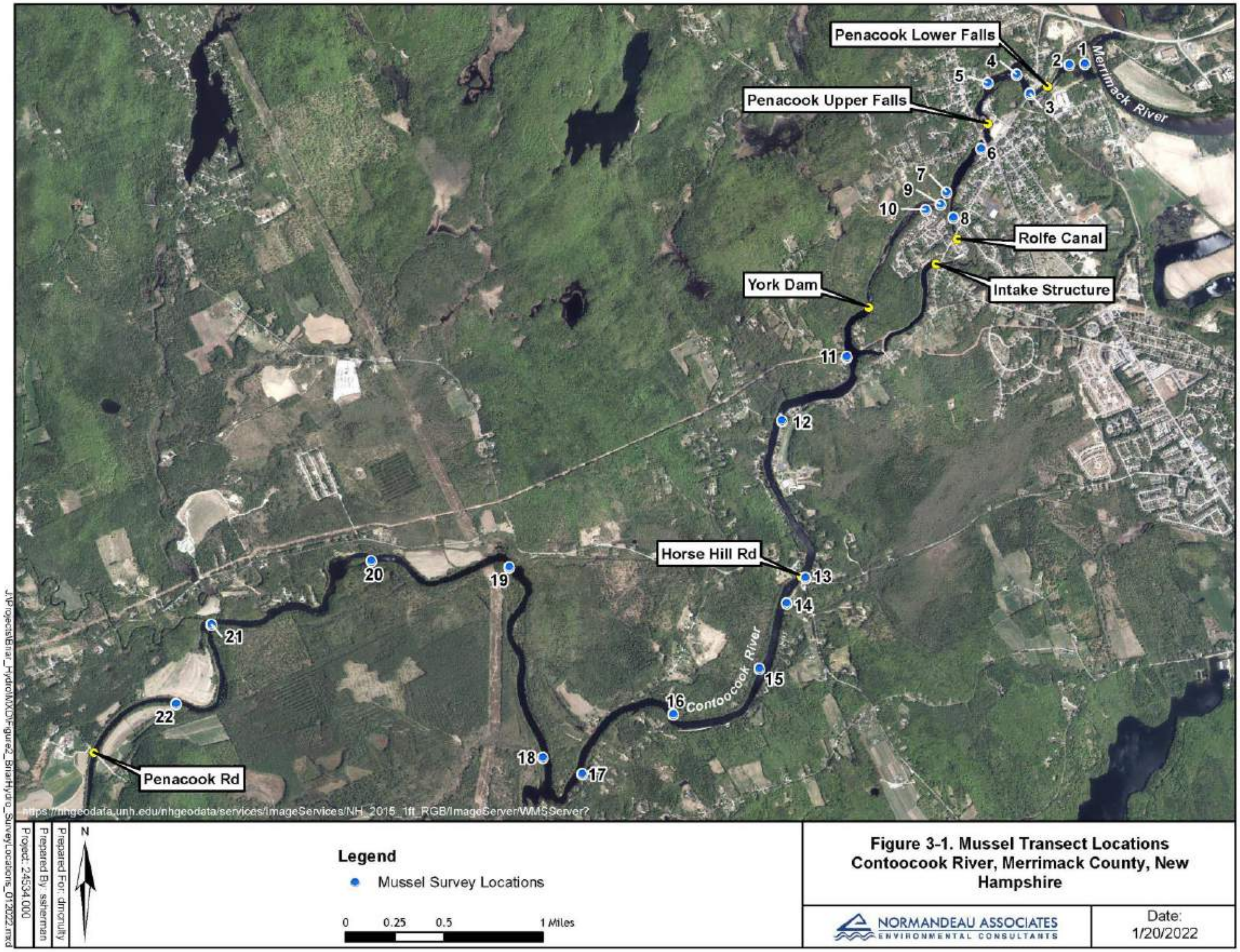

Figure 3-1. Mussel Transect Locations Contoocook River, Merrimack County, New Hampshire

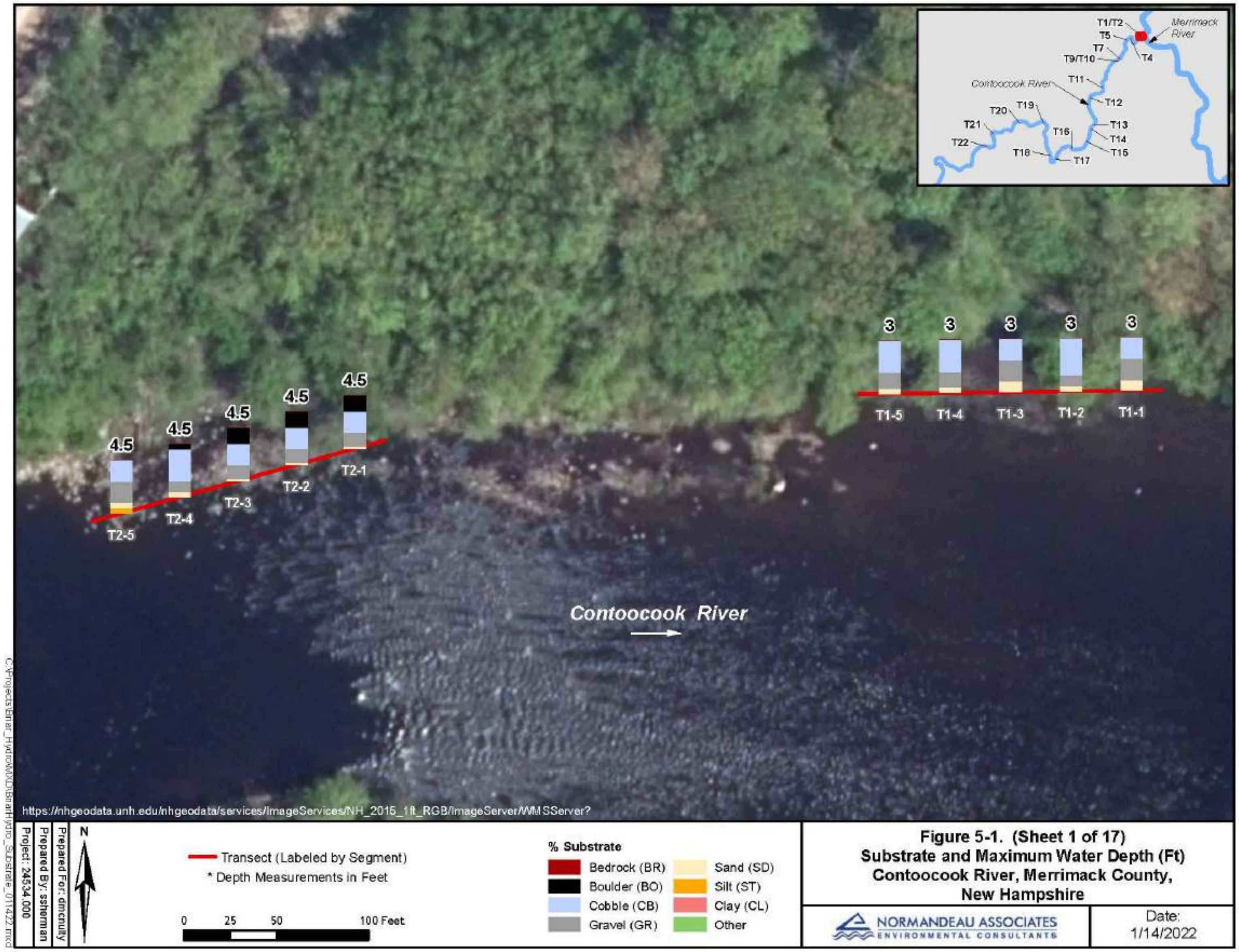

Figure 5-1. (Sheet 1 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County,
New Hampshire

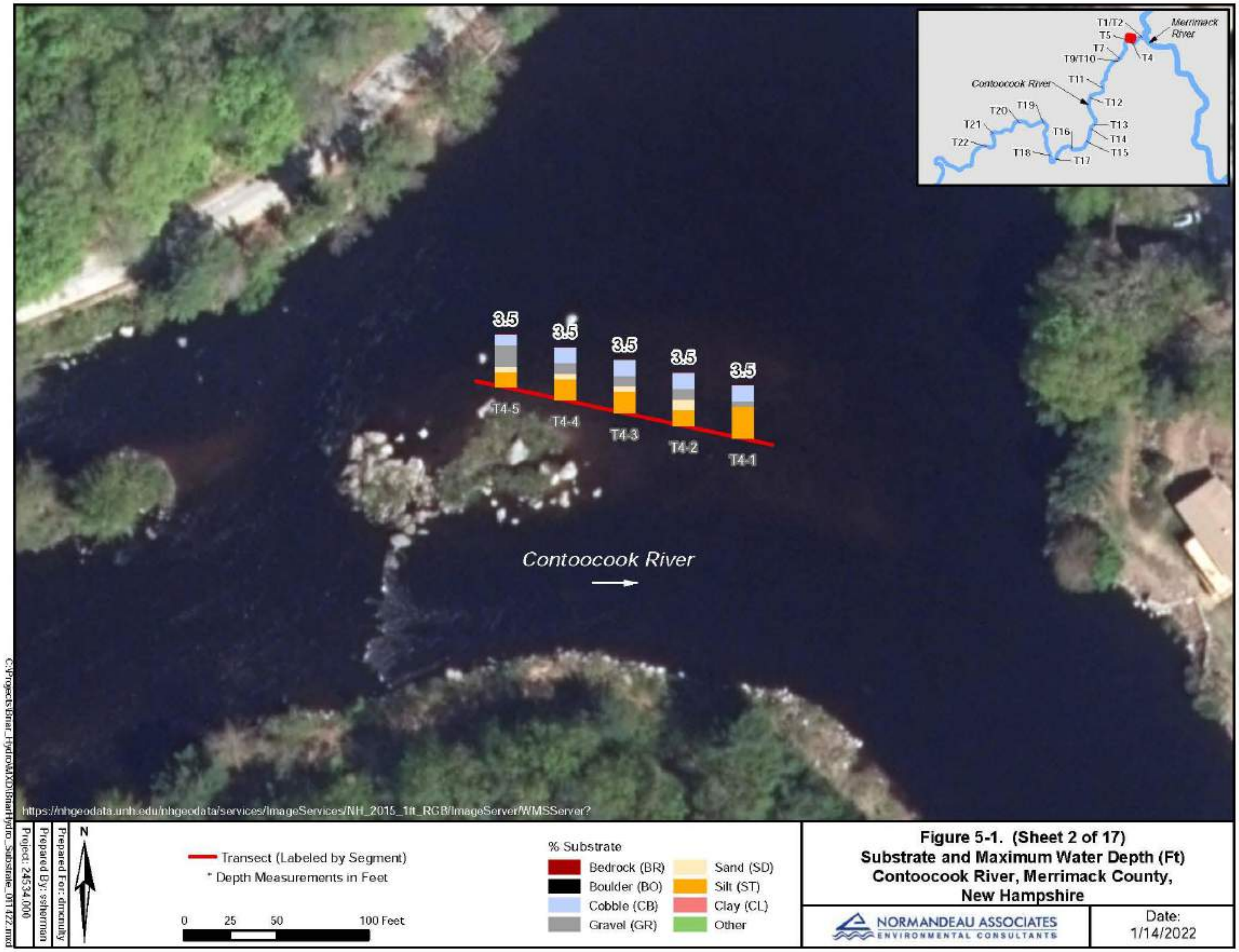

Figure 5-1. (Sheet 2 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

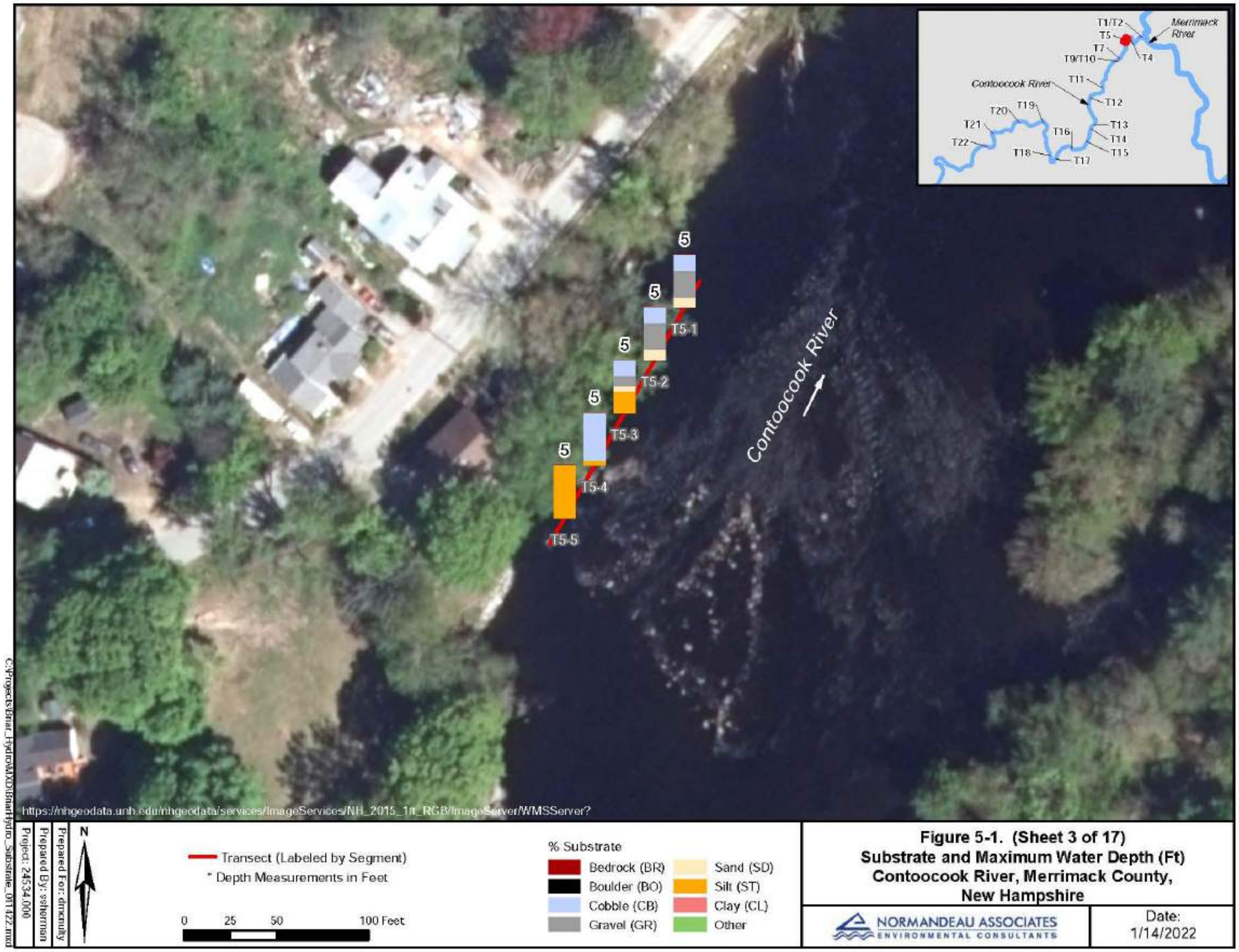

Figure 5-1. (Sheet 3 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

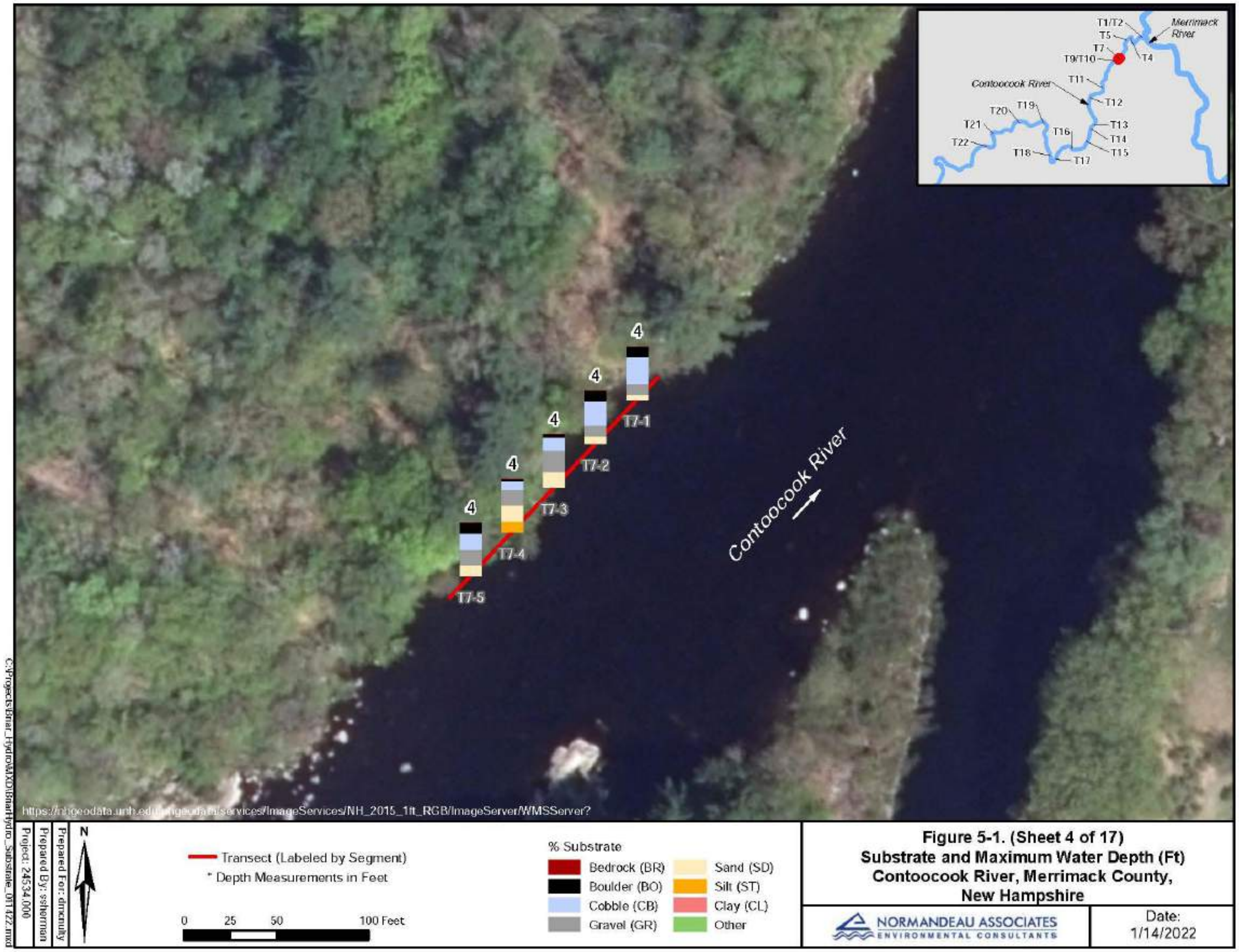

Figure 5-1. (Sheet 4 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

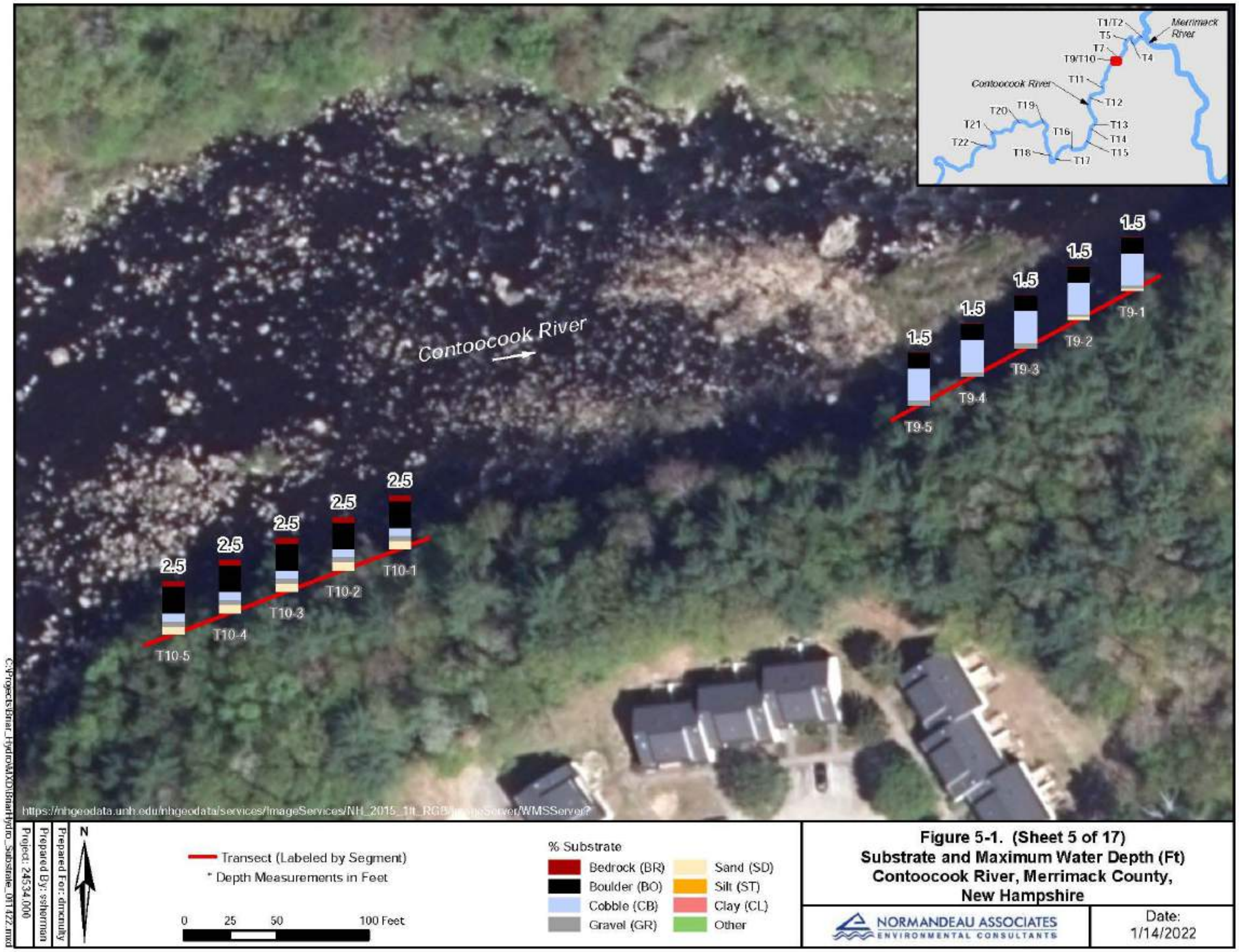

Figure 5-1. (Sheet 5 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

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Date: 1/14/2022

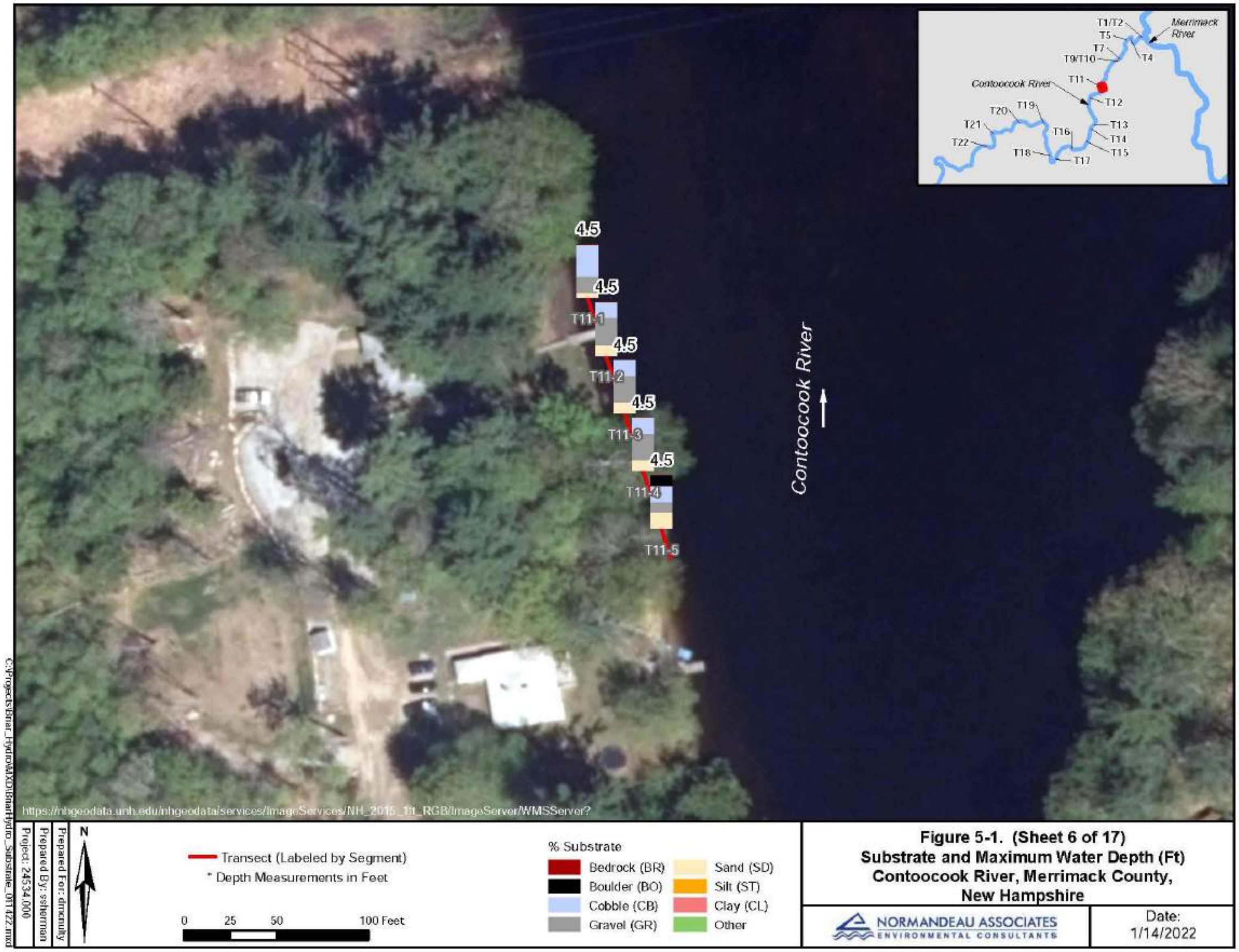

Figure 5-1. (Sheet 6 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

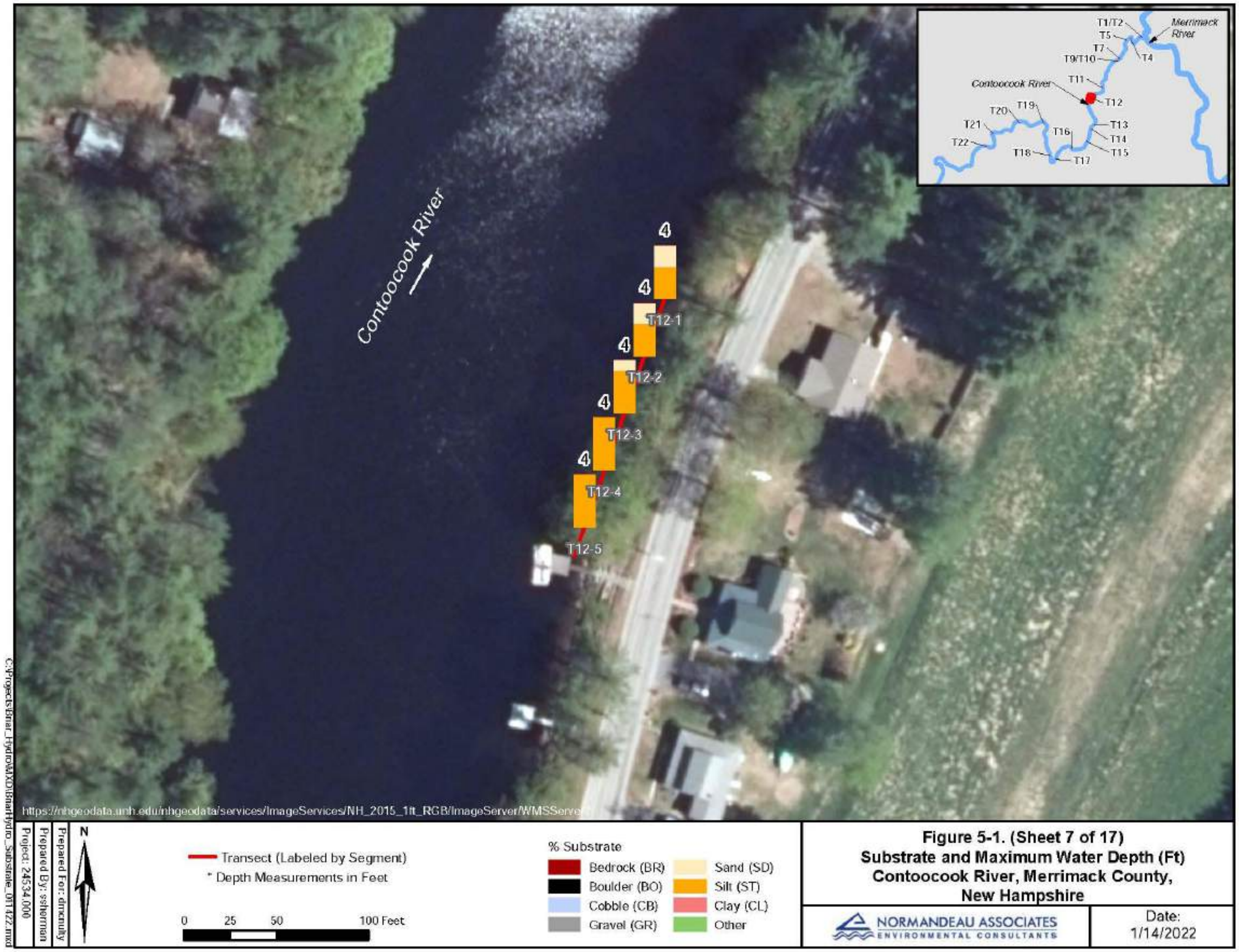

Figure 5-1. (Sheet 7 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

Figure 5-1. (Sheet 8 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

Figure 5-1. (Sheet 9 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

C:\Projects\Briar_Hydro\MXD\BriarHydro_Substrate_011422.mxd
Project: 24534.000
Prepared By: ssherman
Prepared For: dmcnulty

N

Transect (Labeled by Segment)
* Depth Measurements in Feet

0 25 50 100 Feet

% Substrate

Bedrock (BR)	Sand (SD)
Boulder (BO)	Silt (ST)
Cobble (CB)	Clay (CL)
Gravel (GR)	Other

Figure 5-1. (Sheet 10 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

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ENVIRONMENTAL CONSULTANTS

Date:
1/14/2022

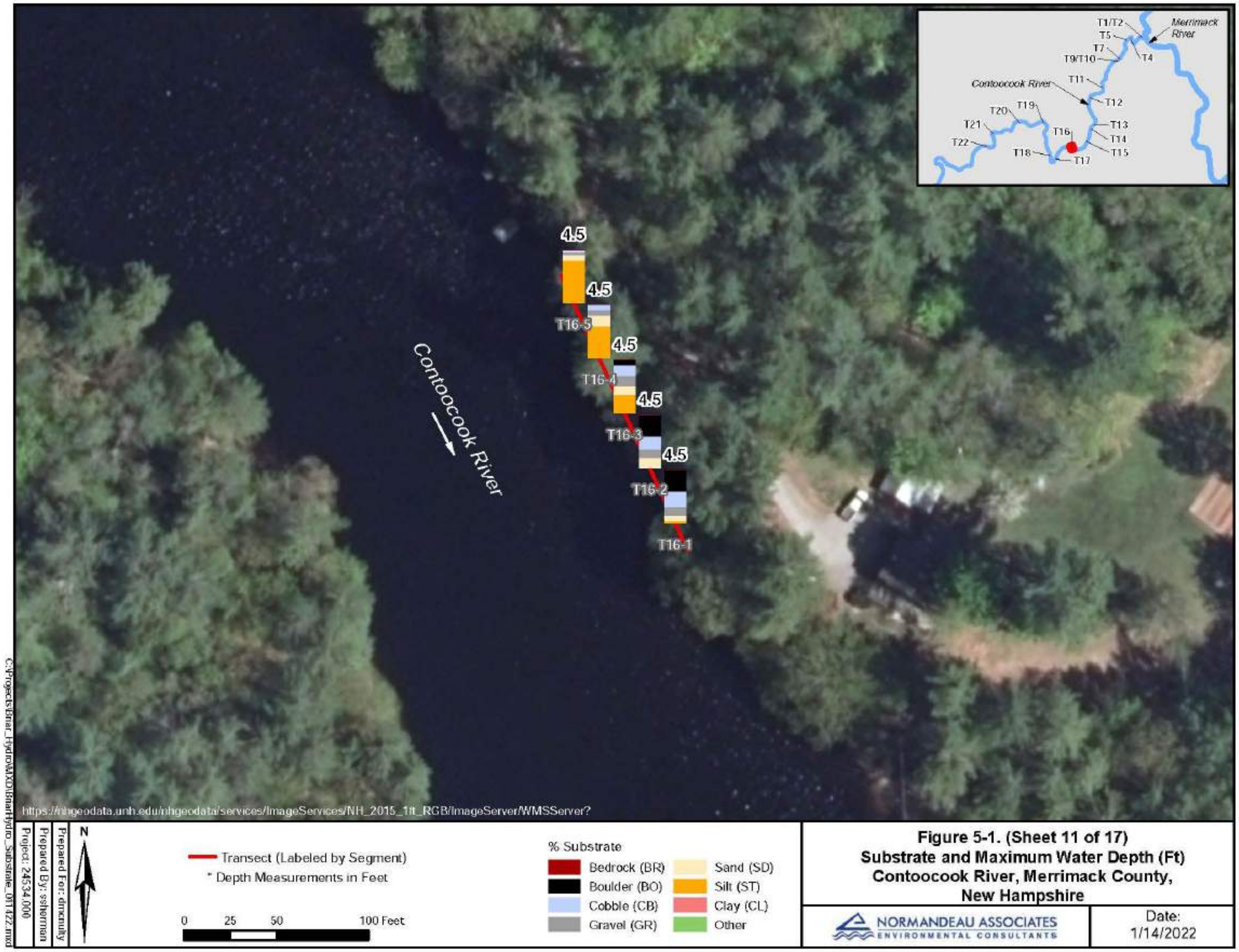


Figure 5-1. (Sheet 11 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

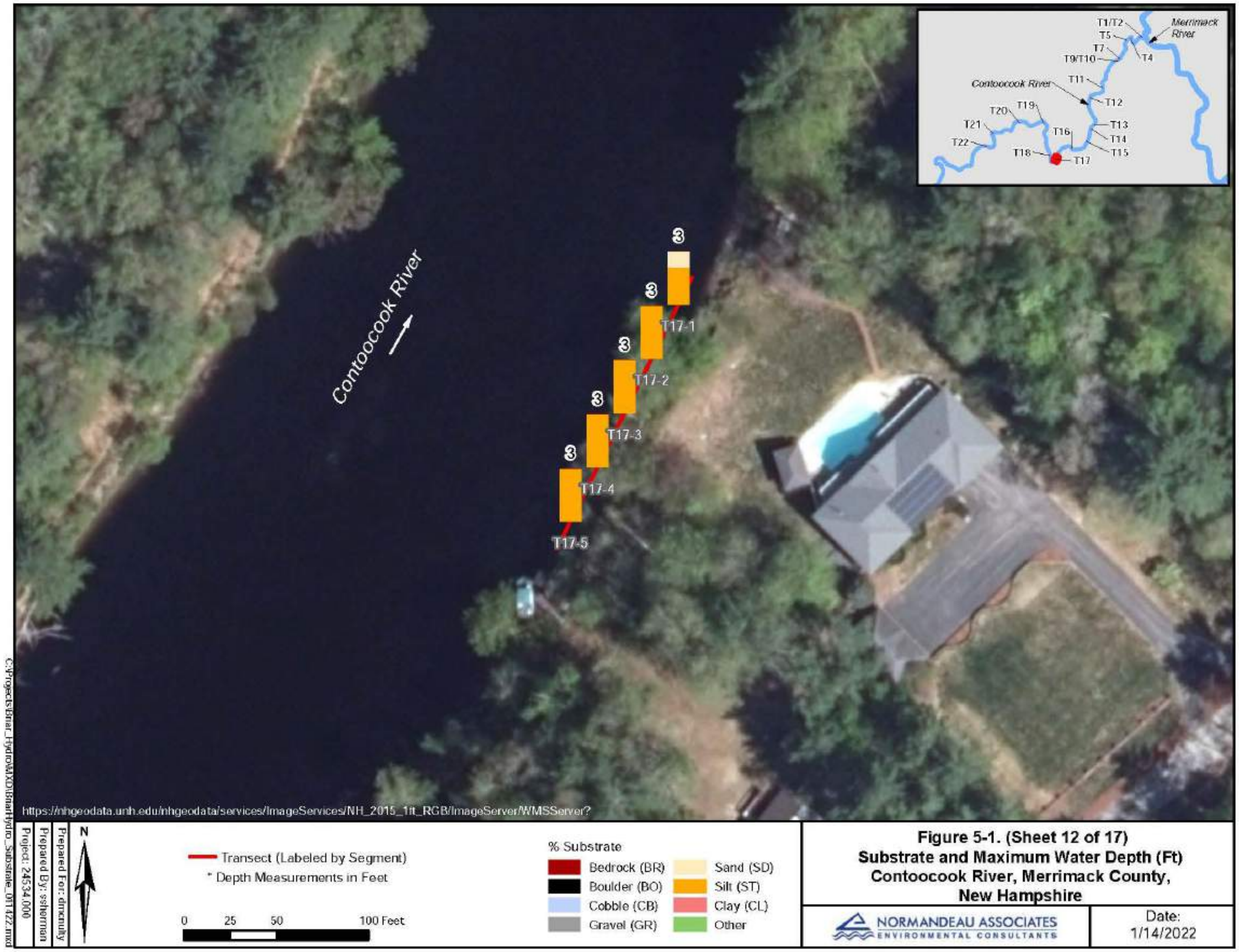


Figure 5-1. (Sheet 12 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

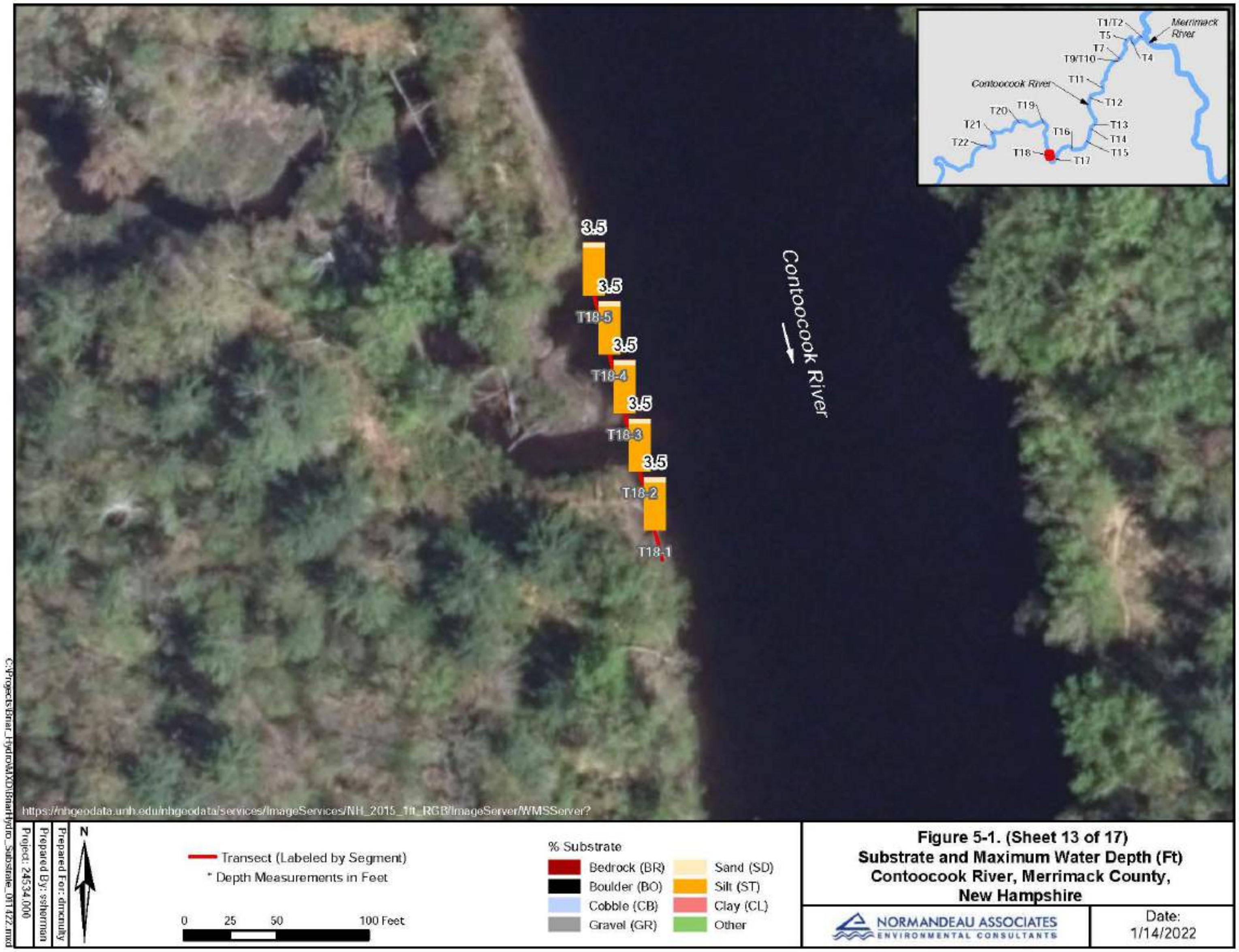


Figure 5-1. (Sheet 13 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

NORMANDEAU ASSOCIATES ENVIRONMENTAL CONSULTANTS

Date: 1/14/2022

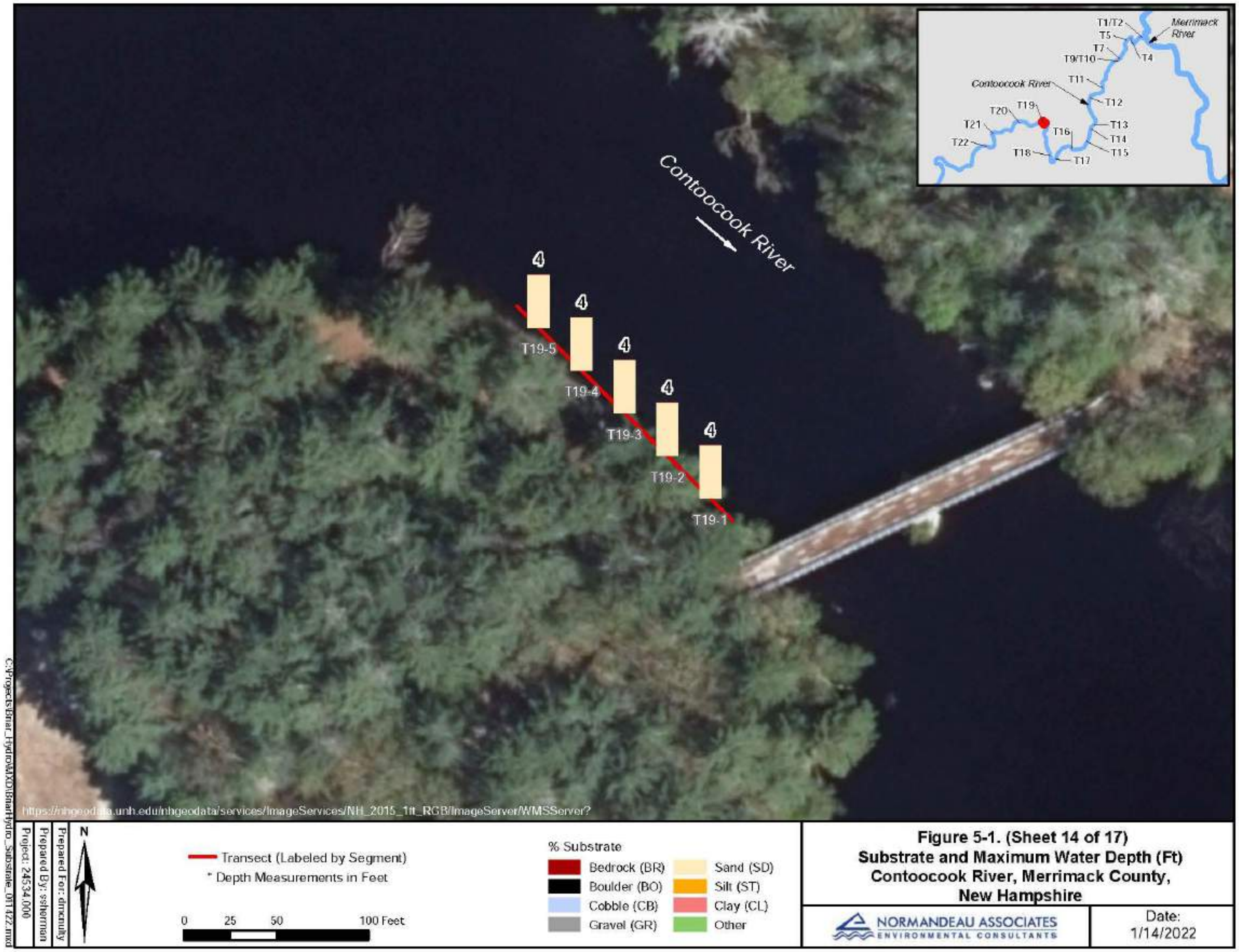


Figure 5-1. (Sheet 14 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

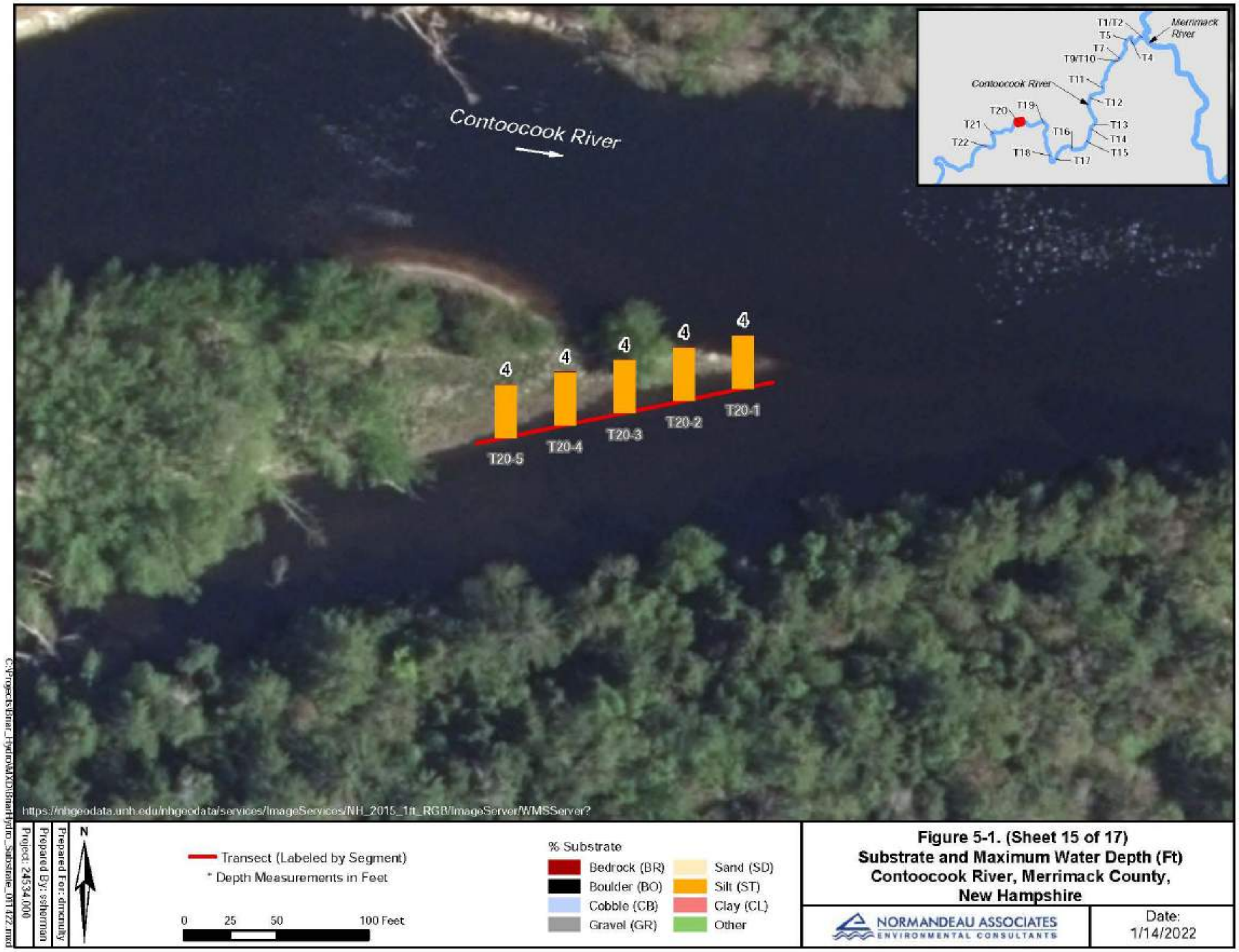


Figure 5-1. (Sheet 15 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

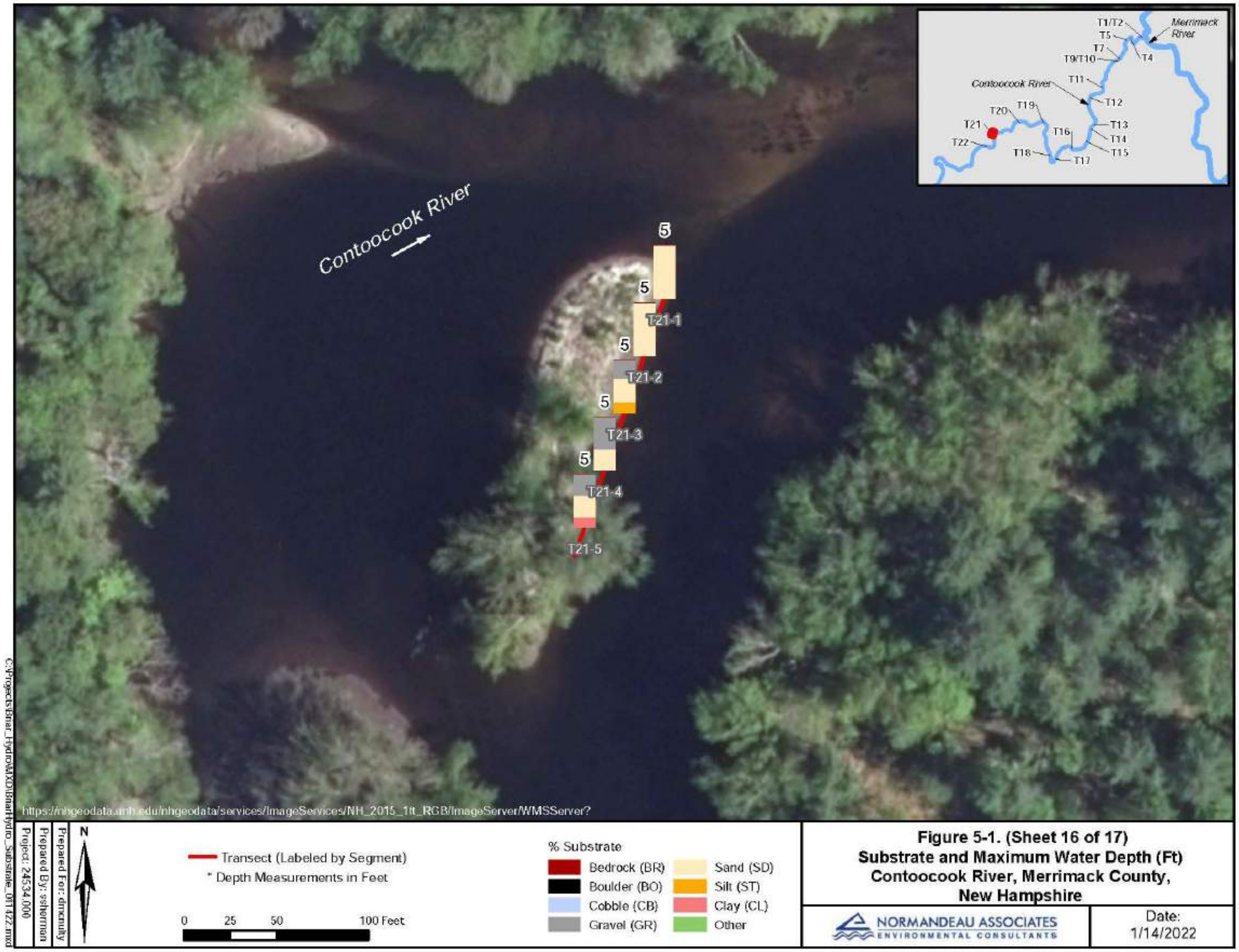


Figure 5-1. (Sheet 16 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

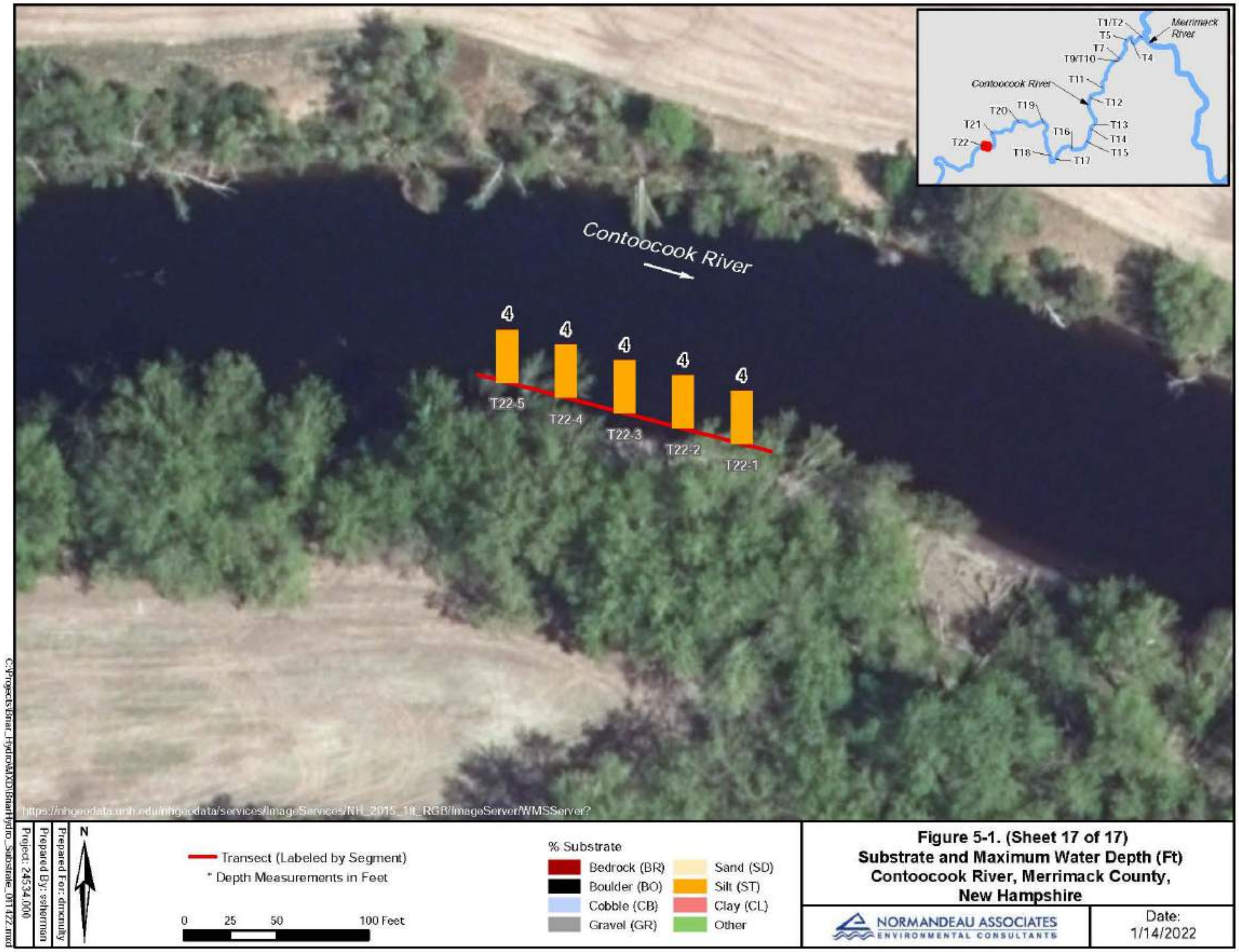


Figure 5-1. (Sheet 17 of 17)
Substrate and Maximum Water Depth (Ft)
Contoocook River, Merrimack County, New Hampshire

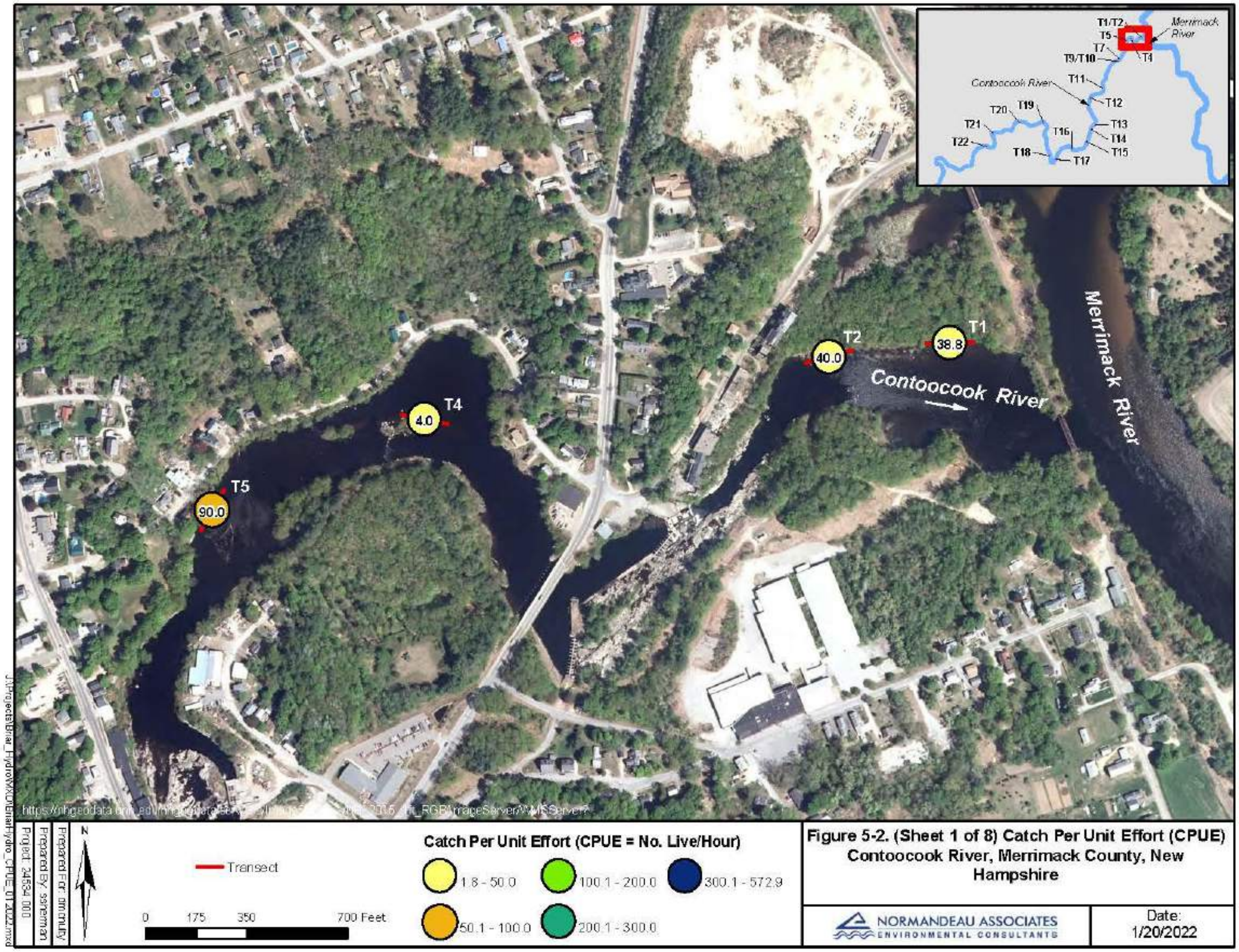


Figure 5-2. (Sheet 1 of 8) Catch Per Unit Effort (CPUE) Contoocook River, Merrimack County, New Hampshire

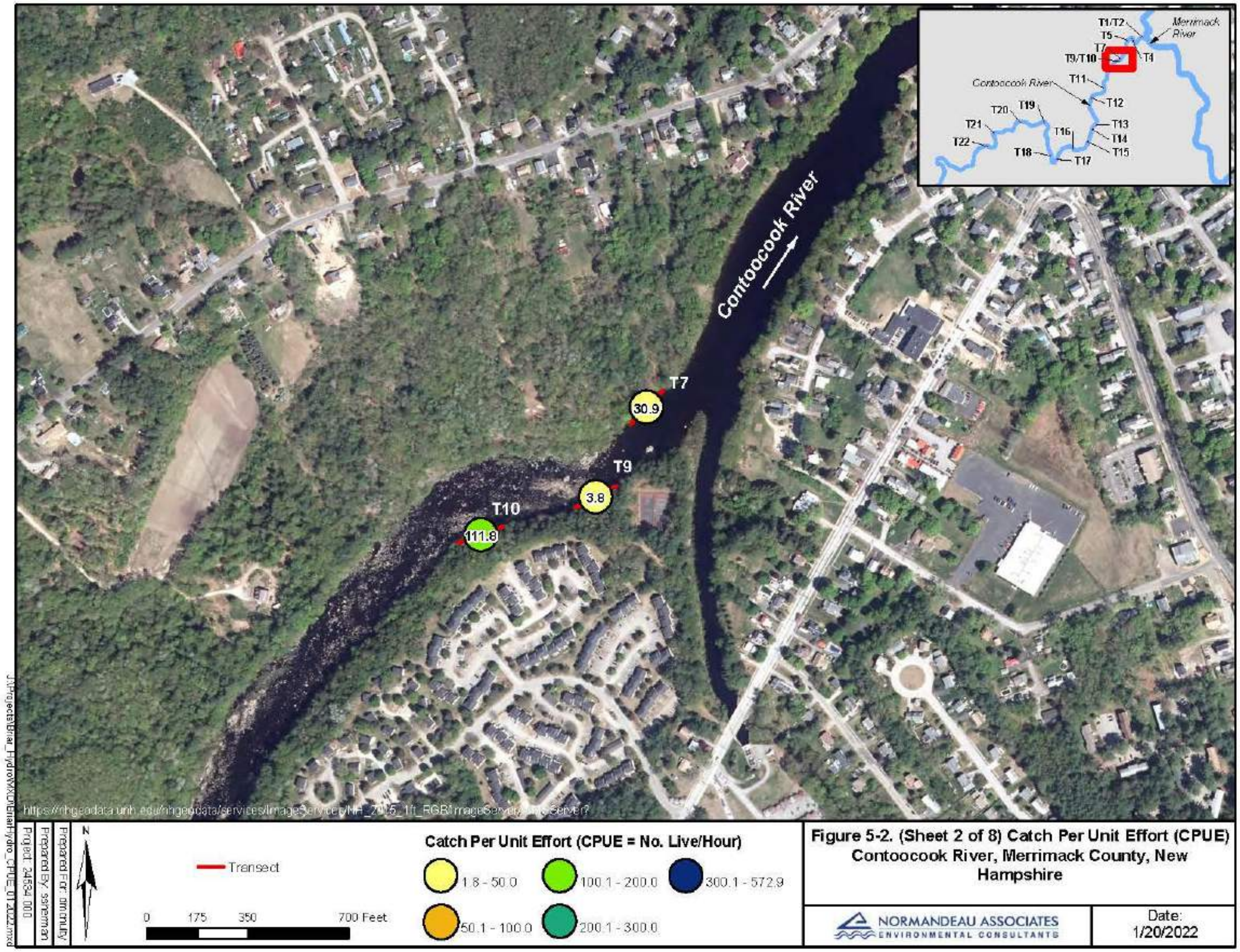


Figure 5-2. (Sheet 2 of 8) Catch Per Unit Effort (CPUE) Contoocook River, Merrimack County, New Hampshire

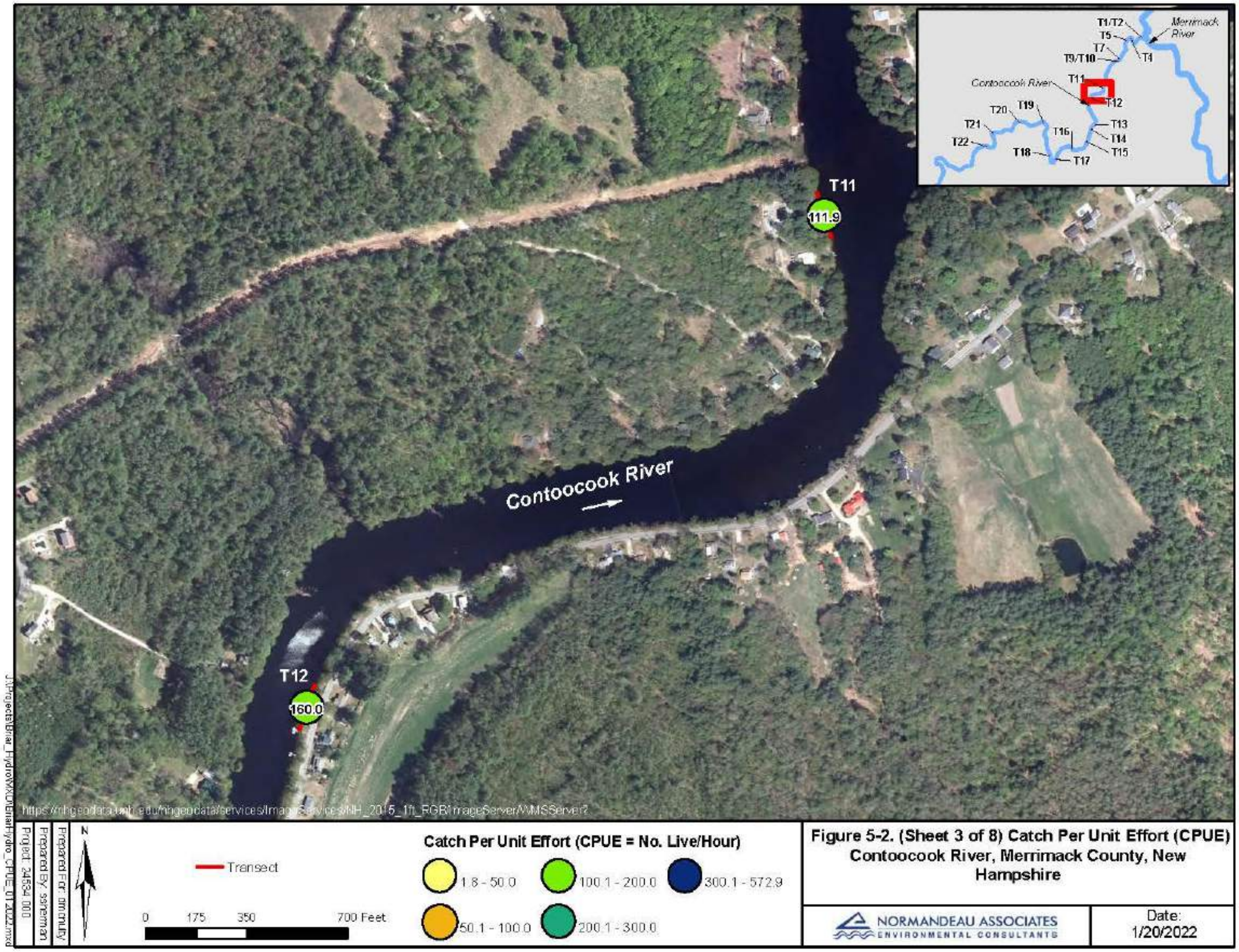


Figure 5-2. (Sheet 3 of 8) Catch Per Unit Effort (CPUE) Contoocook River, Merrimack County, New Hampshire

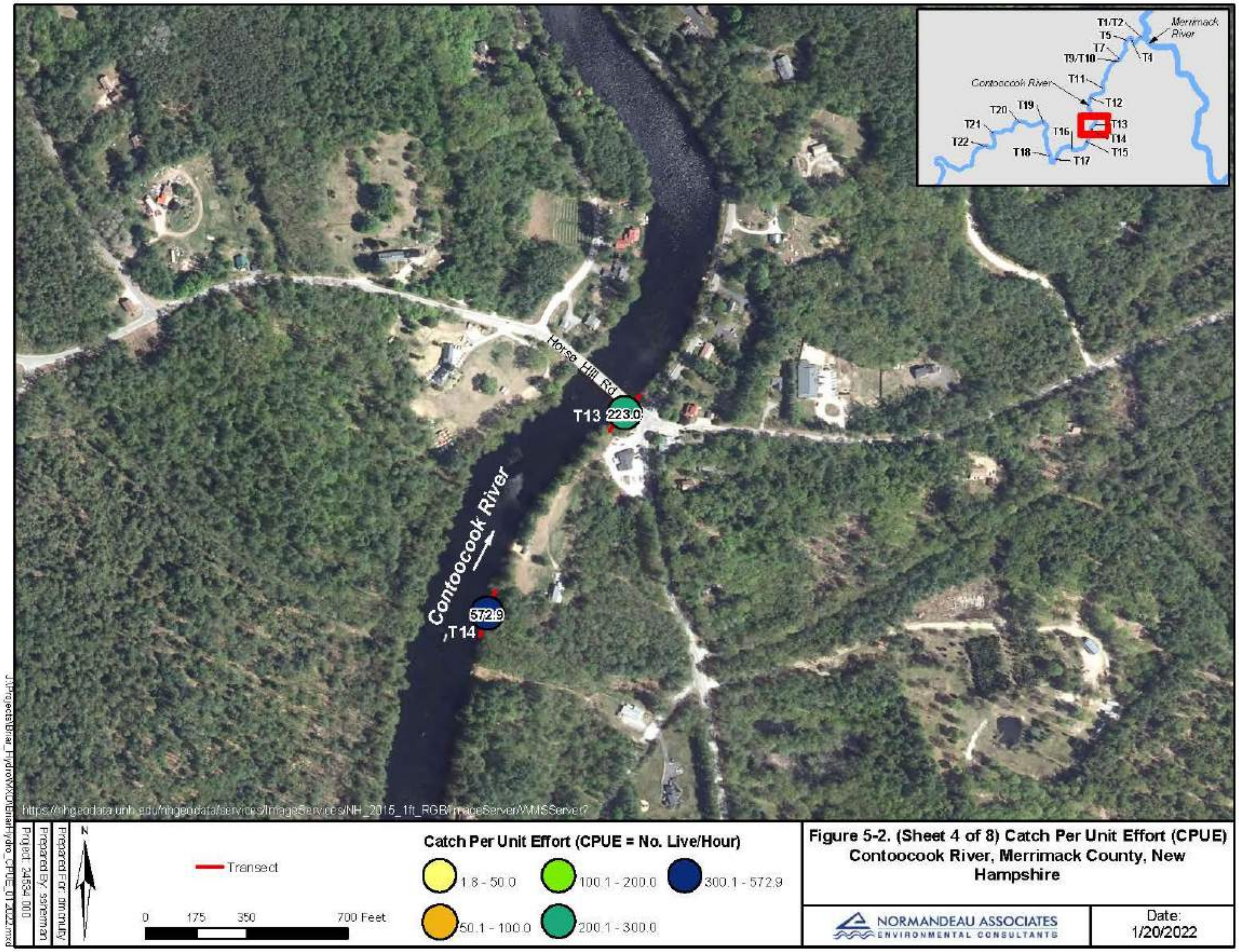


Figure 5-2. (Sheet 4 of 8) Catch Per Unit Effort (CPUE) Contoocook River, Merrimack County, New Hampshire

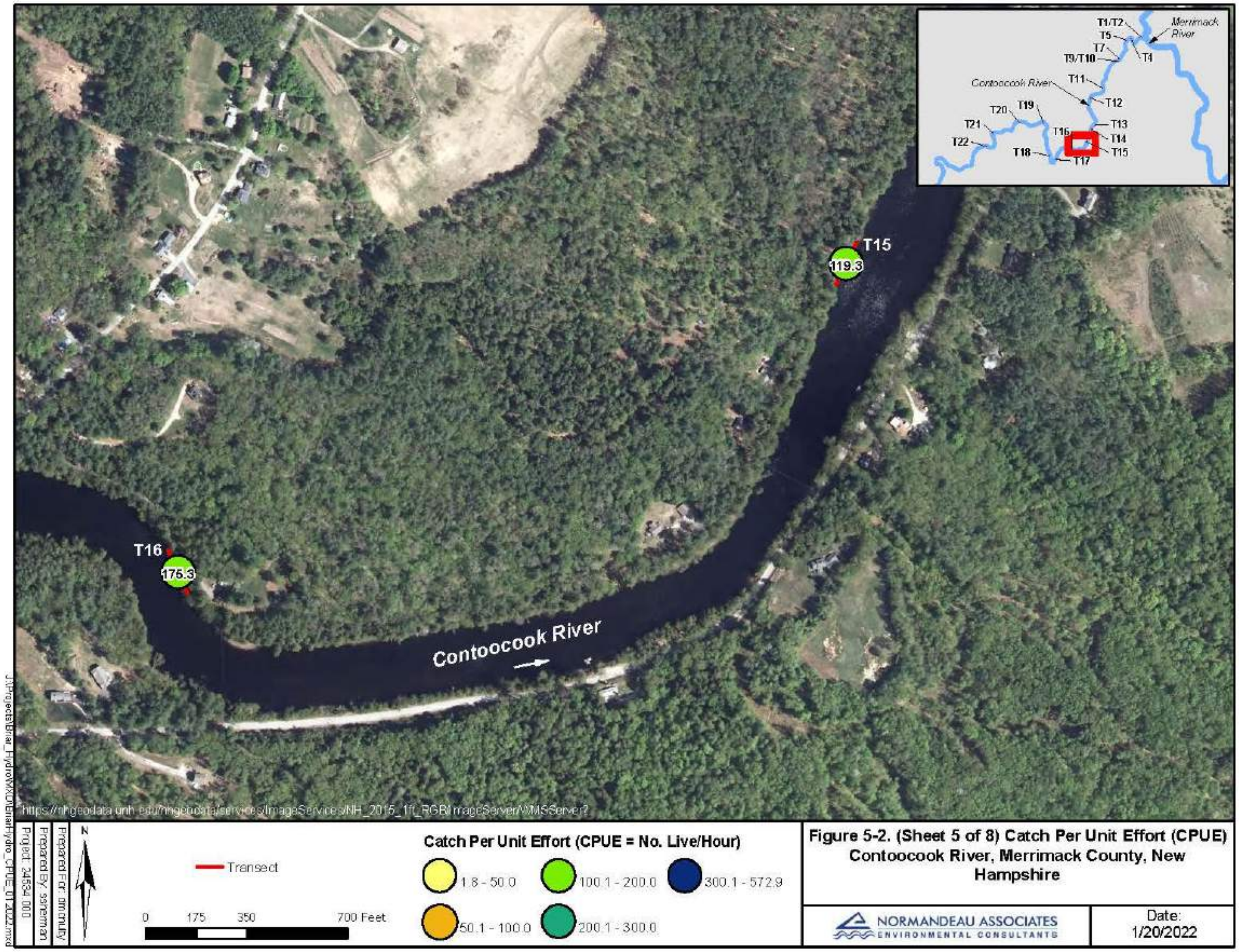


Figure 5-2. (Sheet 5 of 8) Catch Per Unit Effort (CPUE) Contoocook River, Merrimack County, New Hampshire

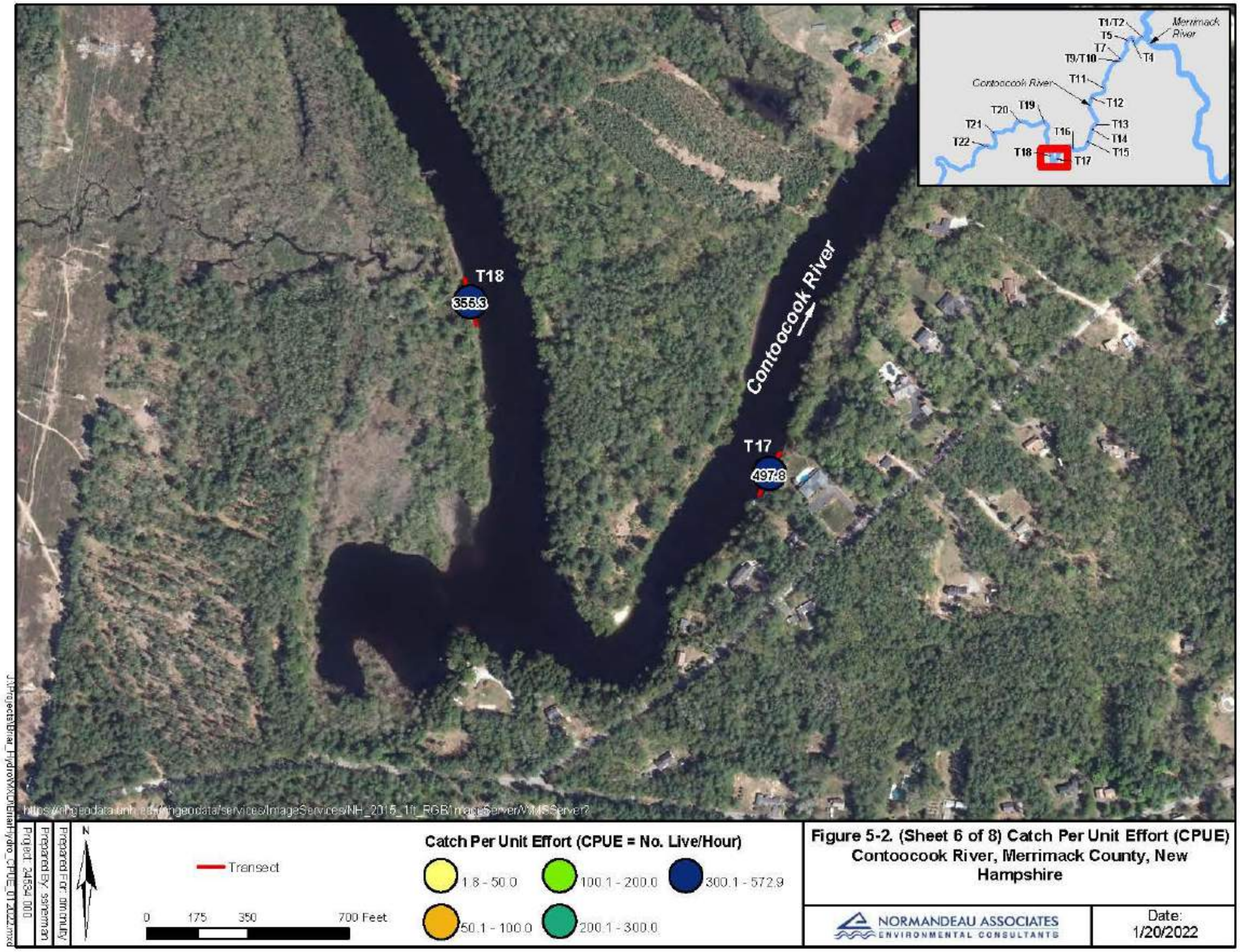


Figure 5-2. (Sheet 6 of 8) Catch Per Unit Effort (CPUE) Contoocook River, Merrimack County, New Hampshire

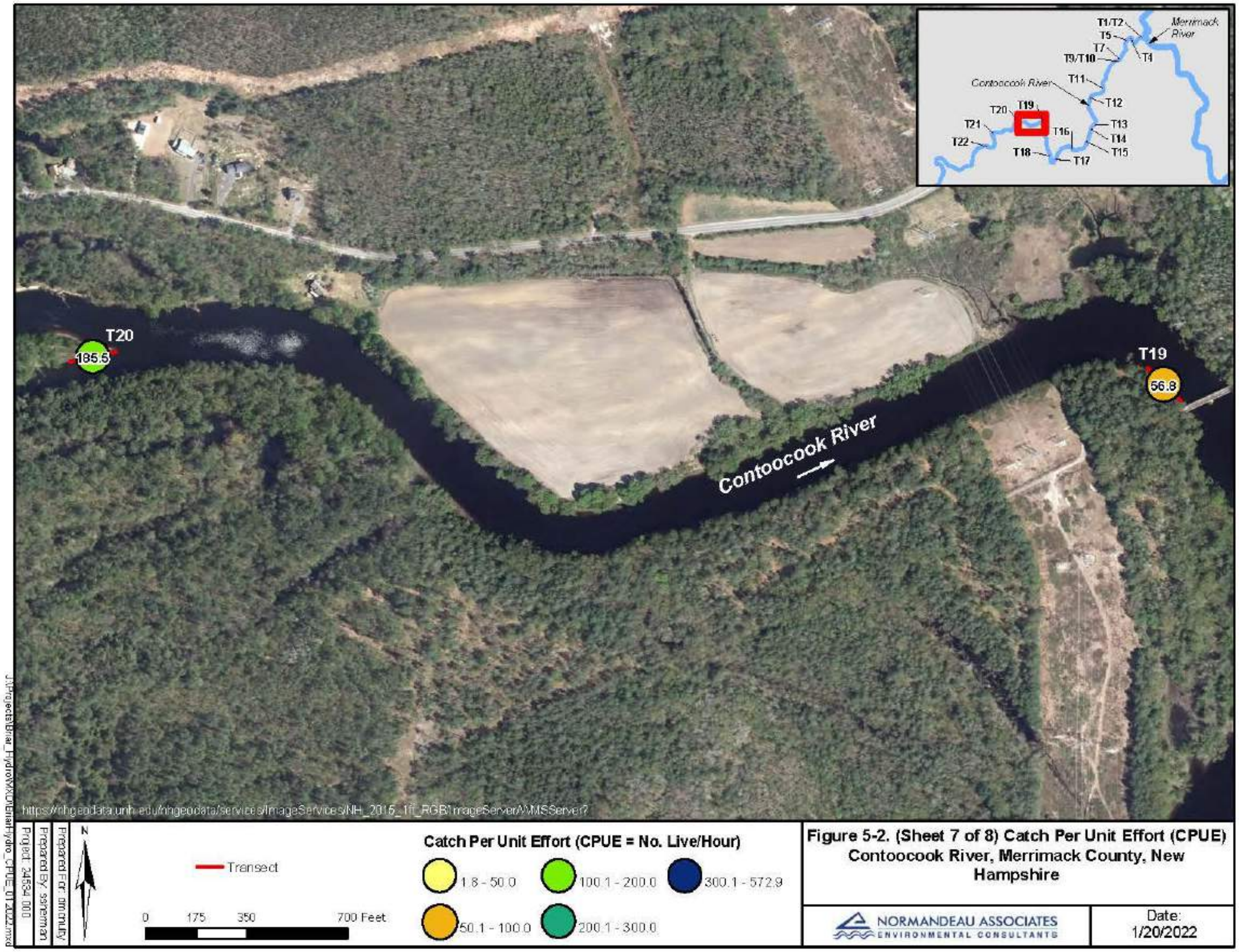


Figure 5-2. (Sheet 7 of 8) Catch Per Unit Effort (CPUE) Contoocook River, Merrimack County, New Hampshire

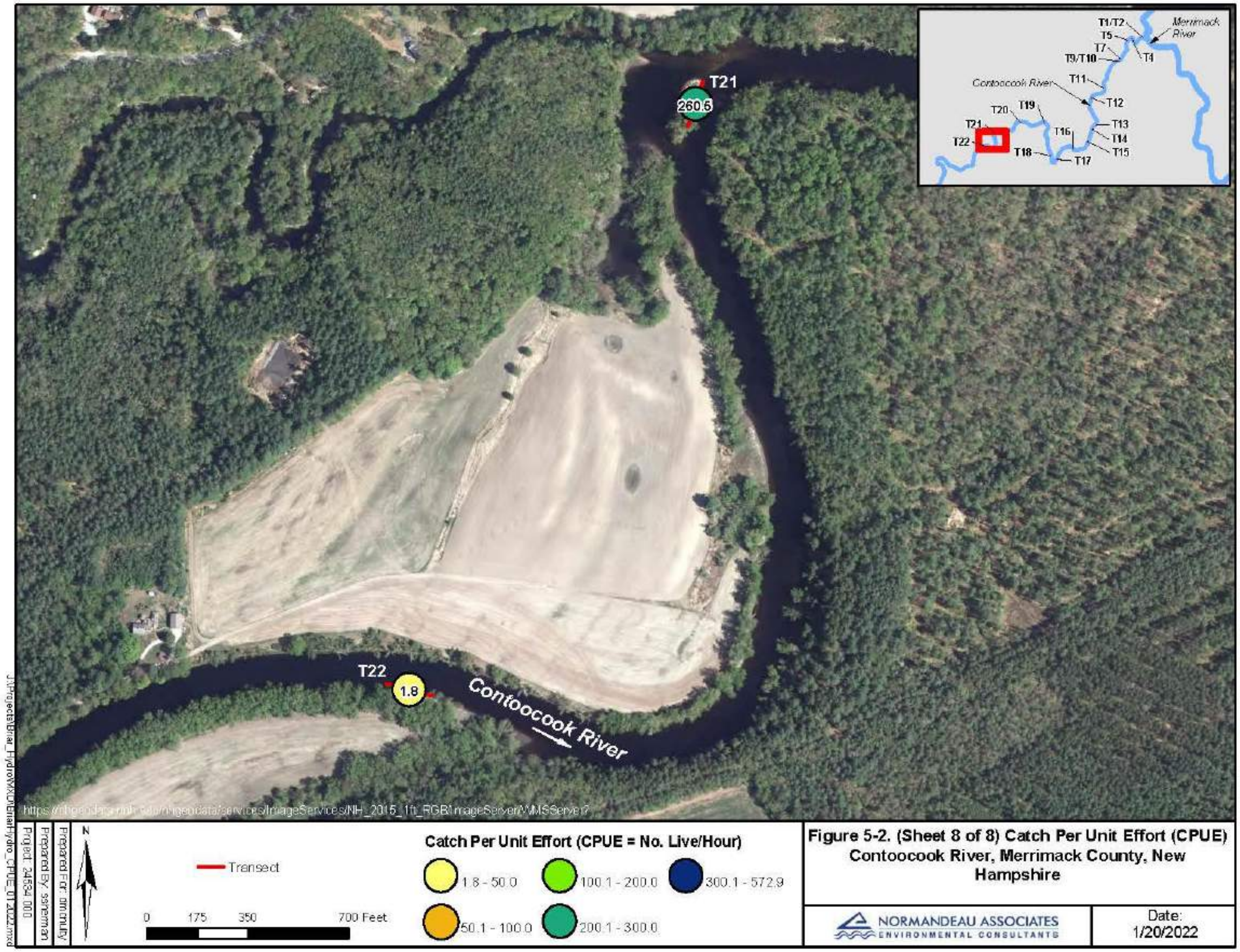


Figure 5-2. (Sheet 8 of 8) Catch Per Unit Effort (CPUE) Contoocook River, Merrimack County, New Hampshire

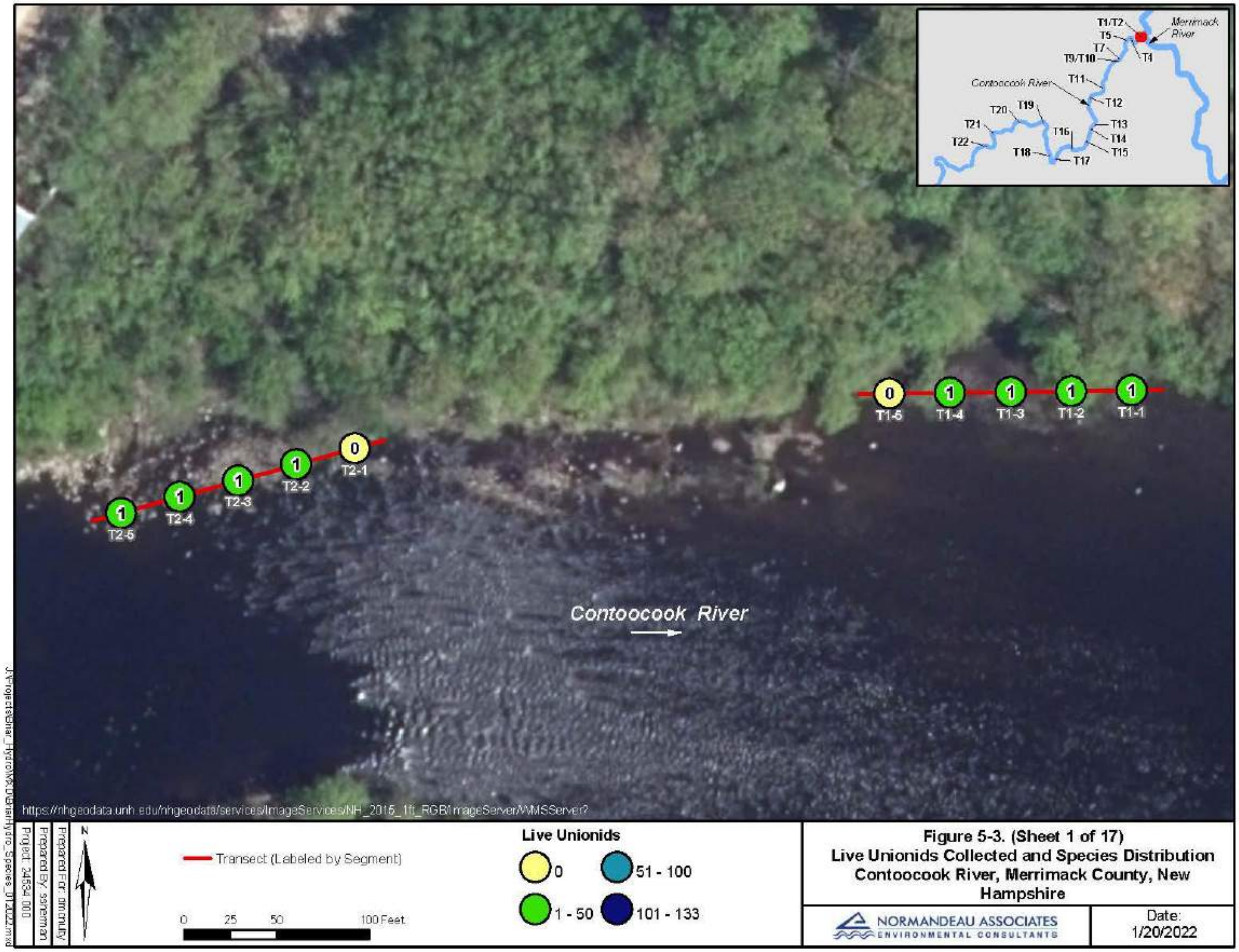


Figure 5-3. (Sheet 1 of 17)
Live Unionids Collected and Species Distribution Contoocook River, Merrimack County, New Hampshire

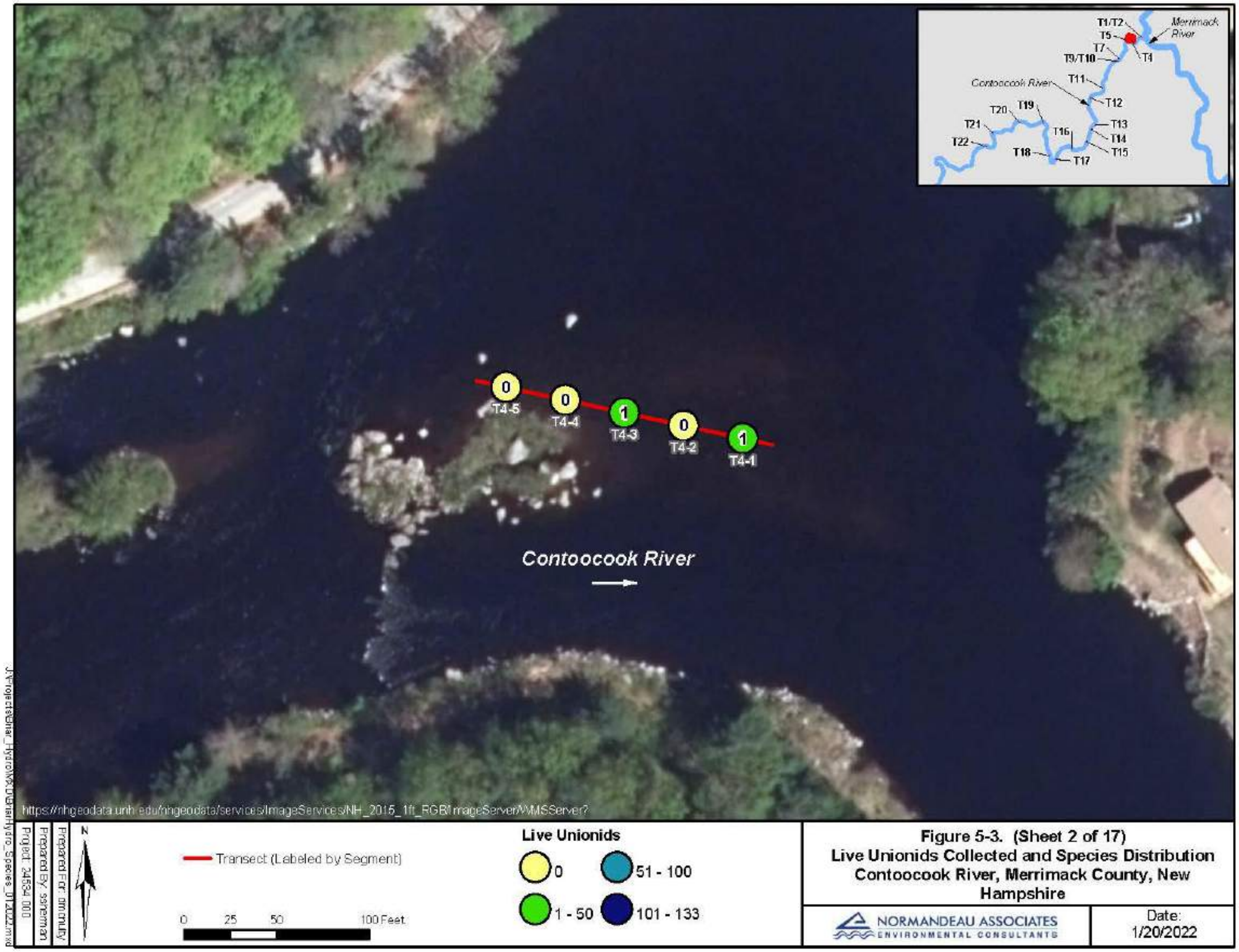


Figure 5-3. (Sheet 2 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire

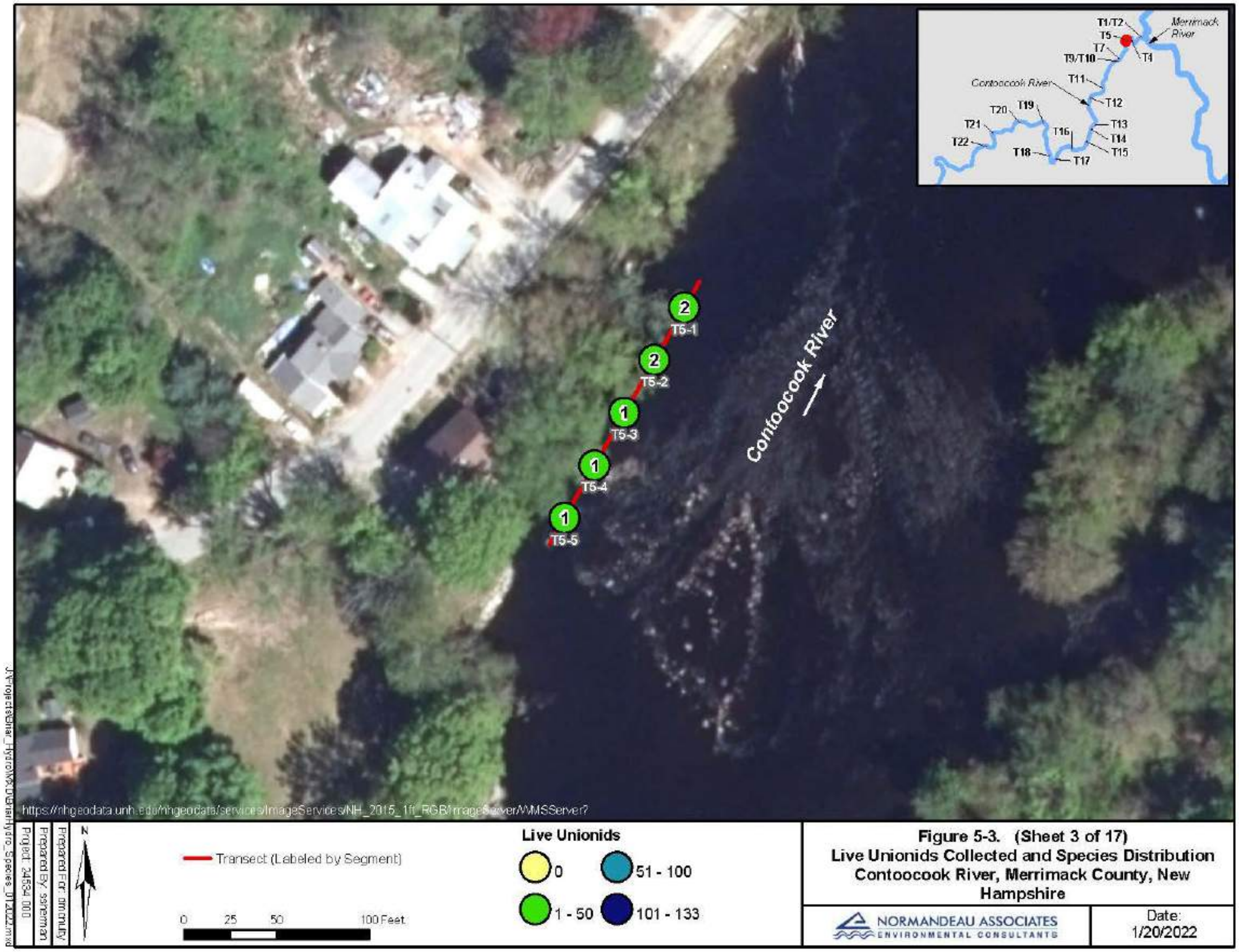


Figure 5-3. (Sheet 3 of 17)
Live Unionids Collected and Species Distribution Contoocook River, Merrimack County, New Hampshire

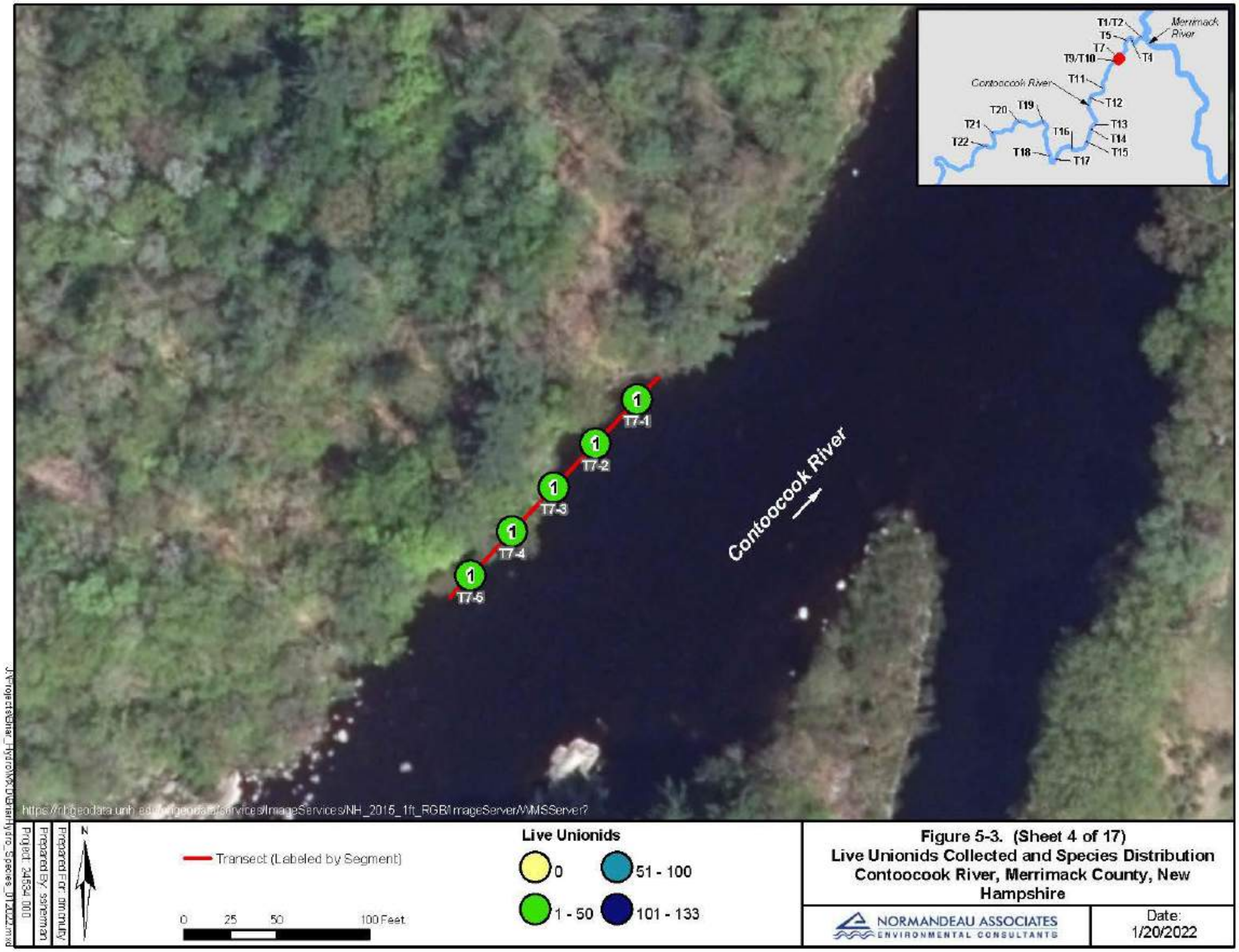
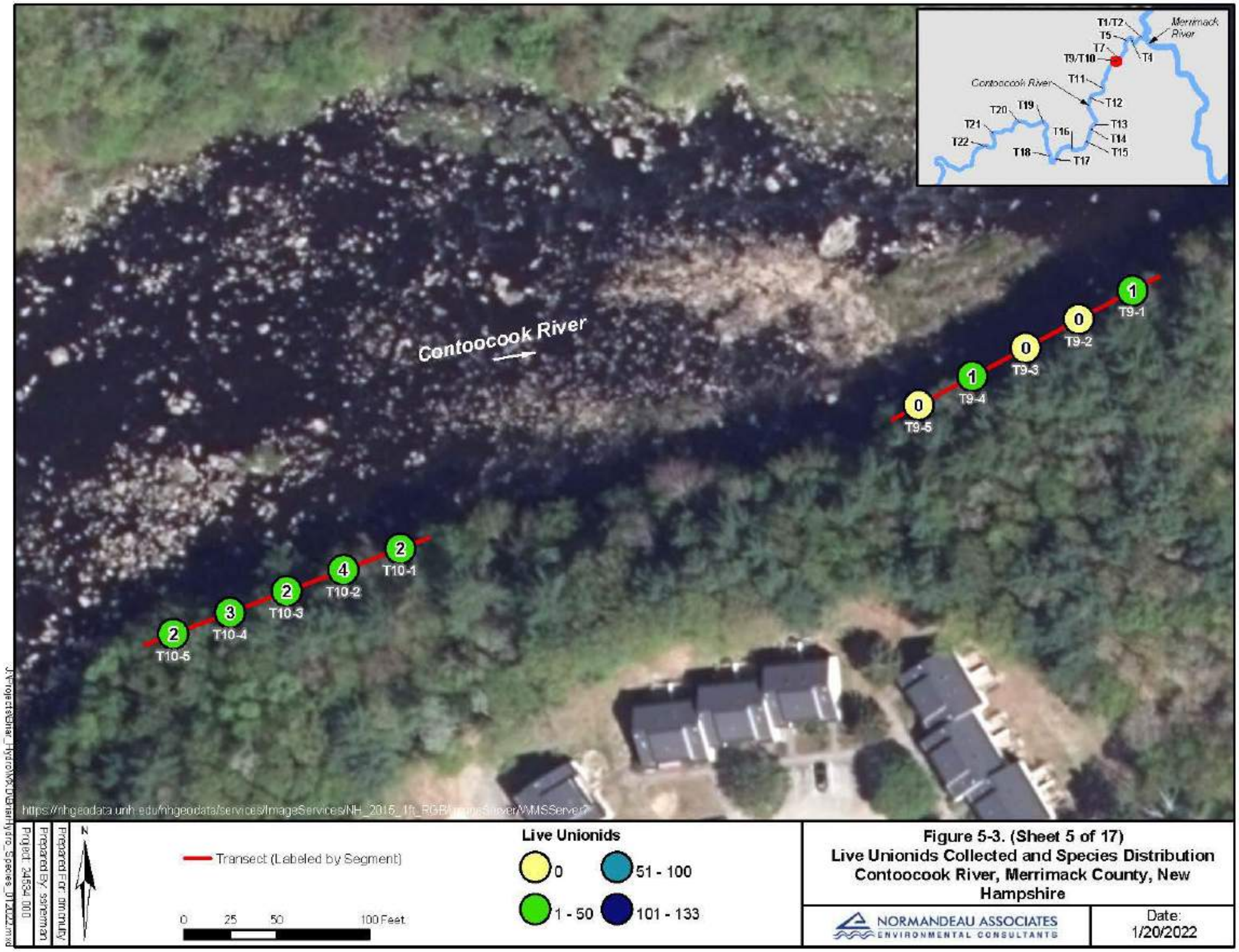


Figure 5-3. (Sheet 4 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire



T1/T2
T5
T7
T9/T10
T4
Merrimack River
Contoocook River
T11
T12
T19
T20
T21
T22
T16
T13
T14
T15
T18
T17
Contoocook River
1
T9-1
0
T9-2
0
T9-3
1
T9-4
0
T9-5
2
T10-1
4
T10-2
2
T10-3
3
T10-4
2
T10-5
Project: 24584.000
Prepared By: ssheman
Prepared For: dmmuly
N
Transect (Labeled by Segment)
0 25 50 100 Feet
Live Unionids
0
1 - 50
51 - 100
101 - 133
Figure 5-3. (Sheet 5 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date:
1/20/2022

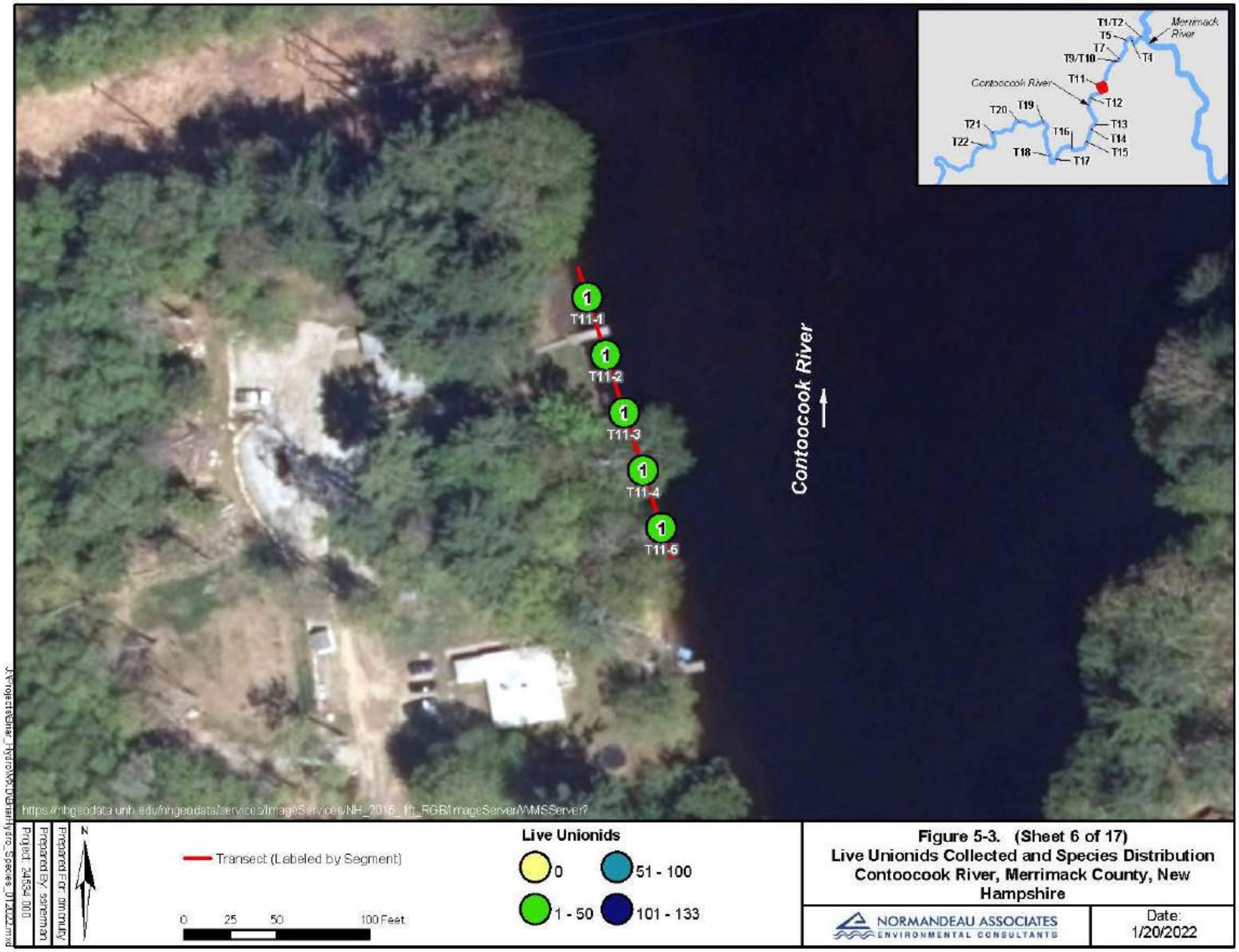


Figure 5-3. (Sheet 6 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire

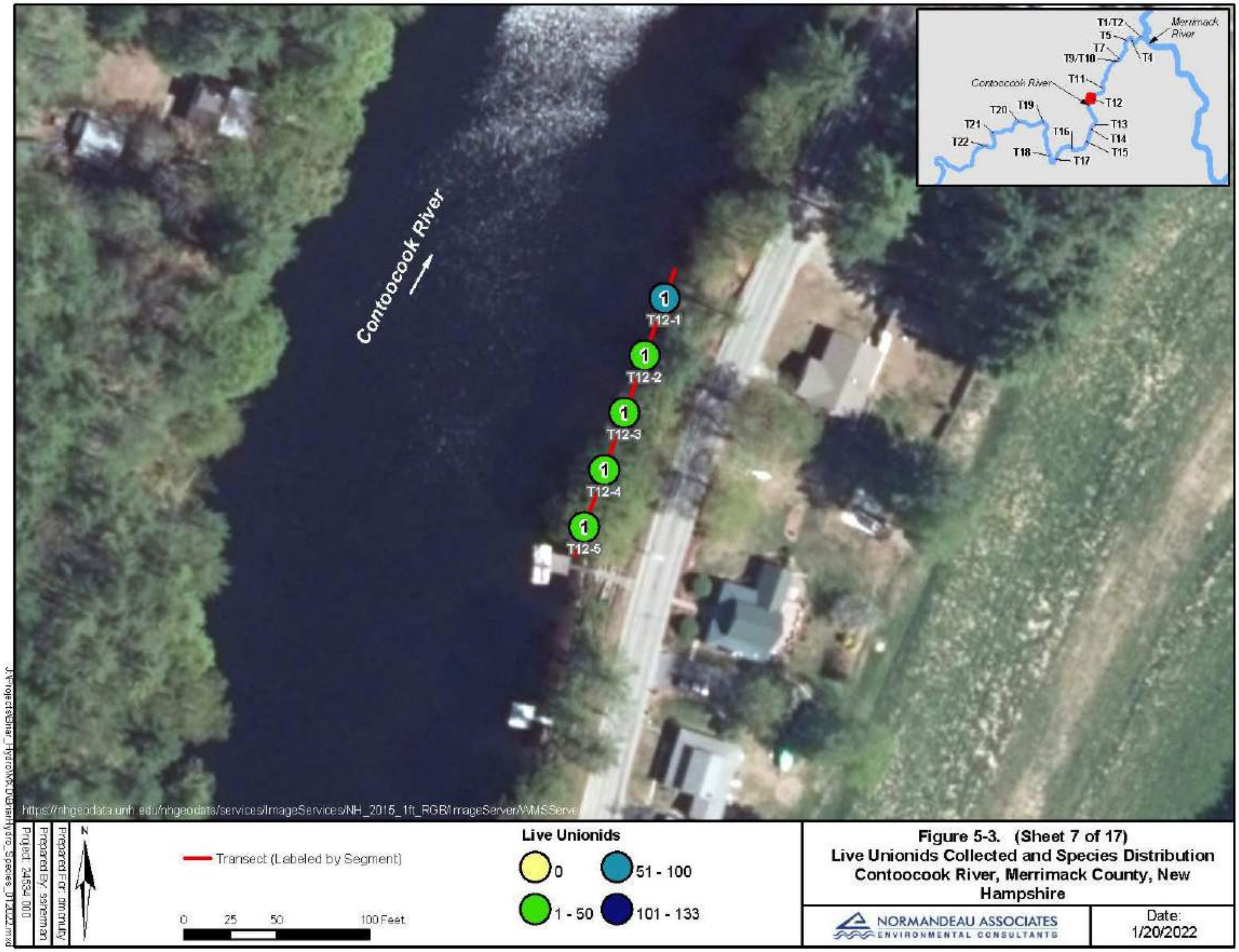


Figure 5-3. (Sheet 7 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

Date: 1/20/2022

Figure 5-3. (Sheet 8 of 17) Live Unionids Collected and Species Distribution Contoocook River, Merrimack County, New Hampshire


Contoocook River
T14-1
T14-2
T14-3
T14-4
T14-5
1
1
1
1
1
T1/T2
T5
T7
T9/T10
T4
Merrimack River
Contoocook River
T11
T12
T13
T14
T15
T16
T17
T18
T19
T20
T21
T22
Transect (Labeled by Segment)
0 25 50 100 Feet
Live Unionids
0
1 - 50
51 - 100
101 - 133
Figure 5-3. (Sheet 9 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire
NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS
Date: 1/20/2022
Prepared For: dmmulry
Prepared By: ssherman
Project: 24584.000
N

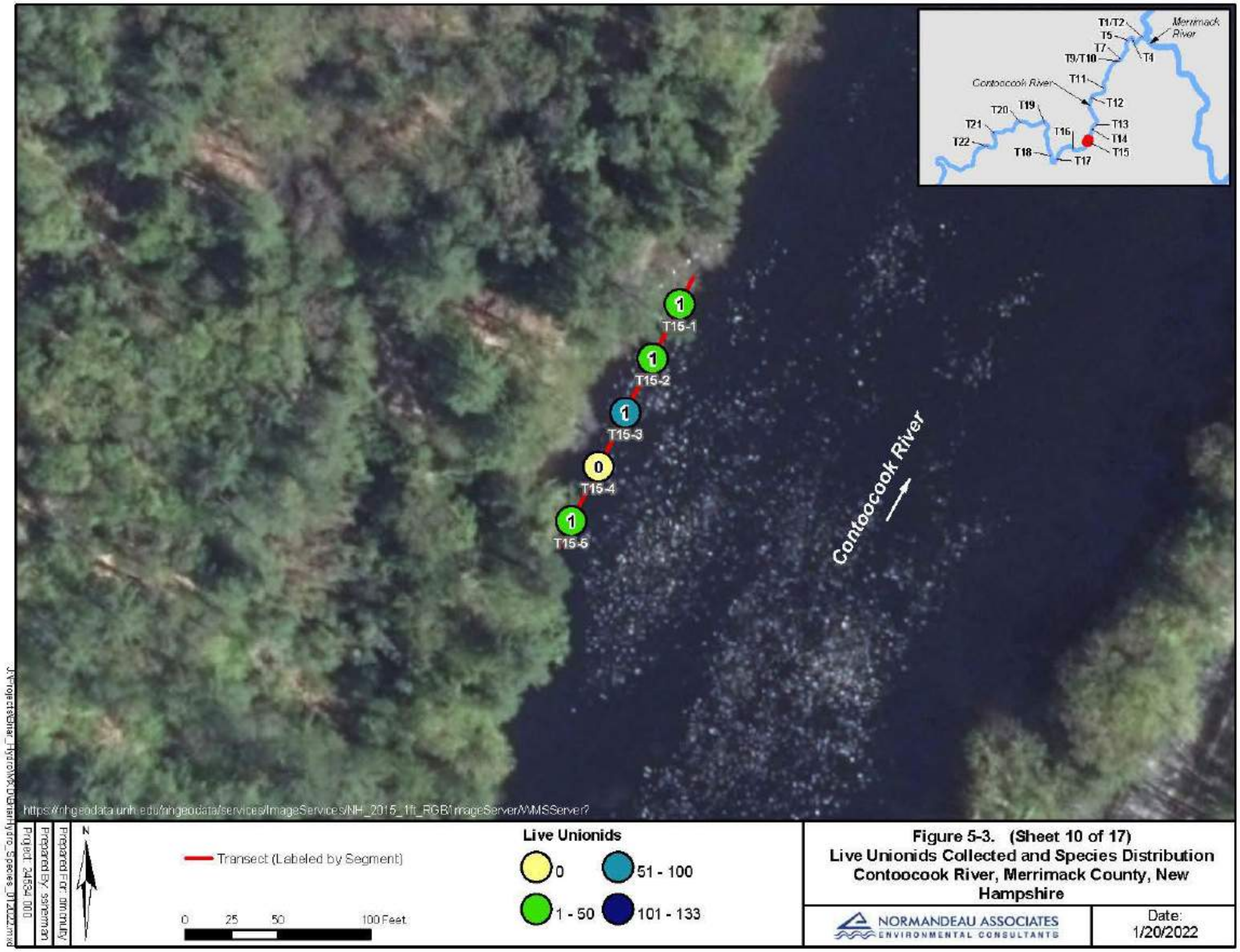


Figure 5-3. (Sheet 10 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire

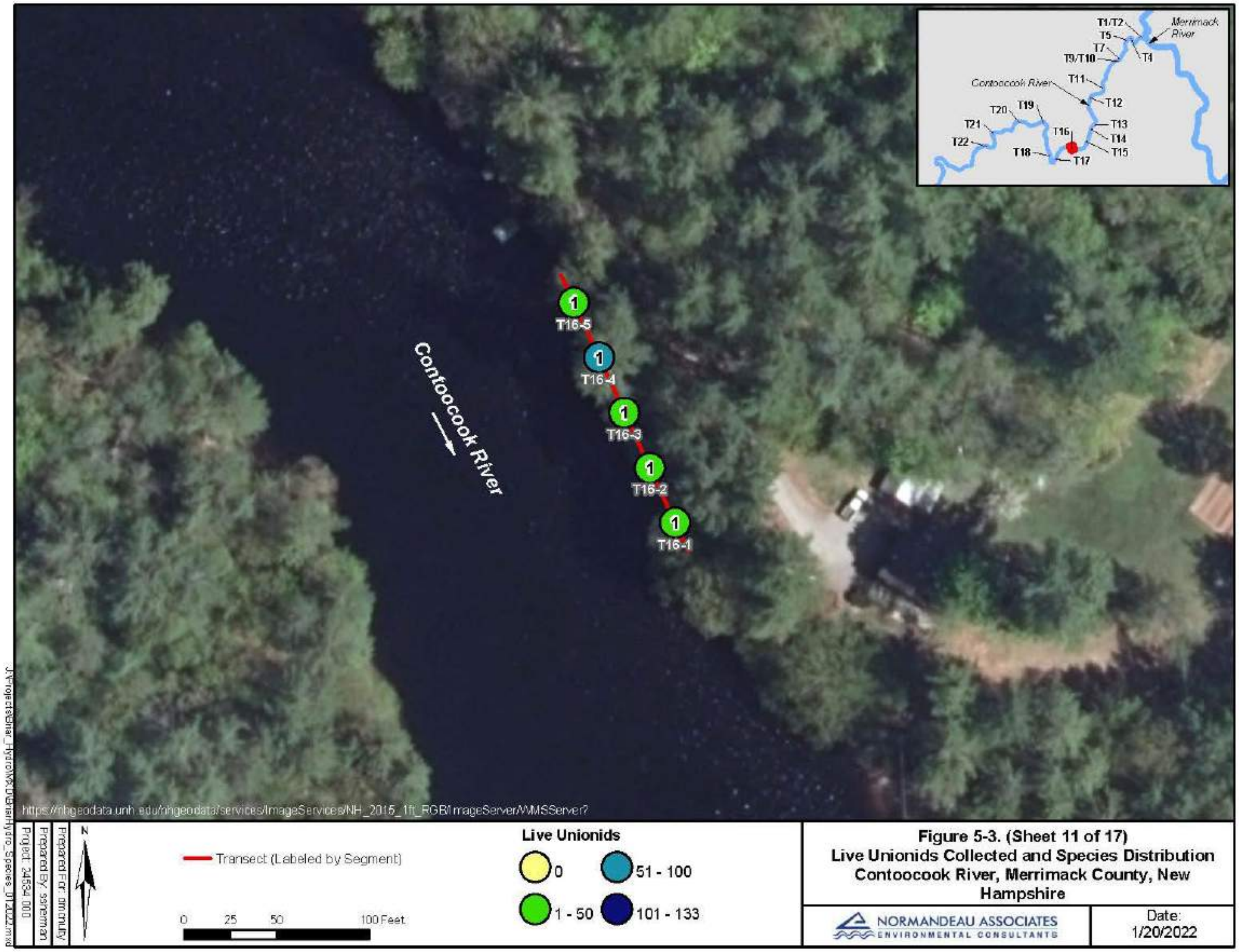


Figure 5-3. (Sheet 11 of 17)
Live Unionids Collected and Species Distribution Contoocook River, Merrimack County, New Hampshire

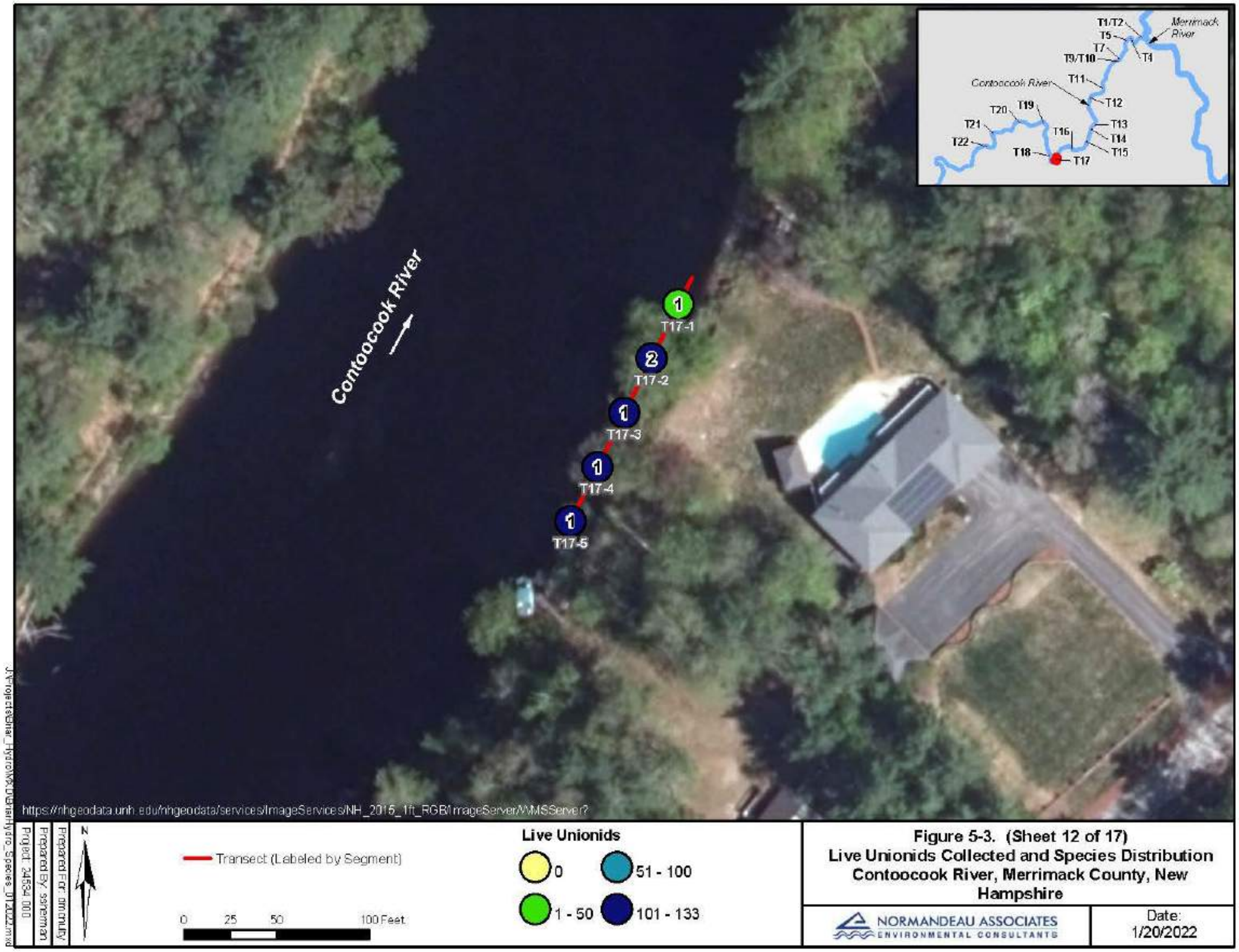


Figure 5-3. (Sheet 12 of 17)
Live Unionids Collected and Species Distribution Contoocook River, Merrimack County, New Hampshire

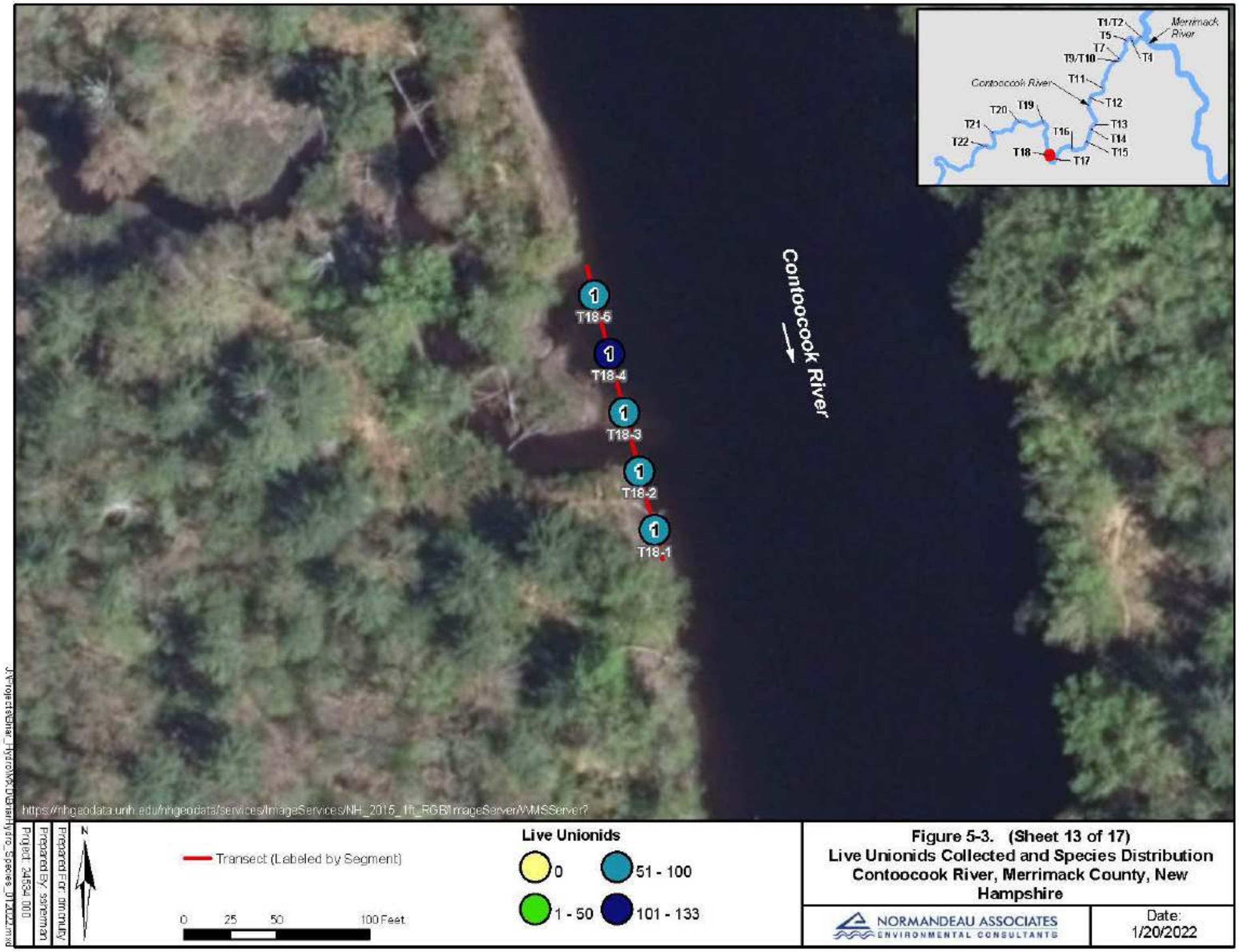


Figure 5-3. (Sheet 13 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire

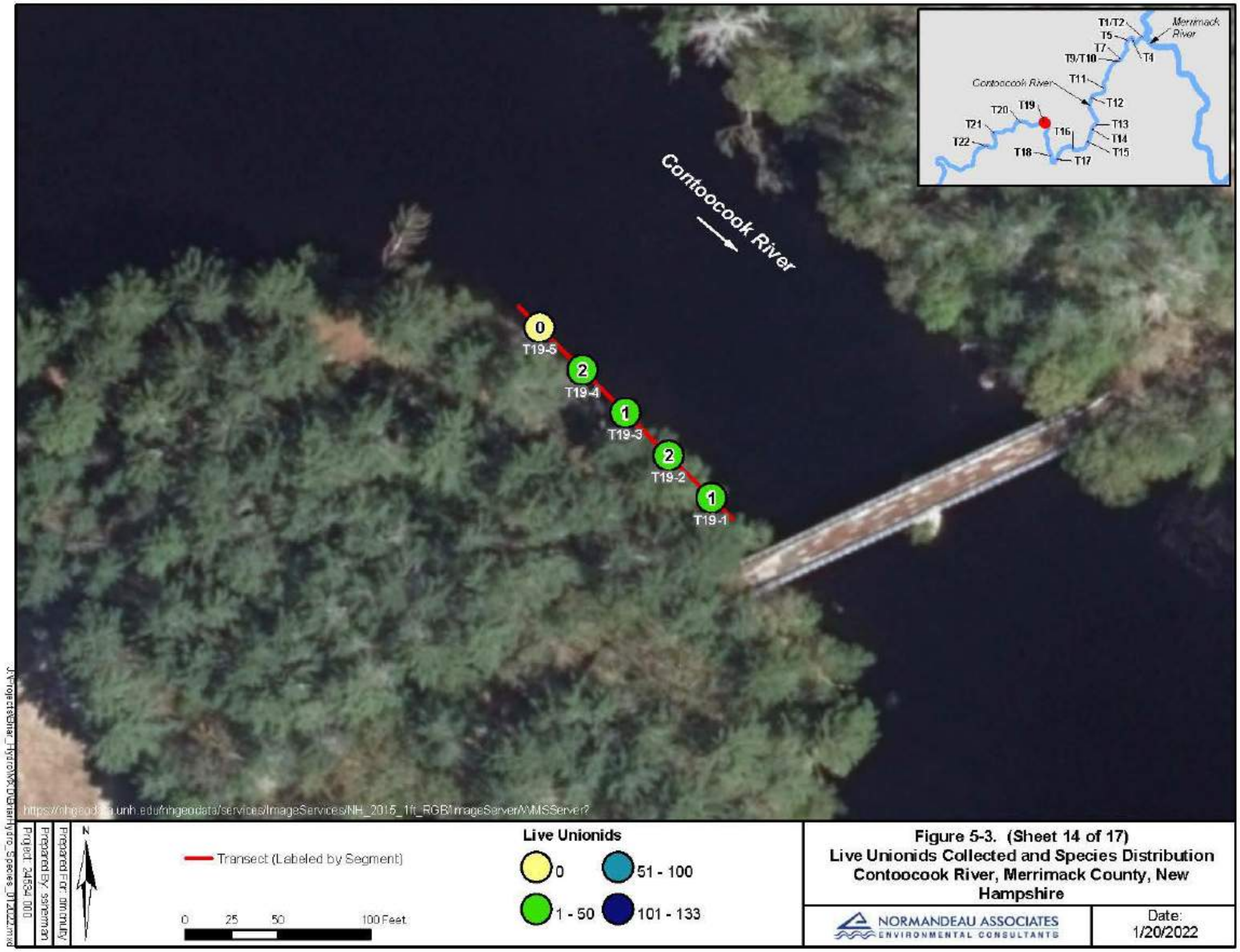


Figure 5-3. (Sheet 14 of 17)
Live Unionids Collected and Species Distribution Contoocook River, Merrimack County, New Hampshire

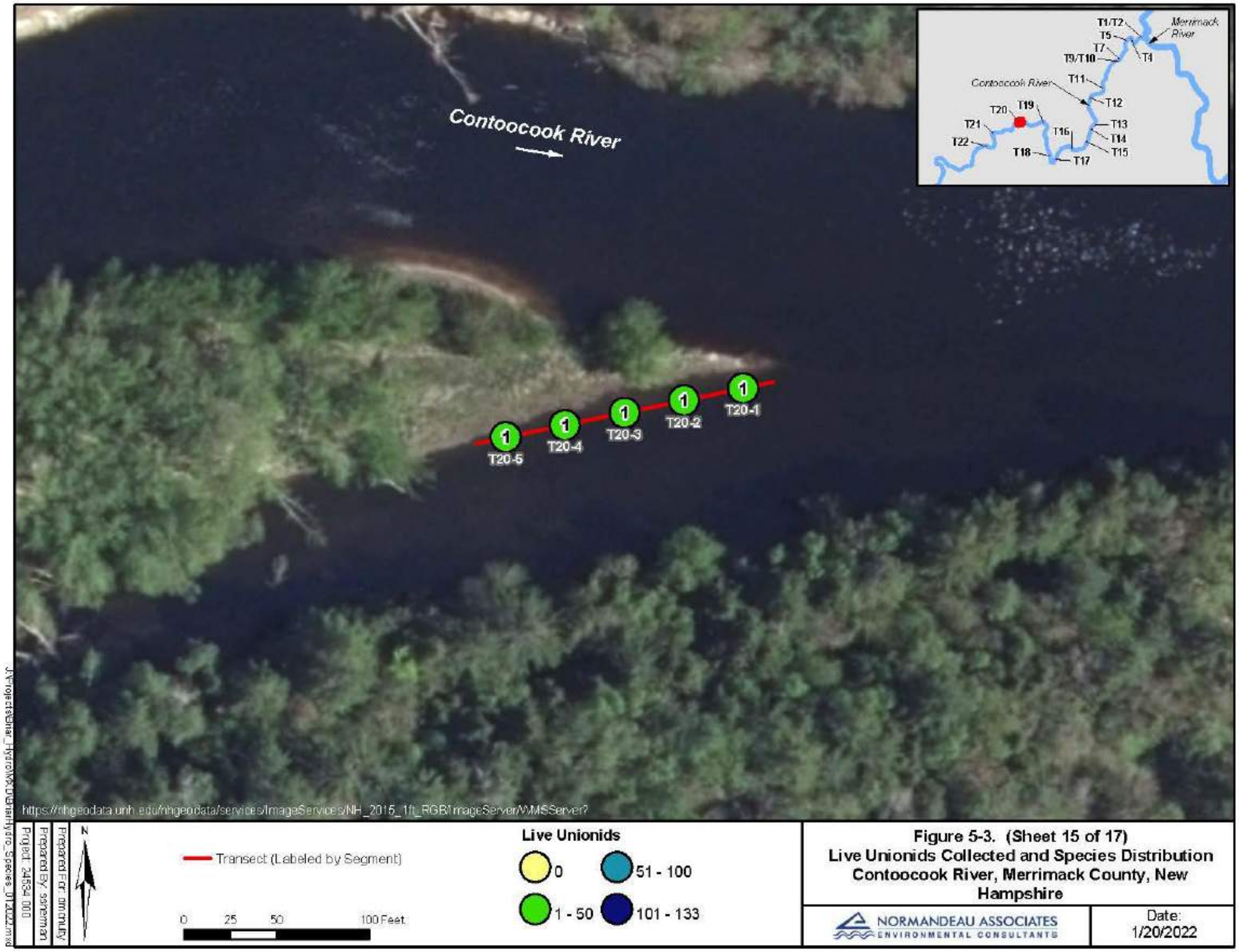


Figure 5-3. (Sheet 15 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire

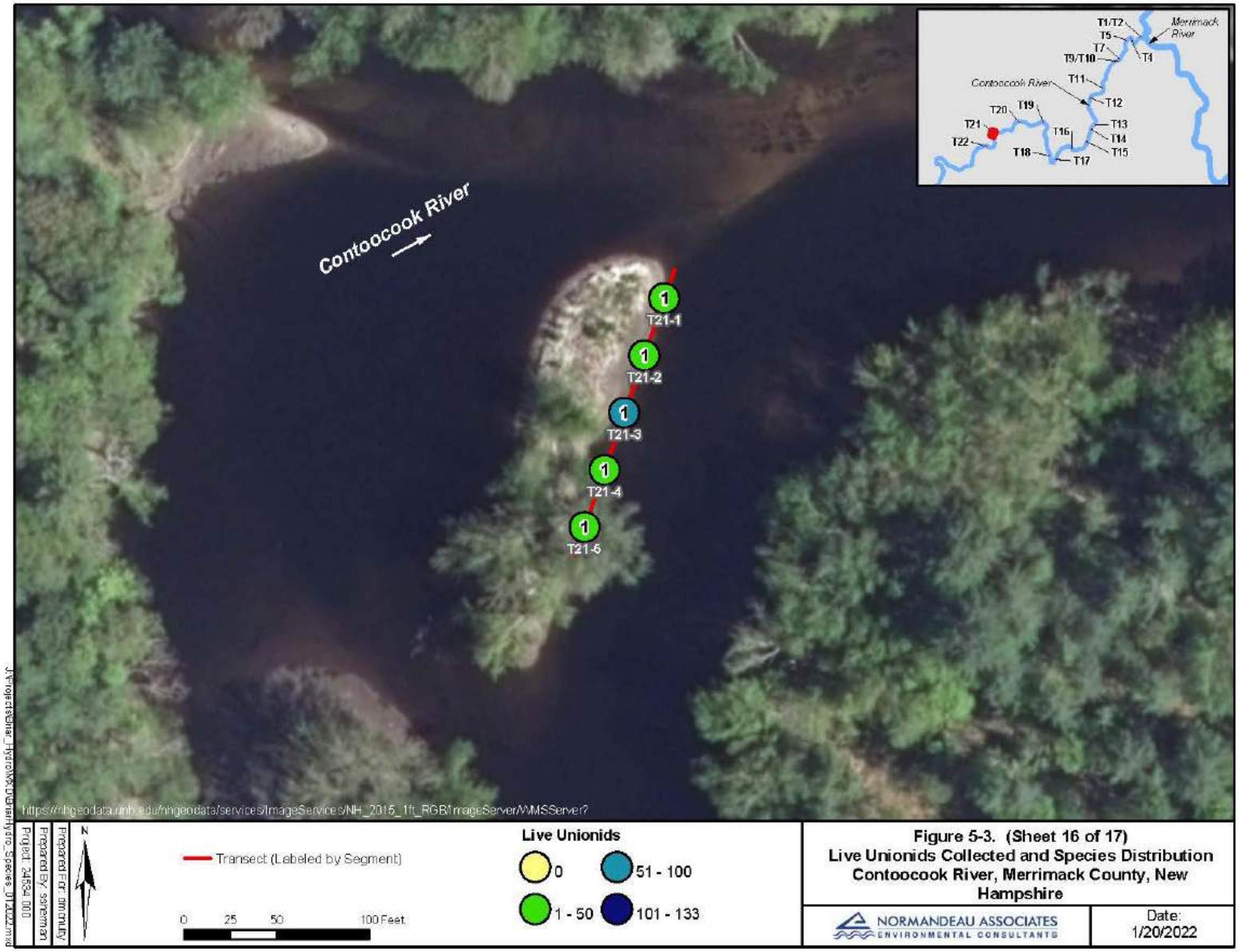


Figure 5-3. (Sheet 16 of 17)
Live Unionids Collected and Species Distribution
Contoocook River, Merrimack County, New Hampshire

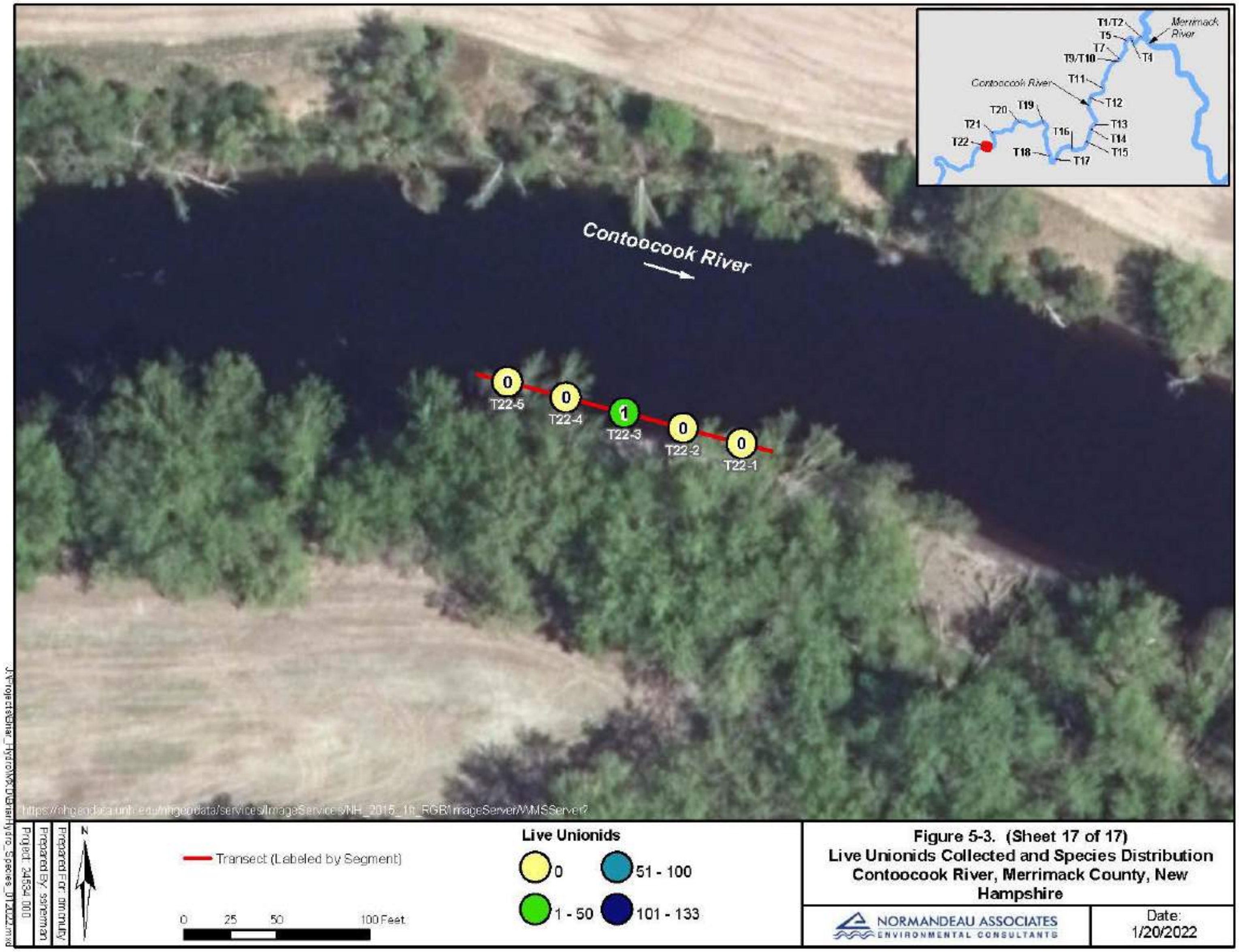


Figure 5-3. (Sheet 17 of 17)
Live Unionids Collected and Species Distribution Contoocook River, Merrimack County, New Hampshire